Offshore structures under special loads including Fire resistance
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Lecture - 07
Offshore Triceratops

Friends today we will have the 7th lecture under the NPTEL course on offshore structures under special loads including fire resistance. Today in this lecture we will talk about one of the new generation platforms, which is recently conceived which is offshore triceratops.

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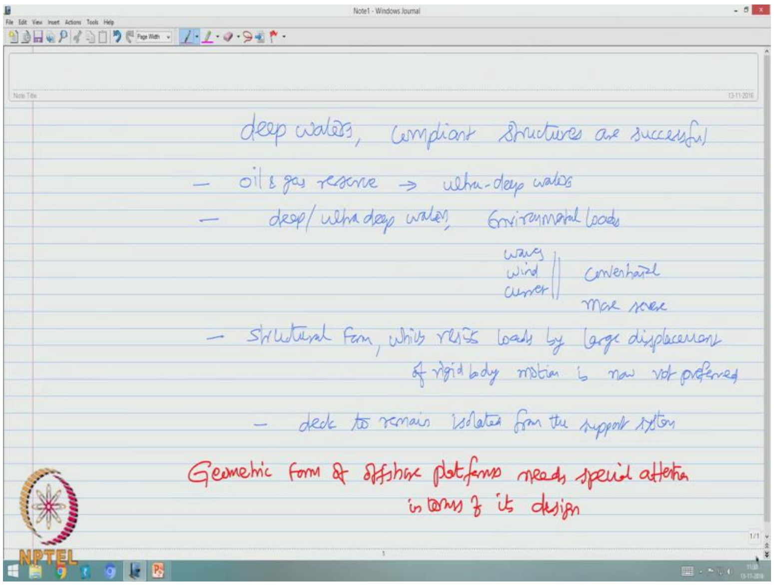

We have already said that in deep waters complaint structures are successful, but there were some limitations. We also agree that oil and gas reserve is move towards ultra deep waters, we also agree that under these deep and ultra deep waters, the environmental loads caused by waves, wind, current etcetera though they are conventional, but they are more severe.

Hence a structural geometry or a structural form, which resist loads by large displacement of rigid body motion is now not preferred. We do not want preferably the deck to remain isolated from the support system. Hence one can say now the geometric form of offshore platforms need special attention in terms of its design.

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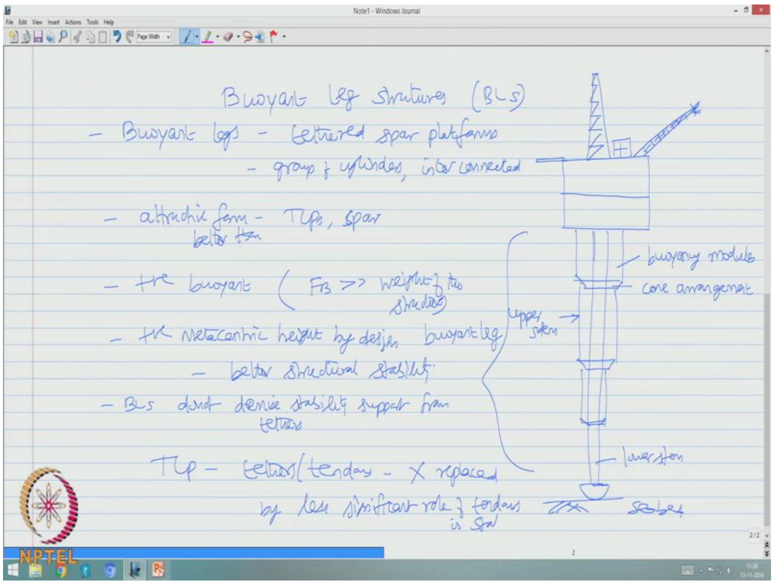

There are different types of new generation platforms which are conceived for ultra deep waters, foremost idea which came into bind is from buoyant leg structures. Essentially they have the top sides as similar to a drilling platform with a multi tier hull, where the drilling derrick is located and drilling is enabled through the derrick, there are other facilities like a flare boom a helideck, a living quarter's etcetera which are present.

