Offshore structures under special loads including Fire resistance
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Lecture - 02
Offshore Structures: Novelty

Welcome friends to the 2nd lecture in module 1, of the NPTEL course titled offshore structures under special loads including Fire resistance.

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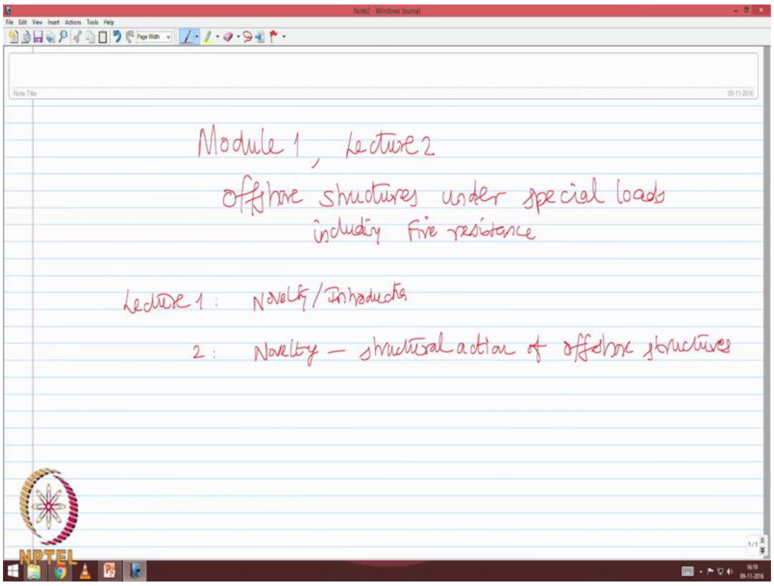

In the last lecture we discussed about introduction and novelty, in this lecture we will continue to discuss about the novelty in terms of structural action of offshore structures.

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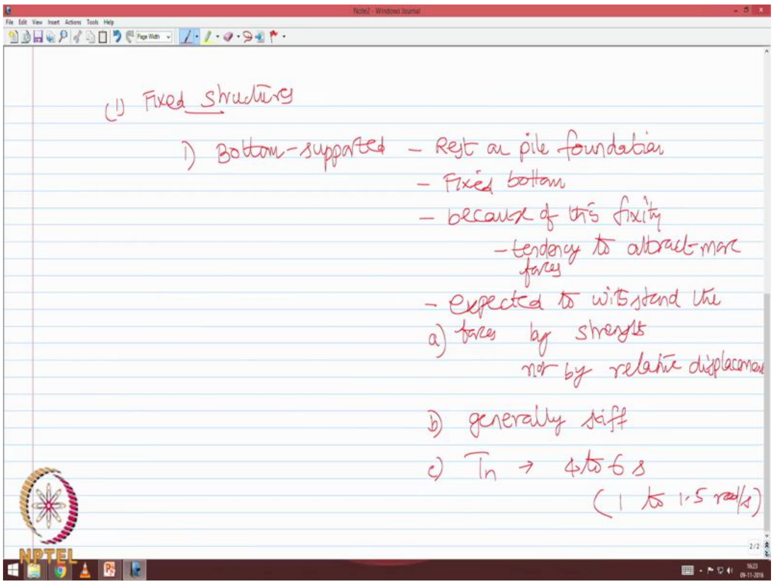

We already said that offshore structures are classified in 3 different forms; the first one is what we call as fixed structures. Before understanding the specialty in terms of this kind of offshore structure, let us try to understand its geometric form.

Usually they are bottom supported it means they rest on piles. The moment I say that the geometric form of the offshore structure rest on pile foundation, it is having a fixed bottom because of this fixity; the structure will have a tendency to attract more forces. So, one can easily write an understanding that this structure is expected to withstand the forces by strength and not by relative displacement that is the first observation we have. The second observation we have is since it is going to rest the forces by its strength, they are generally stiff. On the contrary if the geometric form is going to resist the environmental loads by displacement, then we can say these structural systems will be flexible. So, generally they are stiff, the natural periods vary anywhere from 4 to 6 seconds, in fact the natural periods 4 to 6 seconds equivalently 1 to 1.5 radians per second.

