Offshore structures under special loads including Fire resistance
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Lecture - 03
Offshore Structure: Novelty of Compliant Platforms

Friends, welcome to the 3rd Lecture on the course title Offshore Structures under special loads including Fire Resistance Design.

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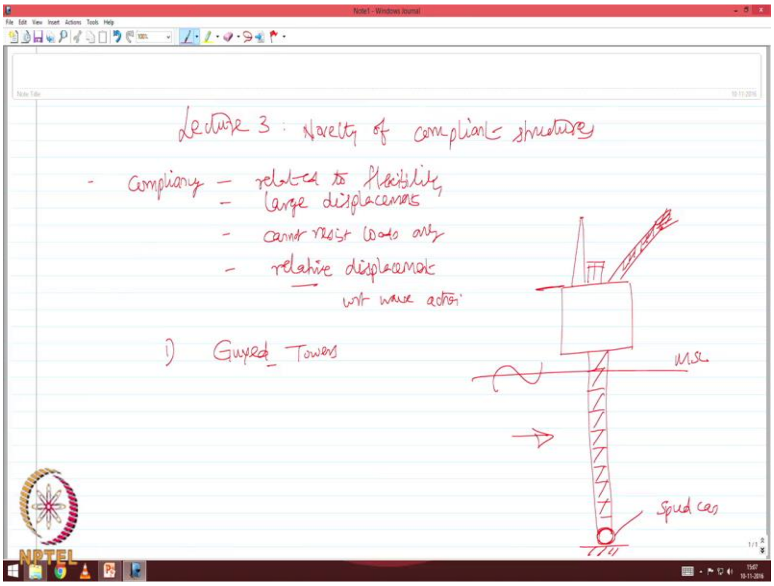

In this lecture we will continue discuss about novelty of complaint structures. We already said the compliancy is a term related to flexibility, if the platform is made flexible it is obvious to understand the platform will undergo large displacements. Since, it is flexible it cannot resist loads only by it is strength, because it is stiffness is lower. In that situation it resist load by it is relative displacement relative with respect to wave action.

So, the first kind in compliant structures which has a very interesting novelty is Guyed Towers, which we discussed in the last lecture partly. Guyed tower is essentially consists of at top site with all interesting data of drilling derrick, the flare boom, the helipad, the living quarters etcetera. It rests on a steel tower which is strengthened to resist lateral loads; the main sea level is about at this place. The tower is resisting on the seabed using a spud can arrangement.

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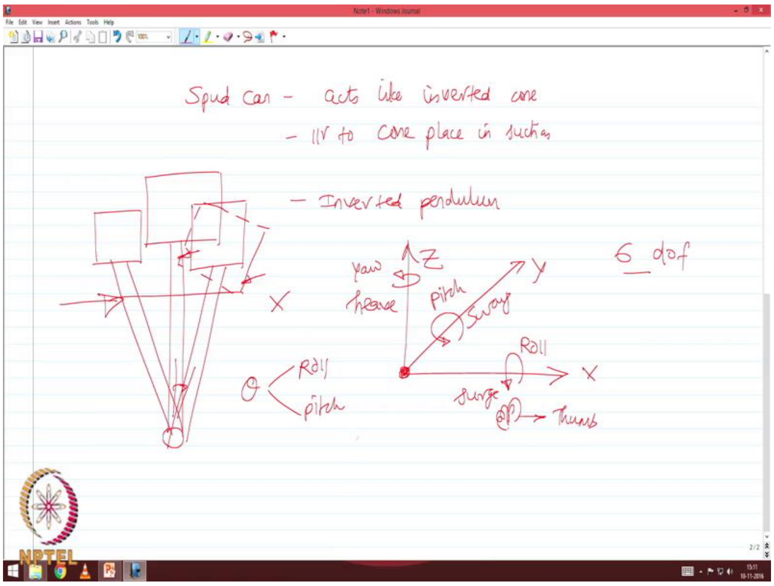

Whereas spud can arrangement acts like an inverted cone, it is similar to cone placed in section. Now, what is the novelty or what is the displacement offered by this platform which enables the platform to encounter environmental loads. When the platform is in it is initial equilibrium position under the wave load the platform is in initially equilibrium, because of the spud can action it acts like an inverted pendulum. So, the platform undergoes displacement or this way.

Interestingly, the top side essentially should remain horizontal, but the top side will also be straightly rolled or pitched depending upon the degree of freedom. Friends, let us try to understand a very important algorithm behind the degrees of freedom which these platforms have. Let say I have got three axis; this is my x axis, this is my positive y, this is my positive z. If this is my horizon displacement along x axis is named as surge, displacement along y axis is called as sway, and displacement along z axis is called as heave.