Now, the support system is very interesting in this case, let us (Refer Time: 04:57) the support system can resist the lateral loads through the spur can arrangement in the tower should be now supported with additional buoyancy modules. So, these are buoyancy modules. So, the connectivity between the modules is what we call the cone arrangement, this is called as the upper stem and this is of course called as the lower stem.

So, in general we call this as buoyant leg therefore, buoyant legs are actually similar to tethered spars, take the sometimes also have group of cylinders connected together, they are seem to be attractive form compared to TLPs and spare platforms, they are better. They are essentially positive buoyant where one can say buoyancy very much exceeds the weight of the structures, they also have a positive metacentric height by design, which enables a better structural stability. So, essentially buoyant leg structures do not derive stability support from tethers.

So, the ideas of TLPs supported by tethers are tendons, becoming integral part of the weight distribution system is now replaced by less significant role of tendons in stability. So, essential features of any buoyant leg system – one, a deep draft system. Two, high stability; these two characteristics makes it in sensitive to ultra deep waters. So, we design it may be preferable, let us now look into the construction aspect. We already know for deep waters too effective conceive structural forms where TLPs and spar platforms.

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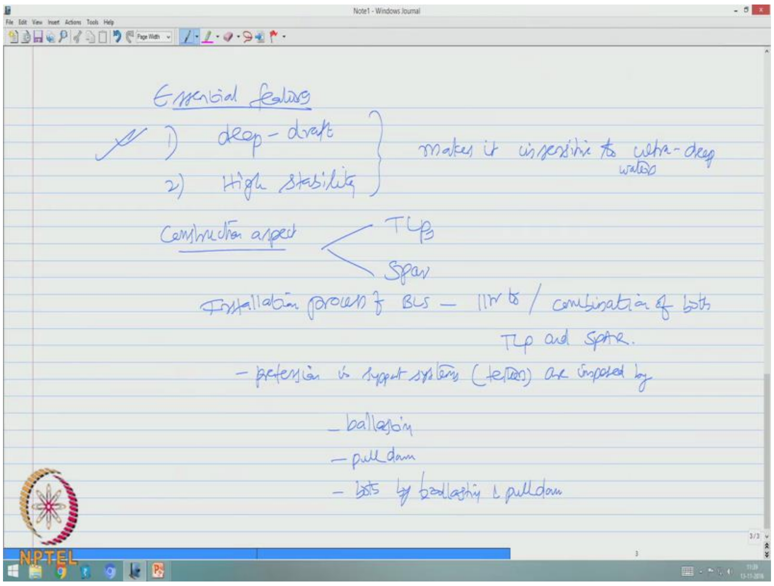

So, installation process of a buoyant leg structure is similar to this or rather we can say a combination of both TLP and spar. So, pretensions in support systems like tethers are imposed by either ballasting or by pull down or sometimes both by ballasting and pull down.

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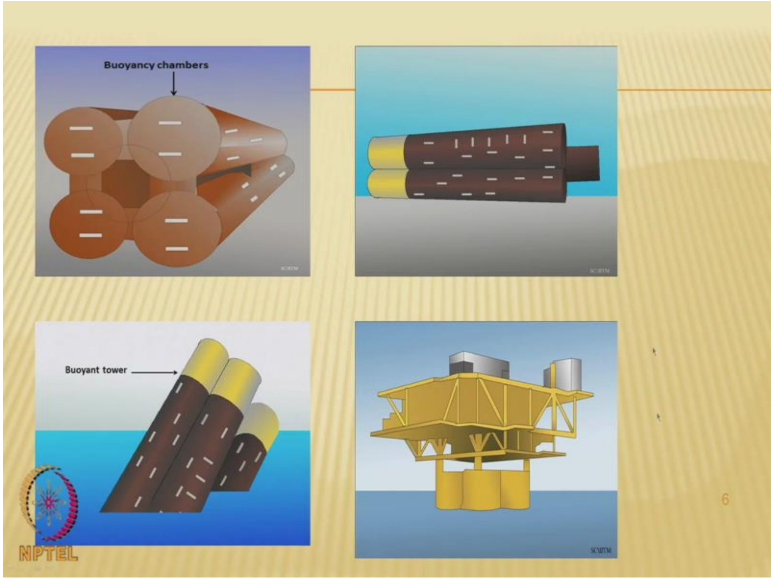

Please look at the screen, these are different forms of buoyancy chambers which a generally used as buoyant towers, which comprises a buoyant leg structure (Refer Time: 11:18) into the large diameter towers which are essentially used as buoyancy chambers in a given system, which actually supports the deck and then further connected to the seabed either by a more in system are by a TLP similar to a tendons system.