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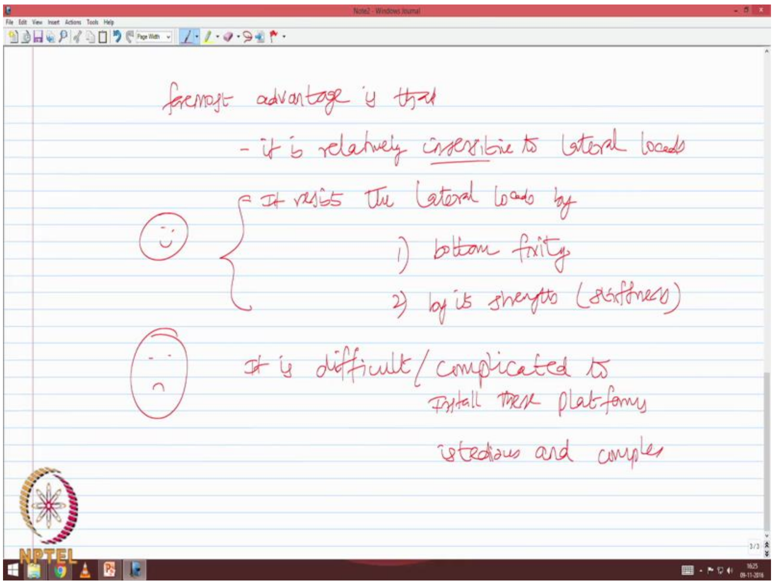

One can always expect the system to have a great advantage if it is stiff; one of the foremost advantages is that it is relatively insensitive to lateral loads; it means the encountered environmental loads cannot cause any serious defamation to the platform. It resists the lateral loads by 2 actions, one by its bottom fixity, second by its strength or say to be very specific stiffness. If you say and feel happy that the structural system is insensitive by virtue on these two actions, it may be a good point but the associated negative point with this is it is difficult or complicated to install these platforms, insulation is tedious and complex.

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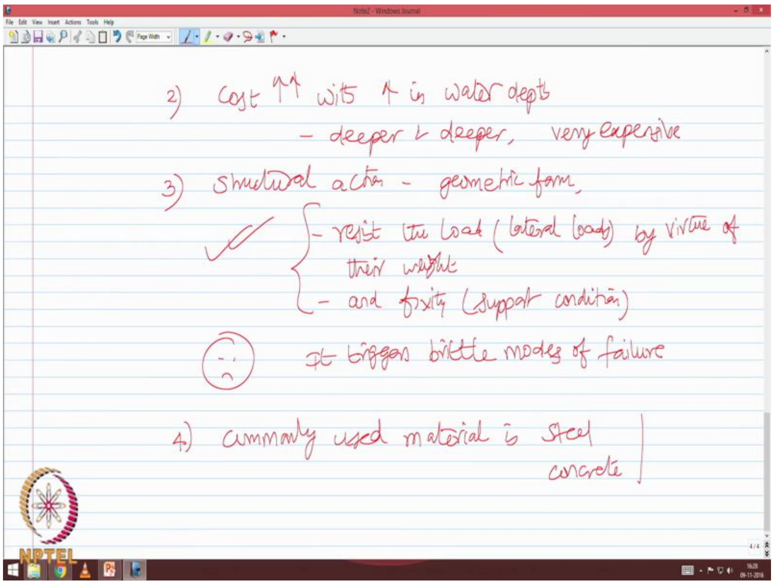

The next factor what we can see as one of the important directives towards this kind of directive platform is that, cost of the platform increases with increase in water depth. So, as therefore, as you go deeper and deeper, these kinds of platforms were proved to be very expensive. Considering the structural action of this platform which arise from the geometric form, they actually resist the loads to be very specific lateral loads by virtue of their weight and fixity that is support condition.

So, one good thing about this is because of the increased weight in the system, they are insensitive which can be an advantage, but the disadvantage is correspondingly it triggers brittle mode of failure. One can ask me a common question what is the kind of material being used for constructing such platforms. Most commonly used material is steel, alternate material is concrete.