You put your thumb towards the axis remaining four fingers let say this is my thumb remaining four fingers will have an idea, so these four fingers will give me the single rotation, whereas this is my thumb. So, this rotation about x axis is called roll, similarly rotation about y axis is called pitch, rotation about z axis is called yaw. So, these are a 6 degrees of freedom what an offshore platform has in a 3 dimensional space.

So, now I should say in this case as this becomes rotation it is the wave direction if I call the wave direction as x axis I am rotating it about the vertical axis on the vertical plane. Therefore, I can see very well that the rotation can be either name as roll or pitch. So, theta can be either roll or pitch depending upon your angular approach there is this along x or along y respectively. So, when the wave hits the platform the platform rotates about the hinged joint and this process differential buoyancy on these elements.

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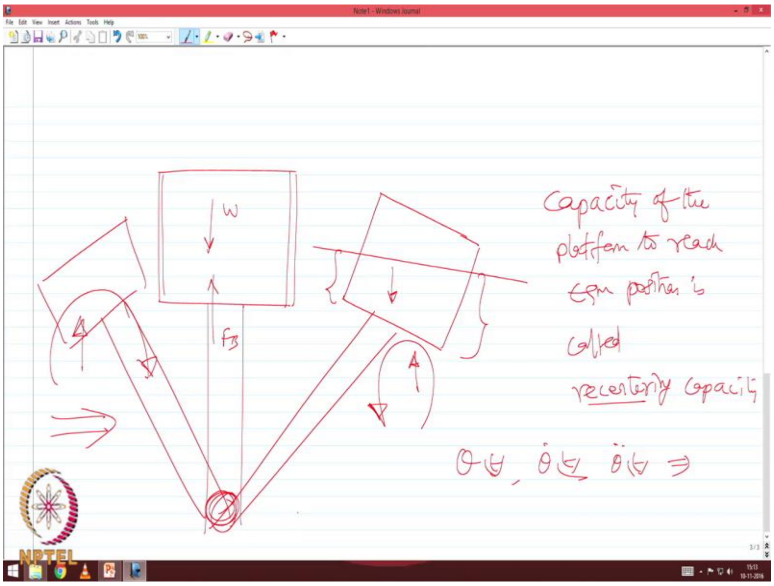

And that enables for example; initially for the body for each let us about the body I have Cg, I have w acting, I have a FB acting which is in equilibrium. When the body submerges partially there is a change in the immersed volume on the right side compact to that of the left side. So, there is a shift in the buoyancy compact to the weight which causes anti clock wise moment.

So, when the platform is moved to the right the platform is enable to back to rotate back to it is equilibrium position. While it rotates, it rotates or recenters faster the platform gets a new position now. So because of this the center of buoyancy now shifts, it cause the clock wise moment now about this point and the platform keep on oscillating about this point. So, the capacity of the platform to reach initial equilibrium position is called recentering capability; so the platform try to recent.

So, this displacement of theta of t or theta dot of t or theta double dot of t displacement, velocity and acceleration enables the platform to counter act the wave forces acting on the platform. The novelty of this platform now gets along with displacement allowed. Now the displacement is position restrained in this case.

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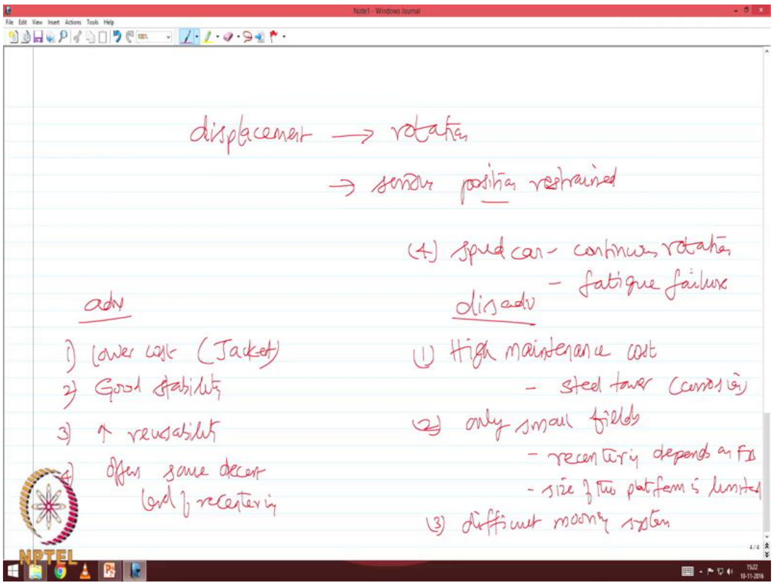

The displacement, what we see here is actually rotation with a very serious position restrain offered. What do you understand by position restrained? The platform cannot move from this point, but only oscillate about this point; that is called Position Restrained. Since it is seriously position restrained it is called Semi-Compliant; so the semi compliancy offshore resistance to the lateral loads.