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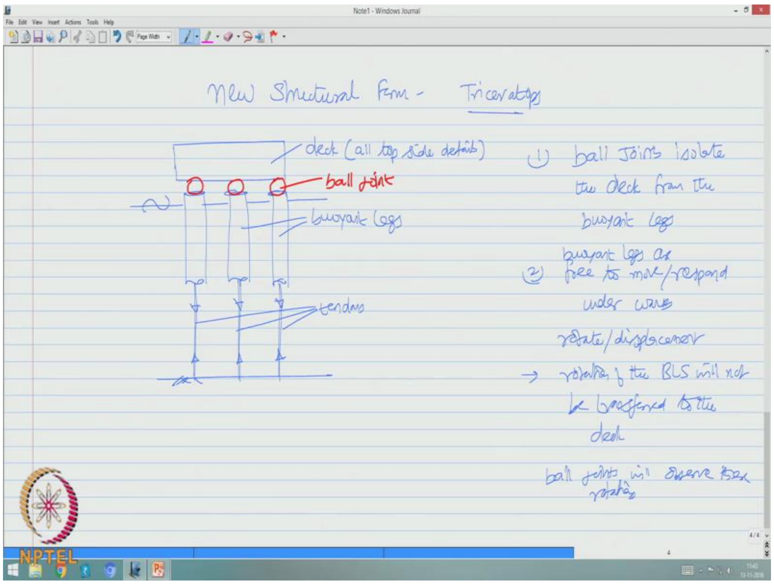

Extending this philosophy, offshore engineers innovated new structural form called triceratops. A typical triceratops conceived in the beginning of an idea consist of a deck with all top side details with the buoyant legs, 3 set of buoyant legs the seabed is somewhere here, this buoyant legs one end is connected to the seabed using a tether or a tendon, so these are tendons.

Similar to that of a TLP they will be an axial tension, the other end of this buoyant legs was connected to the deck with a help of a ball joint. So, essentially joints isolate the deck from the buoyant legs. So, buoyant legs are free to move or to respond under waves because this is going to be my water line. So, they can rotate and they can displacement; however, is interesting that the rotation of the buoyant legs will not be transferred to the deck because the ball joints will observe these rotations.

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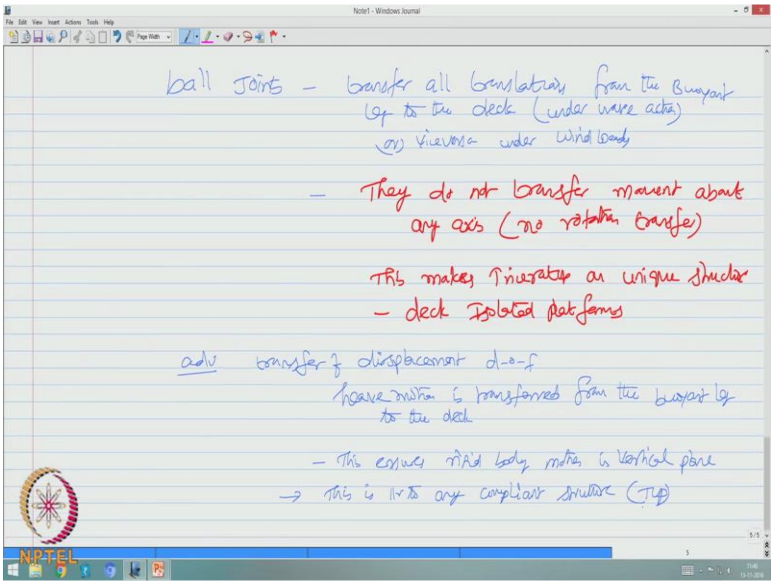

So, one can say that ball joints transfer, all translations from the buoyant leg to the deck under wave action or vice versa under windows, they do not transfer moment about any axis that is no rotation transfer.