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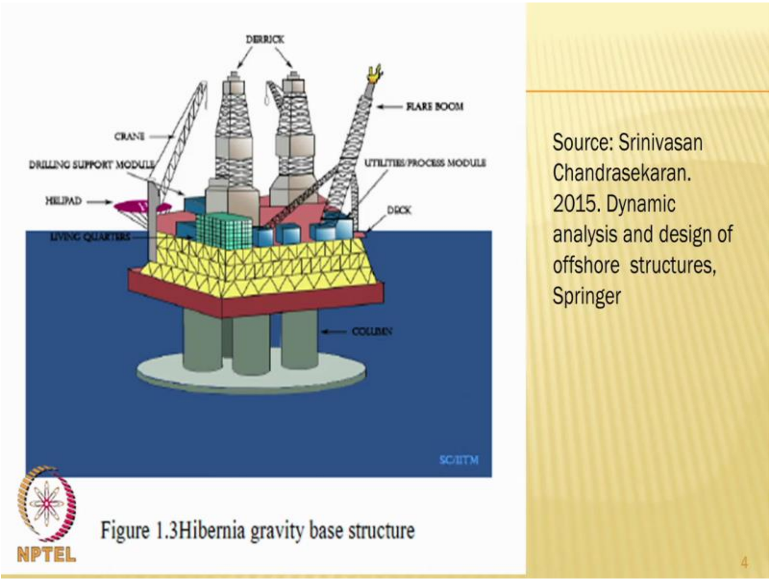

Figure 1.3Hibernia gravity base structure

A typical photograph of a platform is shown on the screen now, which is a fixed platform, it is a photograph of a gravity based structure taken from the source; the photograph clearly shows the complicated top side detail of the typical offshore platform. These are the drilling derricks which are used for drilling wells into the sea bed, these are the columns on which the top deck is being supported, the deck usually is the multi tire supporting system on which various mechanical electro systems are assembled, a flare boom is required to release the gas and the extra flare from the topside of the platform, there are other utilities and process module which are placed on the top side of the platform including living quarters, drilling support modules, different varieties of cranes etcetera in addition to the derricks being used in principle for drilling. The topside platform also has a helipad for housing facilitated conditions during the drilling operations.

If one is interested to know what are those classical environmental loads acting upon these kinds of fixed platforms which are not special loads, but conventional loads.

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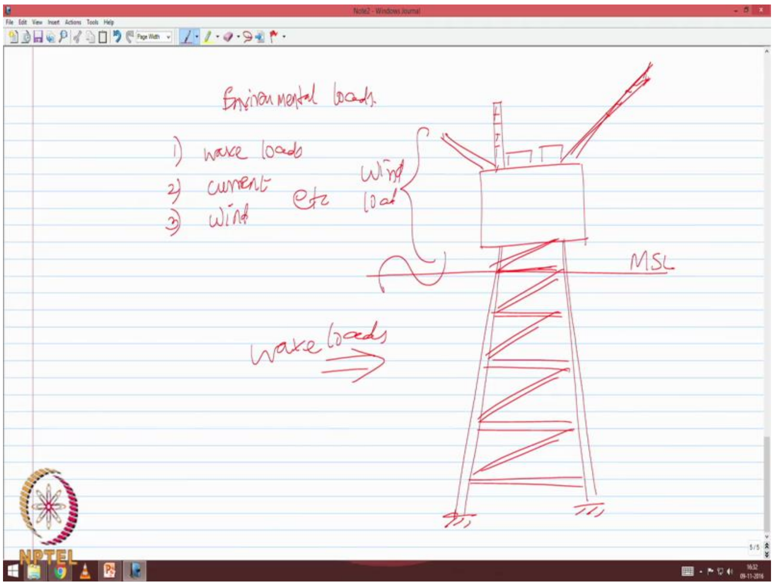

One can list them as wave loads, loads arise from current, load arise from wind etcetera. One will be interested to know how they are typically distributed along the height as far as wind is concerned and along the depth as far as wave is concerned. If this is my typical offshore platform which is having the flare boom, the living quarters, the drilling derrick is resting on legs as a jacket structure, which are also laced lacings and batons are used to improve the lateral resistance to the loads. If this is my typical water level which is the mean sea level, one is interested to know what will be the distribution of the wave loads acting in the sub structure and what will be the distribution of the wind load acting on the super structure.

Please pay attention to the screen now.

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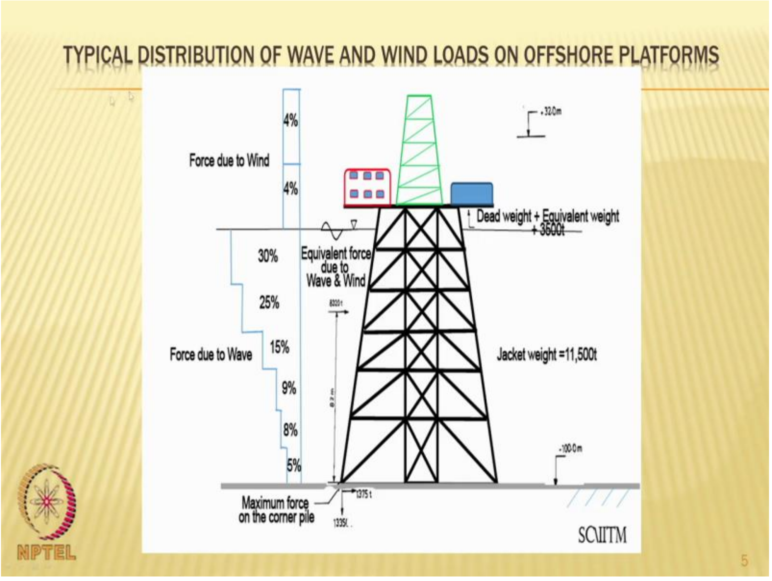