This platform of course, as some advantages as some disadvantages as well. This platform is lower cost compare to bottom supported structure, the platform as got good stability, it has got high reuse ability; it offers some decent level of recentering. It has got some disadvantages: very high maintenance cost; this is essentially due to the steel tower it gets corroded. It is applicable to only small fields; the reason being the restoration or recentering depends on buoyancy force, but the size of the platform is limited. The third reason could be it has got here difficult mooring system. The fourth reason could be we write down here the system has got spud can support which essentially undergoes continuous rotation and that can cause a fatigue failure.

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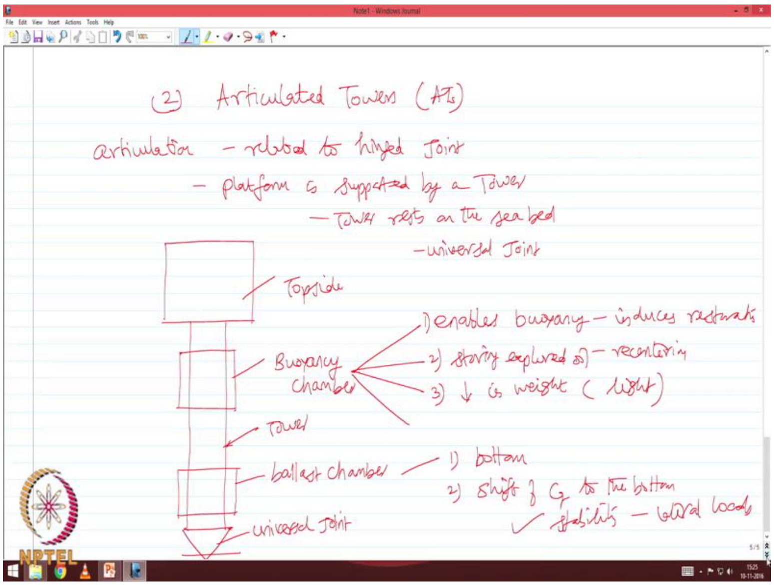

The next set up platform what we have in complaint system is articulated towers, shortly called as ATs. Articulation is a term related to hinged joint. So, the platform obviously supported by a tower and the tower rests on the seabed through a universal joint. The typical platform looks like this; top side is same as the top previous case. In the previous case the platform had a latish tower of steel, but in this case this can be even a concrete tower which will be now connected to the base by universal joint. To ensure buoyancy and stability of the platform two chambers are attached. The bottom one is called ballast chamber, on the top is called buoyancy chamber. This is actually the tower; of course this is a top side.

The buoyancy chamber as many advantages: it enables buoyancy which induces restoration or recentering. This can be also used for storing they explore oil. The buoyancy chamber enables reduction in weight, therefore makes the structure light. The ballast chamber is located at the bottom. This enables shift of Cg to the bottom which enables good stability of the platform under lateral loads.

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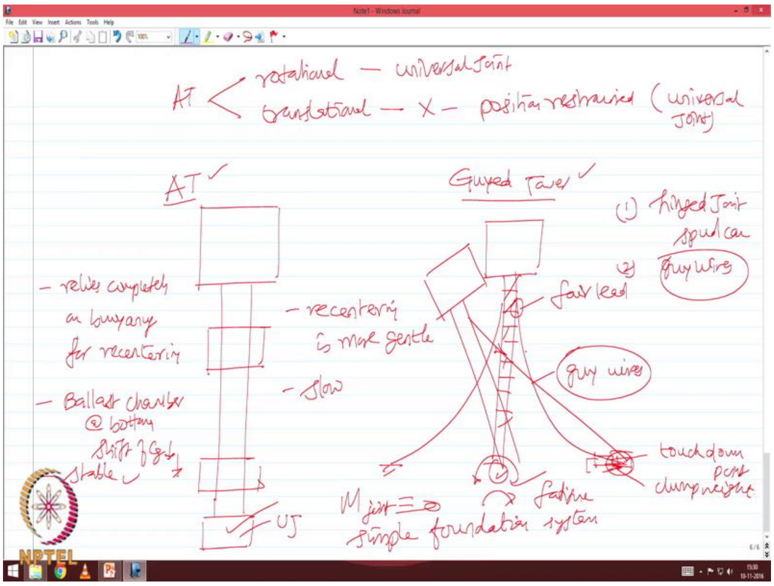

The tower has got two types of responses: one is rotational other is translational. ATs do not undergo translational response because they are again position restrained by the universal joint. They undergo rotational response or allowance in rotation because of universal joint.