So, this makes triceratops a unique structure, one can say it is deck isolated platforms. There is a great advantage of transfer of displacement degrees for example, heave motion is transferred from the buoyant leg to the deck, this ensures your rigid body motion in vertical plane, which is require for any complaint system, this is similar to any complaint structure like a TLP.

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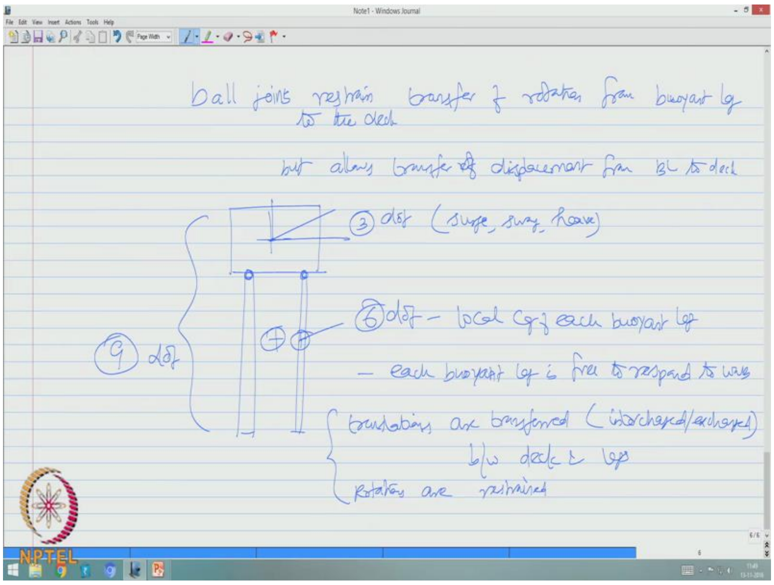

Therefore, ball joints restrain transfer of rotation from buoyant leg to the deck, but allows transfer of displacement from buoyant leg to deck, So obviously, if we have the deck on at cg the system may have 3 degrees of freedom that is surge, sway and heave whereas, the buoyant legs with the ball joint will have 6 degrees of freedom, measure at the local cg of each buoyant leg. Now why each buoyant leg will live independent? Each buoyant leg has a freedom is free to respond to waves. So, the total system will have 9 degrees of freedom translations are transferred. In fact, I should say interchanged or exchanged between deck and legs rotations are restrained. By having such a form what is the advantage?

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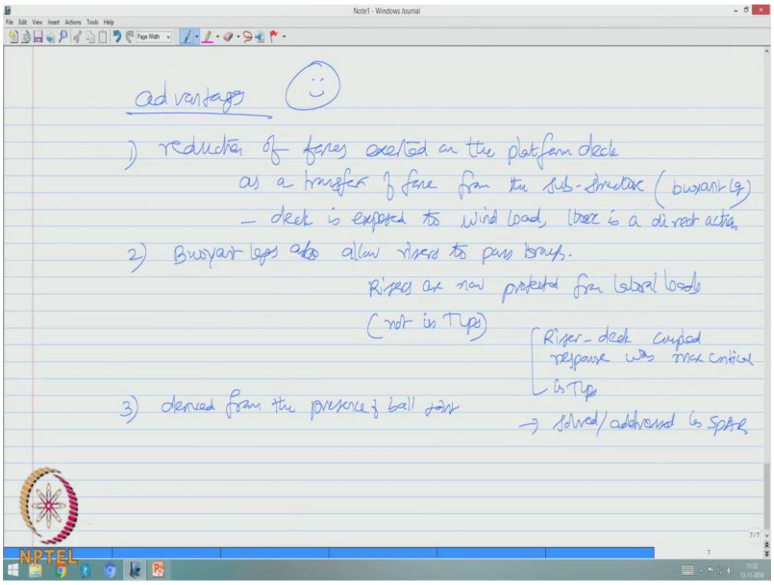

One can expect a large reduction of forces, exerted on the platform deck as a transfer of force from the substructure because we all know deck is not directly exposed wave action; in this case substructure is buoyant leg.