A typical distribution of wave and wind loads and offshore platforms are shown in the screen, a typical jacket structure with a drilling derrick, living quarters and some dead weight of machinery are symbolically indicated on the top side, which are all cause a dead weight or mass on the top side, typical forces arise on this super structure cost because of wind, there are theories available to explain aero dynamic loading on the wind, the jacks on the top side of the platform. The hydro dynamic loading which essentially arise, because of wave action on the platform legs will vary to be maximum near the mean sea level and practically as close to zero near the sea bed. So, this variation is highly non-linear, which has its maximum near the mean sea level and practically zero near the mud level or let say sea bed level.

So, this is a typical combination of wave and wind load acting on the jacket platform as a lateral load, which are not actually special loads, but conventional environmental loads. Let us quickly see what are the advantages of a fixed platform and what are the disadvantages. The moment we know advantages and disadvantages we will have a reason to really go for another kind of platform which are classified platform in other words.

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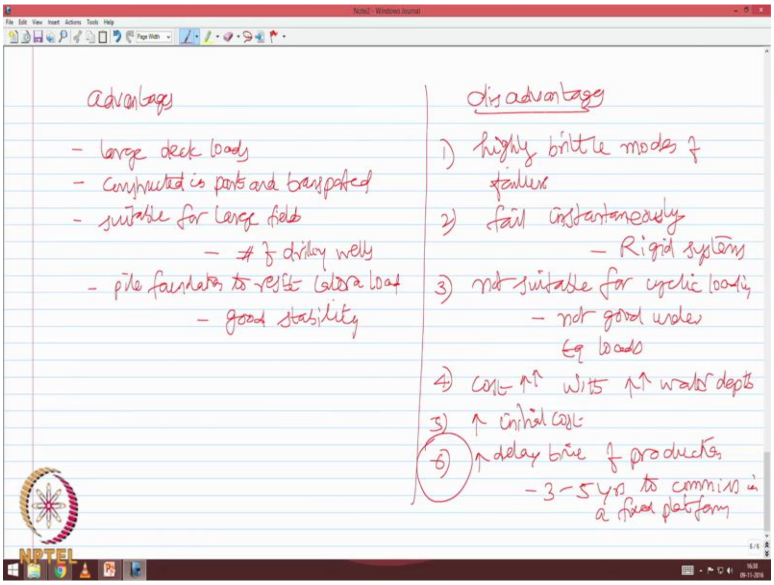

Let us say what are the advantages of fixed type platforms to be very specific the jacket structures? They can support large deck loads, they can be constructed in parts and transported, they are usually suitable for large fields, they can support large number of drilling wells, they use pile foundation to resist lateral load therefore they have very high degree of stability. But bottom support structures do also have disadvantages, they are highly brittle in terms of modes of failure because of the brittle modes of failure being initiated, they generally fail instantaneously because they are more or less identified as rigid systems. Because of the fixidity and high degree of stiffness involved they are actually not suitable for cyclic loads.

Friends, the moment I say they are not suitable for cyclic loading, their behavior under earthquake loads are really worrying. So, not good under earthquake loads the cost of the platform increases larger with increase in water depth, it has got very high initial cost, it has got a very high delay time of production. So, friends, it takes about 3 to 5 years to commission or install a fixed platform. So, early start of production which is a requirement for an offshore platform in the current trend is absolutely missing in this particular platform.