Now, what is the differences in structural action between an articulated tower and the tower guyed tower. So, let say a guyed tower has again latish tower which is connected and there are guy wires which are connected to the seabed. These guy wires the point where guy wire was connected tower is called fair lead. The point where the guy wire touches the seabed is called touchdown point. At the touchdown point lot of contra weights are added they are called clump weights. They hold these guy lines down. These guy lines are provided circumscribe or around the tower in plane, and these guy wires allow the restriction of motion of the tower beyond certain value. So, when the towering claims this guy wire is straightens and tries to bring the tower back.

There are two way actions in guy tower: one restoration is because of the hinged joint which is happening at spud can, the second is by the guy wires. Whereas, in AT the tower is similar, but in this case it is a transparent steel tower, but in this case it may be a concrete tower. Now the joint is universal joint, it has got buoyancy chamber and ballast chamber; guy wires are missing in this case. Therefore, this platform relies completely on buoyancy only for recentering, whereas this platform had buoyancy as well as capability from the guy wires as well.

So, that is the first difference we can see between AT and the guy tower in terms of structural action. The second is the ballast chamber located at the bottom enables shift of Cg downwards closer to seabed; that indicates the platform is more stable compare to this. Thirdly, spud can under continuous rotation undergoes fatigue, universal joint will also undergo fatigue but here the recentering is more or less gentle, so I should say it is slow. Whereas, in this case it is must faster because the recentering happens not only because of spud can, but also because of pulling action of the guy wires. Maybe that is the different between the structural action of articulated tower and that of the guyed tower.

In both the cases the similarity is the moment at the joint is 0 which enables a very simple foundation system.

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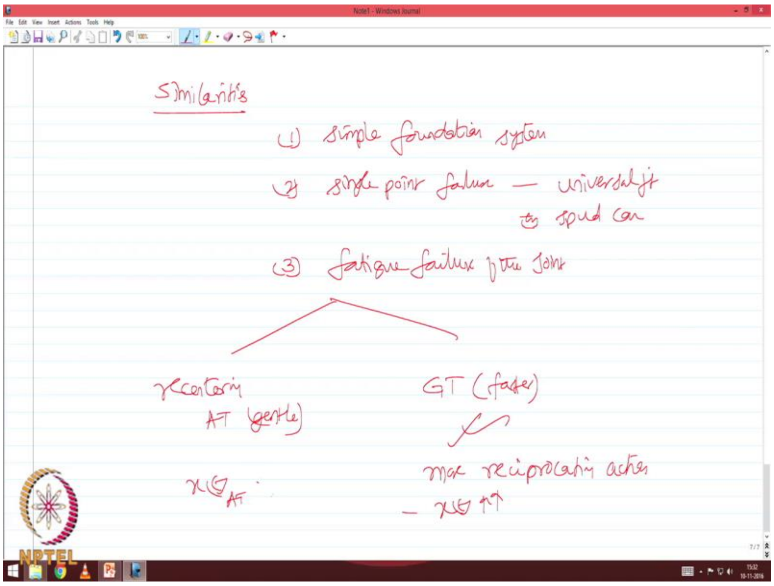

So the similarity: simple foundation systems, both of them actually have a single point failure. How I can say a single point failure, it is actually directed towards either the universal joint or the spud can. In addition guyed wires can also fail the pulling of the guy lines. The third similarity could be fatigue failure of the joint. However, the recentering in articulated tower is more or less gentle, whereas in guyed tower it is more or less faster.

So, though the restoration recentering is faster in this case it is subjected to more reciprocate reaction. Therefore, structural responses of this tower are slightly higher compare to structural response of this term slightly lower.

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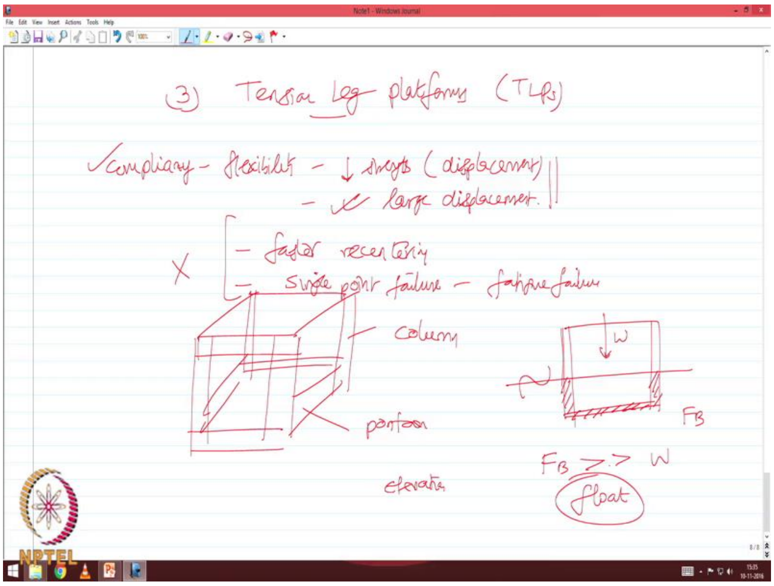