However when the deck is exposed to wind loads there is a direct action. Secondly, the buoyant legs also allow risers to pass through. So, risers are now protected from lateral loads, which was not the case in TLPs; risers are exposed to lateral loads in TLP therefore, the riser deck coupled response was more critical in TLPs. Of course, this problem was solved was addressed in spar platforms because in spar platforms raises are made to pass through the deep draft cylinders, now risers are partially protected from wave action.

So, main advantage is also derived from the presence of ball joint.

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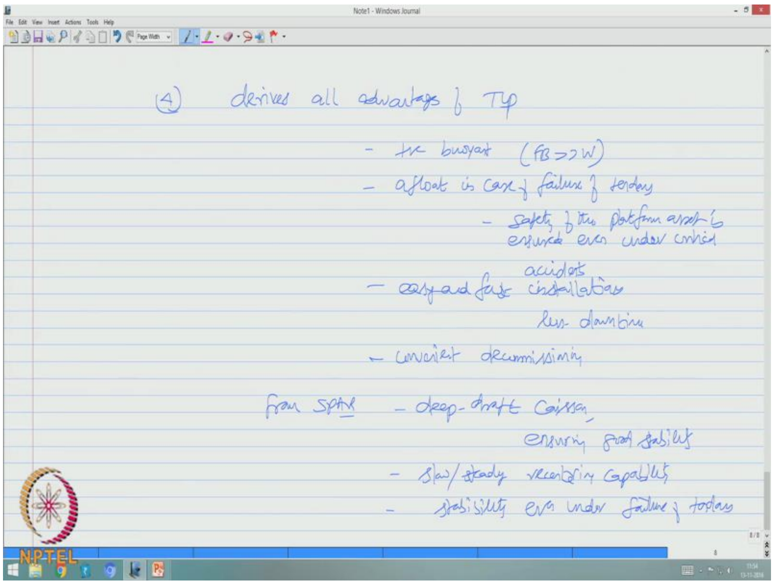

The system of derives all advantages of a TLP be positive buoyant, that is buoyancy force exceeds the weight by a large amount, remains afloat in case of failure of tendons therefore, safety of the platform asset is ensure even under critical accidents, easy and fast installation, less-down time, convenient decommissioning this is also important. It also derives a few advantages from spar, a deep draft caisson ensuring good stability, slow and steady recentering capability, stability even under failure of tendons in addition to this it derives one major advantage due to the presence of ball joint that is deck is isolated from the support system.

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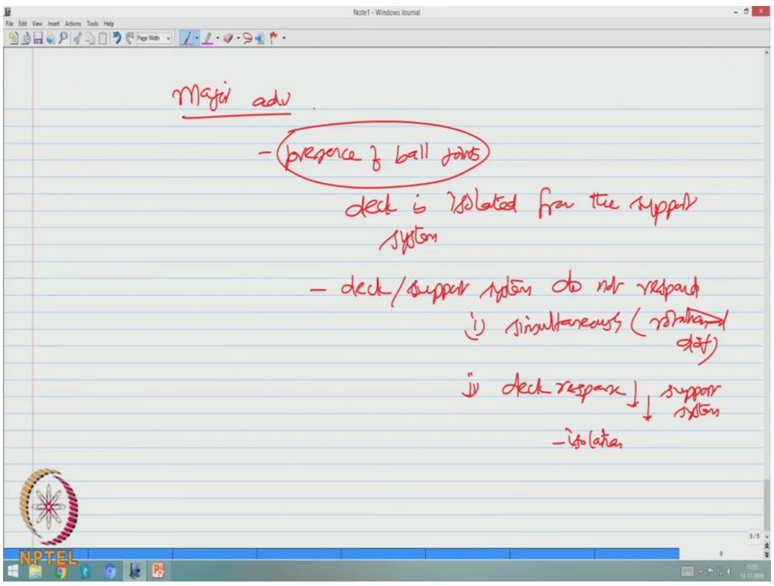

Therefore deck and support system do not respond one simultaneously, at least in rotational degrees of freedom; two, deck responses is expected to be lower compare to the supports because of isolation. So, some of the classical advantages are derived because of presence of ball joint alone.