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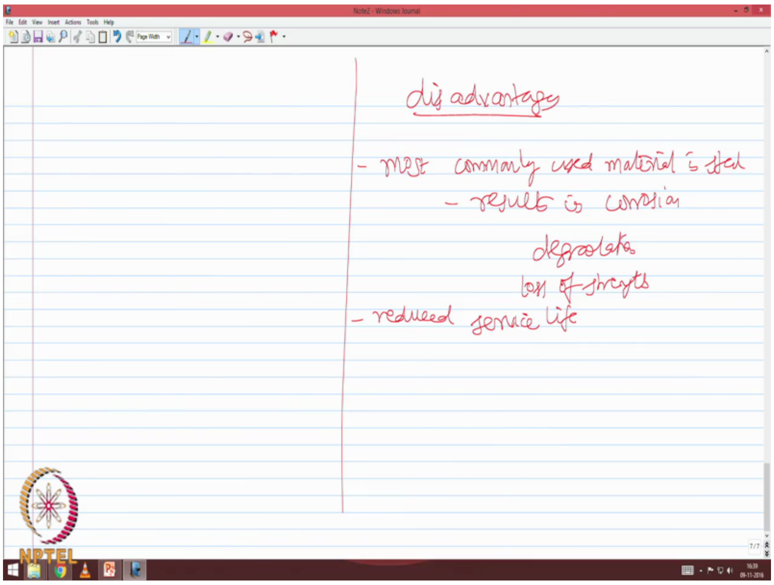

Most commonly used material is steel. Steel has gone problem it results in corrosion, let say material degradation leads to loss of strength, as a result it has got a reduced service life. Now considering these disadvantages, offshore structure engineers wanted to go ahead with a new structural form, which can overcome these demerits. So, the second variety of structural form in its novelty was invented.

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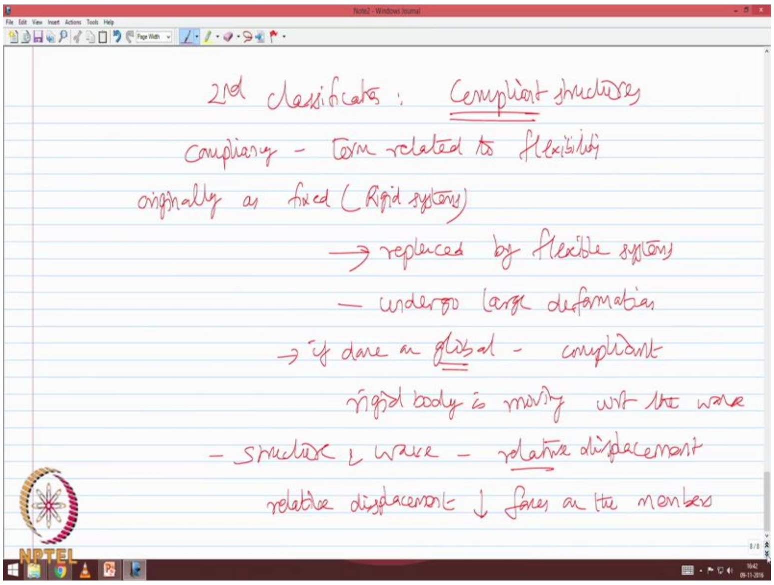

So, the second classification lead to compliant structures, please be careful about the spelling compliancy is a term related to flexibility, fixed type platforms which are originally conceived as highly rigid systems are now being replaced by flexible systems.

Immediately in mind in the engineering prospective one can ask me a question, when the system is flexible the system will undergo large defamation. In fact, the defamation if done on global, we call this as compliant, what do you mean by global displacement? The whole rigid body is move moving with respect to the wave. So, the structure and the wave has relative displacement with each other and this relative displacement reduces the forces on the members, you will now agree that fixed offshore platforms attracted more forces because they were rigid and they were stiff in nature; however, the members of compliant structures are not very flexible, the whole system is made flexible that is very important.

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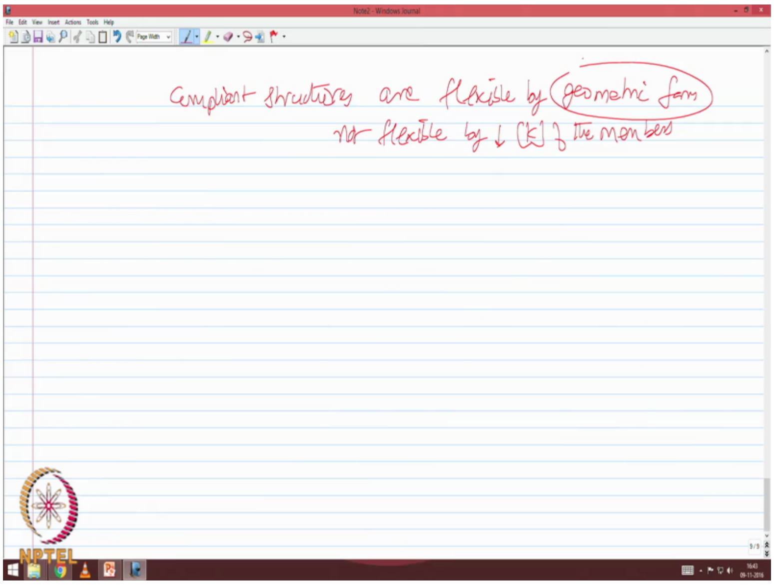