The third category what we have in complaint structures is tension leg platform which we called as TLPs. Now let us look into the novelty of the design in terms of compliancy. We agreed that compliancy induces flexibility; there is reduction in strength in terms of displacement. What does it mean the structure is allowed to undergo large displacements, and it is because of this relative displacement the structure is able to encounter the lateral loads apply on to the structure. So, compliancy is an advantage which is protected in the design.

Let see what is the demerit of the previous two platforms which should be over come in a TLP design. The demerit is: faster recentering, that is the first demerit. The second merit is they had again a single point failure which led to fatigue failure. So, in a TLP these two should be overcome, let see how it has been designed. I have a member, I have a column member, I have another bottom member, so I am drawing elevation of an assembly of four members may be in a three dimensional view looks better like a box. So, these members are called as column members, these members are called as pontoon members.

Now if I have a member which I am drawing elevation now which is submerged only for the partial level they immersed volume of this member, this member completely, and this member. And the associated members on the other direction will have some buoyancy force. All the members will add up to it is weight. If I have a design concept where the submerged volume which induces buoyancy is much higher than the weight of the structure the structure will float.

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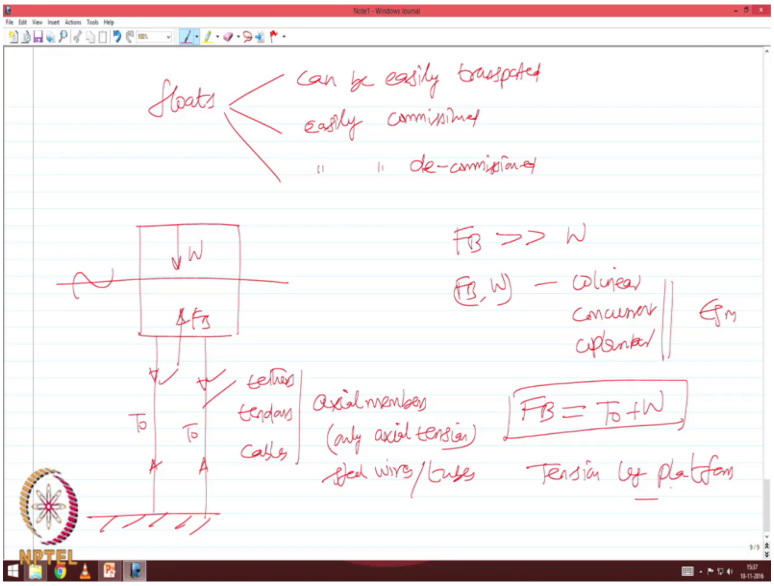

When the structure floats, what are the advantages? It can be easily transported. It can be easily commissioned, let say installed. Most importantly it can be easily de-commissioned. Now, when you have a system which remains afloat because of submerged volume of these particular elements, the system remains a float this mean seabed. But I want to conduct and carry out exploration in this. So, I have to connect this to the seabed by seam mechanism. So, I connect this using wires which are called tethers, they are also called tendons, they are also called cables. They are actually axial members which can sustain only axial pull, essentially steel wires or to be very specific tubes.

Now, we have already said that the buoyancy of the system is much higher than the weight. So, buoyancy is acting upward weight as the platform act as downward, buoyancy and weight essentially of collinear, concurrent, and co-planar for a given system when the system is in equilibrium. Since, buoyancy exceeds the weight I need to have some arrangement by which this should be compromised; let say buoyancy and weight should be compromised. I compromised these two by adding initial tension to the tether. So, the tethers will be all in initial tension. So, this makes an equation of static equilibrium for a given a tension leg platform. Since, all the legs are the platform or in tension all the time the platform is called Tension Leg Platform.