So, compliant structures are flexible by geometry, not flexible by decreased stiffness of the members please understand this is a very important statement members are stiff enough to withstand the forces, but the whole platform remains flexible in terms of its geometric design they are called compliant structures.

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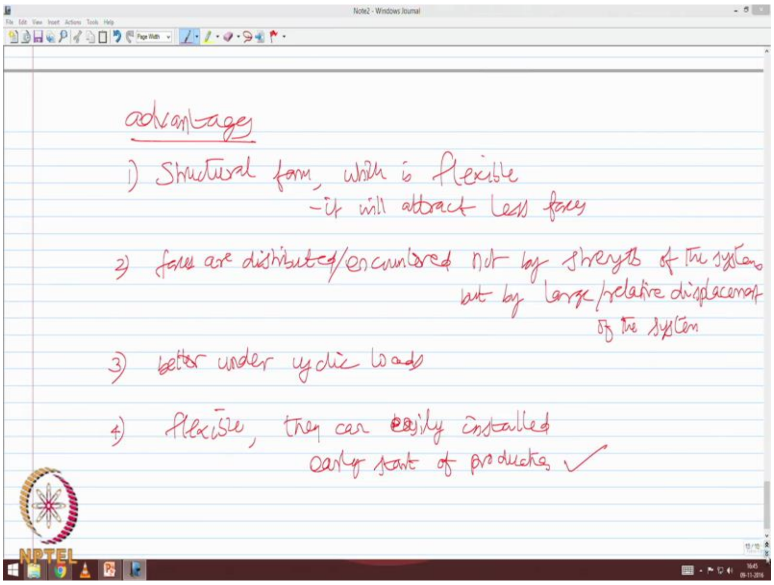

One can say what are the main advantages when you have a structural form, which is flexible the first advantages it will attract less forces, interestingly the forces are distributed or encountered not by strength of the system, but by large relative displacement of the system. Once I say the system is highly flexible and relatively getting displaced they are better under cyclic loads since they are flexible, they can be easily installed compared to fixed structures. So, early start of production was initiated.

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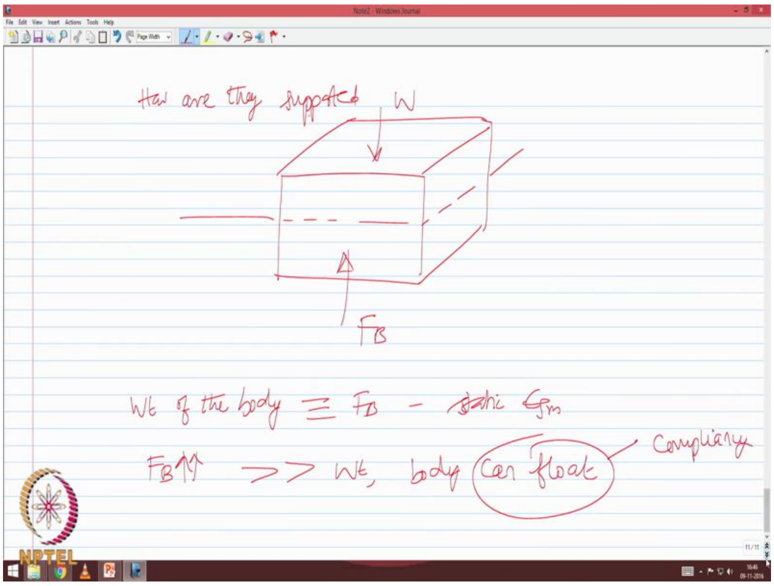

Then the fundamental question comes how are they supported? Imagine a box with a rigid body, which need to undergo a large displacement under the lateral loads, when the body is partially immersed we know the body is subjected to buoyancy force, which is proportional to the displaced volume of the body, the body of course has the mass which is acting downward as weight. If the weight of the body and the buoyancy force acting on the body are made absolutely equal, the body will remain in what we call as static equilibrium, but if we design a system where the buoyancy force which is acting upward exceeds the weight, the body can float because this floatation characteristic has compliancy.