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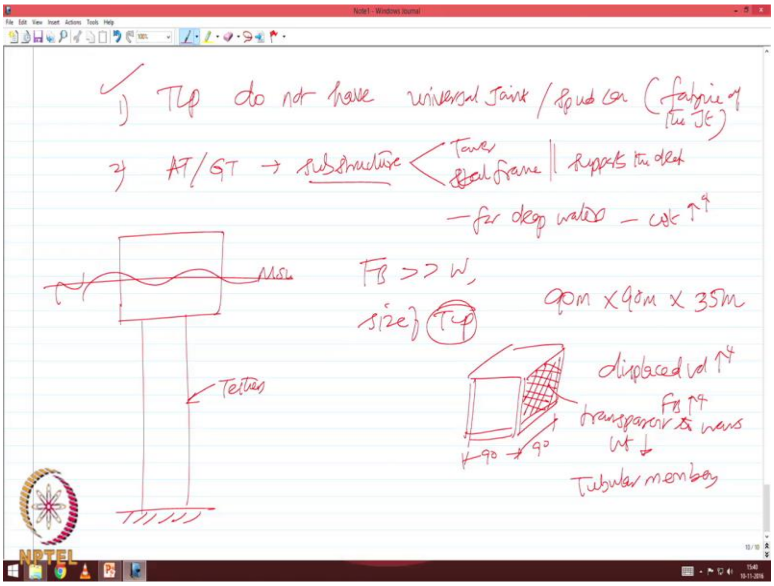

So, one important difficulty which we had in the previous platforms of single point failure is now eliminated, because TLPs do not have universal joints neither they rest on spud can. So, the failure in terms of fatigue failure of the joint is eliminated; that is the first novelty we have. The second novelty is, in both the cases of a t and guyed wires or guyed towers we had a sub system which are either is a tower or a steel frame this supports the deck. Therefore, they cannot be used for deep waters because the cost will go high. Whereas, in TLP we do not have sub structural at all, TLP actually has only super structure. The sub structure is nothing but tethers; this is my mean sea level.

Now one may ask me question I need to have very large buoyancy compare to weight, what is the typical size of a tension leg platform? Typical size of tension leg platform is about 90 meter by 90 meter by above 35 meters. So, I am talking about the plan of size which is 90 meter by 90 meter. So, the submerged volume of this will be very large, the displace volume will be very large which invokes lot of buoyancy, but the weight will be low because I used to tubular members, and more importantly the portion between the member which is hatched here is transparent to waves; waves are allowed to pass through this. Any system which remains transparent waves will attract less force.

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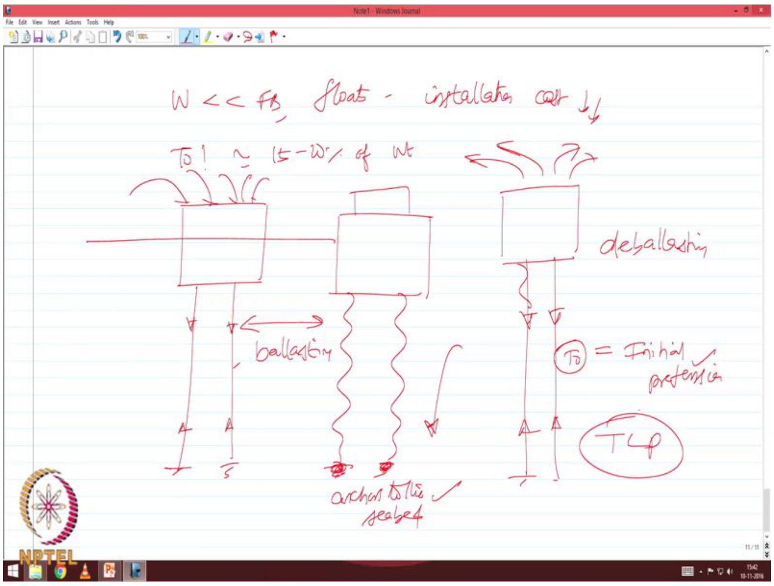

So one point of the difficulties over come; second point, since the weight is very low compare to buoyancy the system sets or floats, so installation cost is reduced tremendously or significantly. But in this case now the issue is what would be the typical value of T 0 which will be approximately about let say 15 to 20 percent of that of the weight of the platform.

Now, I want the platform whose T 0 is relatively high; how do I impose these T 0 to these tethers. So what I do is, I keep on adding weight to the platform this is my main sea level, the platform will settle, now the tethers will be flattened because of the extra weight added the driver goes down connects them anchors them to the seabed, and the (Refer Time: 31:03) are tightened then the extra weight is removed, and the platform now becomes straight. And the additional weight what we imposed will be now gone through the tethers. So, this is called ballasting and this operation is called deballasting. By simply adding and removing the weight in a given platform we will be able to impose pre tension in the tether T 0 is called initial pre tension in the tether. Since all the legs are always in tension the platform is named as tension leg platform.