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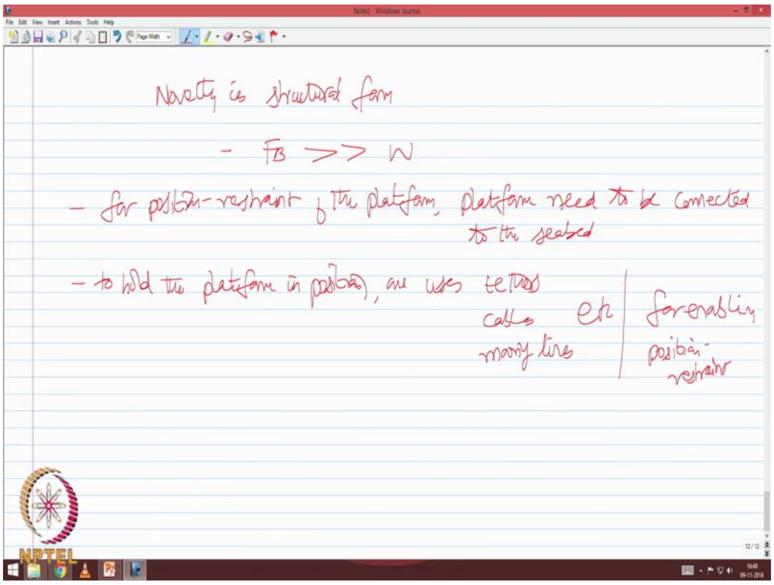

So, the novelty in design or the novelty in structural form comes essentially by keeping buoyancy force much higher than weight, but for keeping the platform in possession, what we otherwise call it as for position restraint of the platform, the platform need to be controlled, need to be connect to the seabed then only the platform will remain in position, otherwise the platform will be continuously floating and no drilling operation can take place. So, to hold the platform in position, one users, tethers, cables, mooring lines etcetera essentially for enabling position restraint in a system.

Once can ask a question what could be advantage of supporting this under cables.

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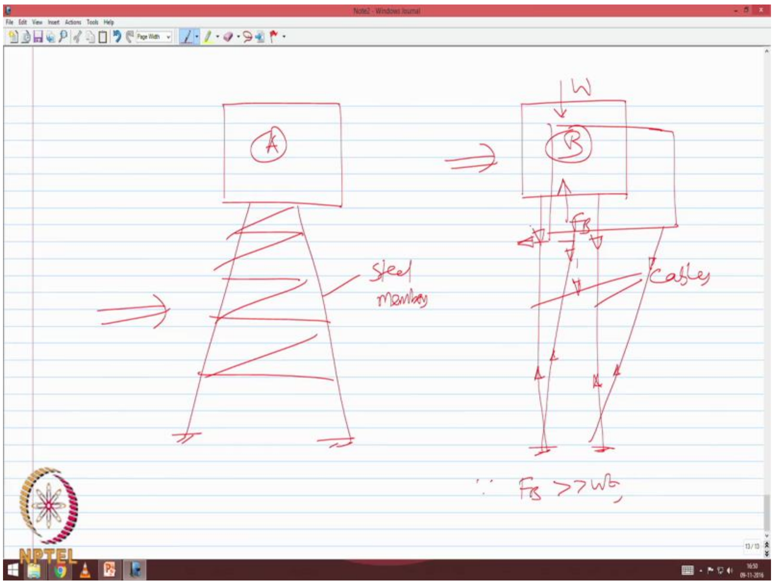

So, let us imagine a platform, which is fixed to the seabed, is the first type of the platform, now let us imagines the same platform, but not fixed to the seabed, but anchored to the seabed using cables; that is why these are cables, these are steel members. So, they have blazing and batons to resist the environmental loads.

Let us imagine that the top side of both the platform A and B are actually similar. Since in B buoyancy exceeds the weight there is in it, upward force which is unbalanced, to balance the net upward force I provide cables which are under tension. When the platform under the wave action moves to the right, which is again connected to the same cable which are in tension, the vertical component of these forces will add to the weight, the horizontal component of these forces will resist the wave length.

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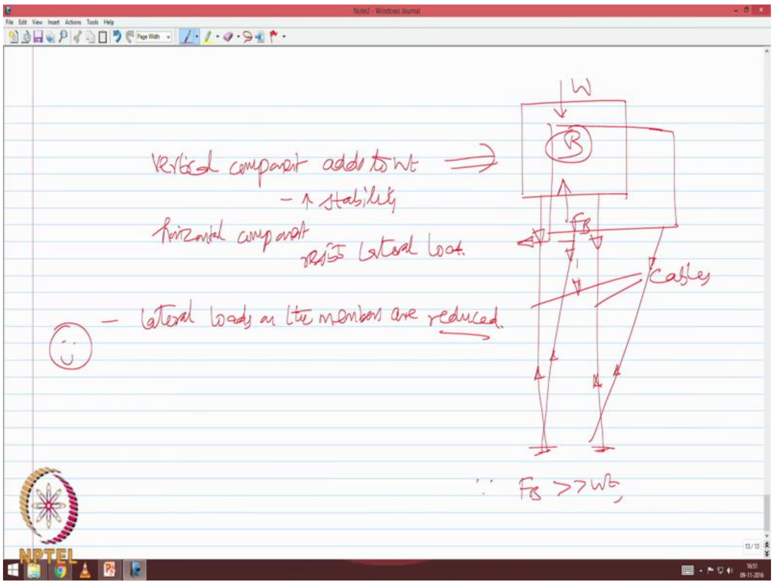

So, interestingly the vertical component adds the weight, improve stability, whereas the horizontal component resist lateral loads. So, the lateral load acted upon the member is now reduced or reduced. So, that is the great advantage we have in the design, there are a variety of compliant structures which have innovative structural forms, which are all conceived by different methods of ideology; however, all of them work on a basic principle that the structure undergoes displacement of a large size compared to the fixed structures.

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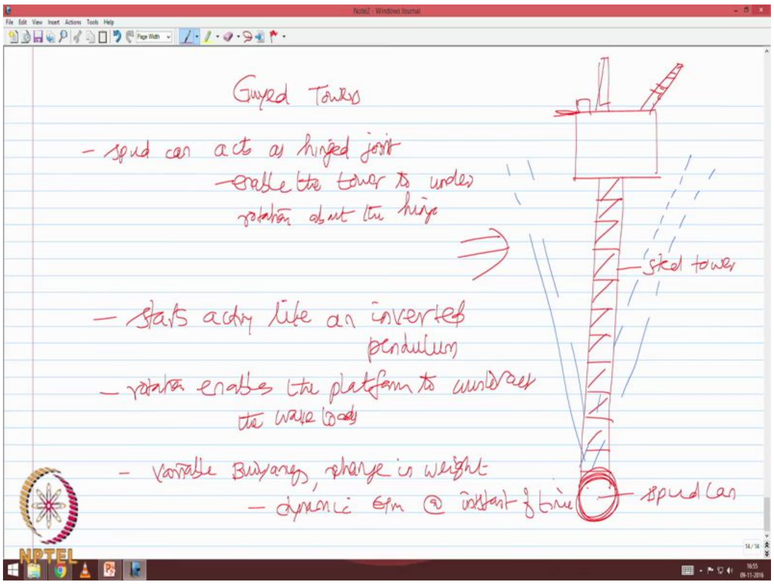

The foremost of its kind what we generally see in offshore platform history is guyed towers, a typical guyed tower has a top side detail, which will be supported by a lattice tower actually a steel tower, which rest on the seabed using a sped can. A sped can arrangement acts as a hinged joint, which will enable the tower to undergo rotation about the hinge. So, under wave action the platform will get rotated or will get rotated. So, the platform starts acting like an inverted pendulum. So, this rotation enables the platform to counteract the wave loads, when the platform is rotating about the hinged point the platform to counteract the wave loads when the platform is rotating about the hinged point the platform has a variable buoyancy, change in weight, which then challenges the dynamic equilibrium of any instant of time.

What are the advantages of different kinds of other forms of platform in compliant systems? How are they improved depending on the design? How do they encounter the structural action against the environmental loads will be discussed in the successive lectures indicating very clearly the novelty of the platform in terms of structural action and the platform geometry.

So, friends in this lecture we discussed about the novelty that arise from the geometric form of offshore platforms. We discussed in detail the structural action of a fixed type of offshore platform, we discussed the merits and demerits of fixed type platforms and then understood the compliant type platforms are superior compared to fixed types, because compliant type platforms can alleviate the environmental loads by large displacements; relative with respect to wave action therefore, can remain flexible at the same time they are strong enough to encounter the environmental forces. In the further lectures we will further discuss about the structural action of other kinds of platforms.

Thank you.