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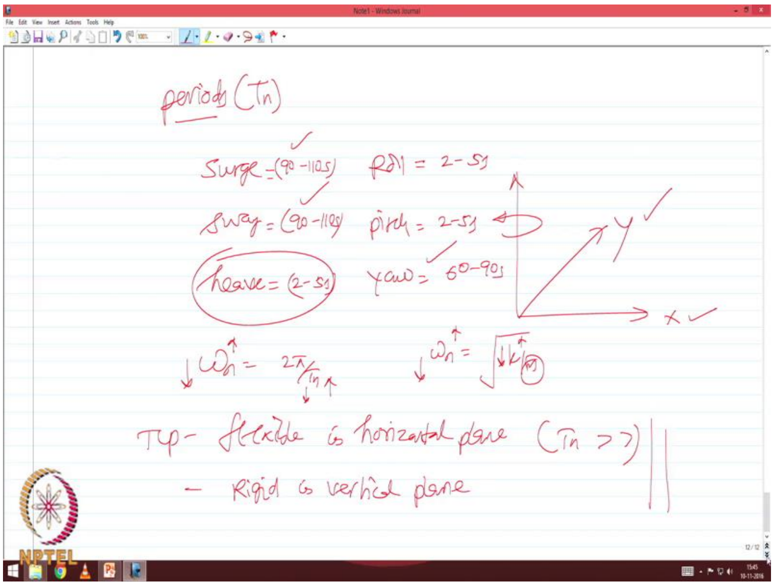

What are the typical periods of platform? Platform has got essentially surge, sway, heave, roll, pitch, and yaw degrees of freedom. Let us look at platform here and not the degrees of freedom since it is x and y axis. So, the periods of surge varies anywhere from let say 90 to 110 seconds I am talking about the periods, natural periods. Sway is also almost same. Heave is about 2 to 5 seconds. Roll is about 2 to 5 seconds. Pitch is about 2 to 5 seconds. Yaw is about 60 to 90 seconds.

Now we all know the natural frequency is 2 pi by Tn, and natural frequency is also root of k by m. For larger periods of surge, sway, and yaw frequency is lower. For lower frequency for the same mass stiffness is lower. So, I can say surge is moment along x, sway is moment along y, and yaw is rotation about this horizontal plane is about this. So, TLPs are flexible in horizontal plane, because the periods are so high, whereas heave is a motion along this z axis which is low period. When the period is very low frequency is high, for a higher frequency for the same mass stiffness is high; so TLPs are rigid in vertical plane.

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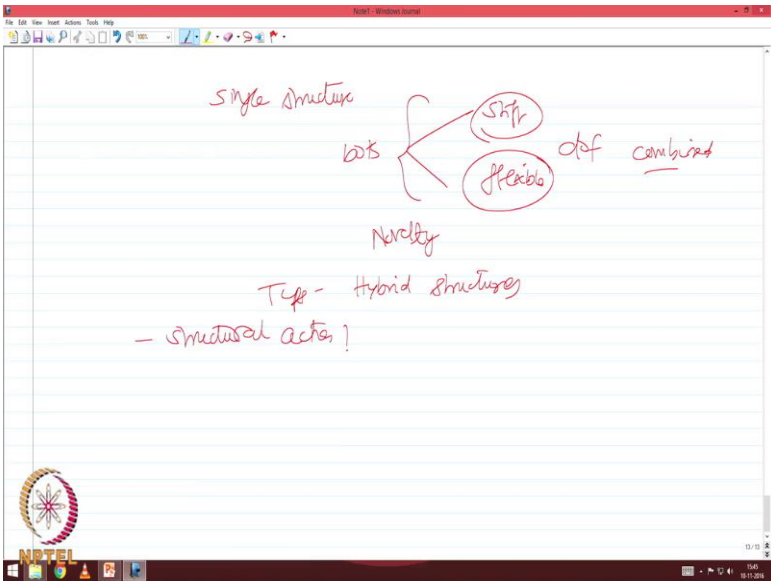

Friends, the novelty of TLP comes from the design. You have one single structure where both stiff and flexible degrees of freedom are combined, is it not; so that is the novelty. It is because of this combination TLPs are also called as Hybrid Structures, because this is the combination of stiff degree and flexible degrees of freedom at the same point. Now let us see, what is the guaranty about the structural action?

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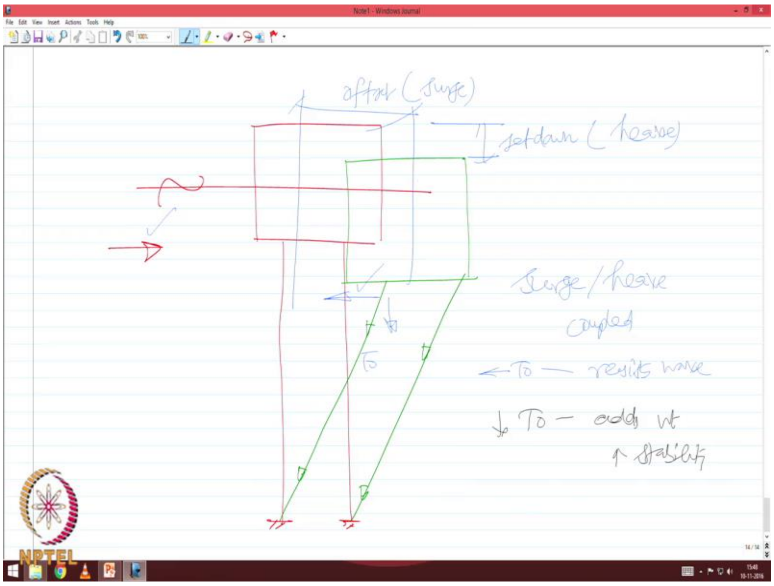

Let say I have a TLP subjected to waves in this direction; so TLP undergoes a new position, they are in tension. The distance between the Cg of this to this Cg new is called offset. The distance between this is set down. So, set down happens in heave degree and off set happens in surge degree. Therefore, surge and heave are coupled strongly. When the platform moves to the right the horizontal component of this which is very high value encounters the wave, so partly the force as the wave is taken care of by the horizontal component of T 0.

The vertical component of T 0 adds to the weight improves stability. So, horizontal component of T 0 resists wave, and vertical component of T 0 adds weight improves stability. So, TLP and hybrid system undergoes surge and set down effect or off set and set down together in a given system which actually helps us to encounter the wave loads acting on the system.

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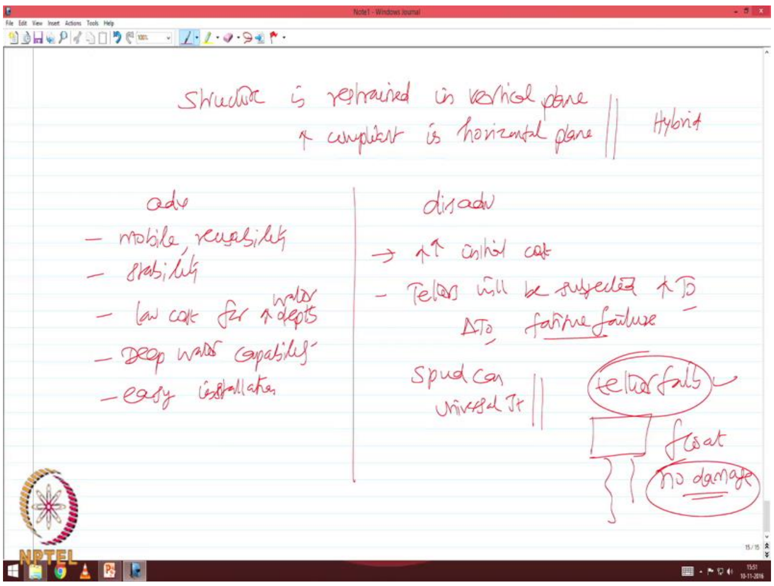

So, I should say structure is restrained in vertical plane, and highly complaint in horizontal plane; that is why it is called hybrid structure. Let see what are the merits and demerits. The merits: high mobility, high reusability, good stability, low cost for increased water depth, deep water capability, easy installation etcetera. Disadvantage could be: very high initial cost, since tethers will be subjected to very high initial tension and change in tension they will undergo again fatigue failure.

So friends, one may ask me a question; if they undergo fatidic failure how this novelty is better than the previous cases. In the previous cases it was a single point failure the spud can or the universal joint failed, whereas in this case even if tethers fails the platform will remain float and no damage to the platform; so no damage to the platform. Therefore, even it failure there is no structural damage; that is a very interesting novelty what you have in tension leg platforms.

So, friends in this lecture, we discuss about novelty of complaint structures, we discussed about guyed wires, guyed towers, we discussed about articulated towers, we also explain about tension leg platform, we will go ahead and explain few more in the next lecture as well before we talk about new generation platforms. I hope you are truly understanding what are those complexities in terms of geometric form of offshore platforms, then what would be the specialty of the behavior under special environmental loads which we will further discuss in detail including the fire resistance design in this course.

Thank you very much.