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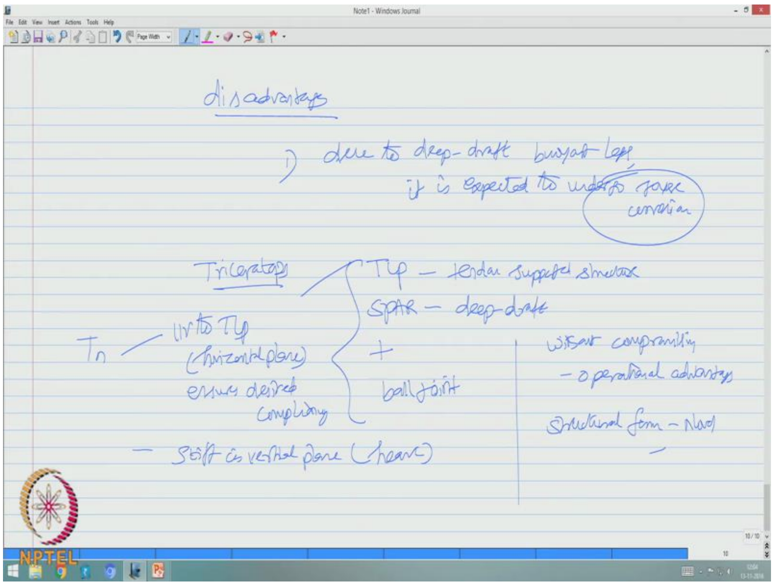

It derives one important disadvantage which was also in present in spar, actually due to deep draft buoyant legs it is expected to undergo severe corrosion. So, that can be a very severe demerit, which is unusual in case of deep water platforms.

Now, friends I would like to show you a very interesting case study which has been carried out at IIT madras, on this new conceived idea which will discussed in detail using experimental investigations.

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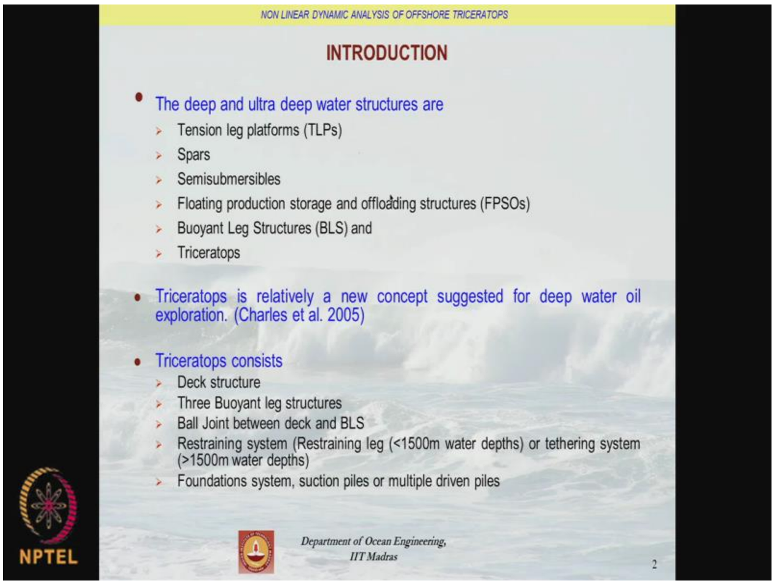

Please pay attention to the presentation now on the slide, we all agree that deep water platforms and ultra deep structures can be with help of TLPs, with help of spar platforms, semisubmersibles, buoyant leg structures and Triceratops. Triceratops is relatively new concept suggested for deep water oil exploration, it consist of a deck structure, 3 buoyant legs, ball joints connected between the deck and buoyant leg under restraining system similar to that of a tension leg platform and of course, a foundation system.

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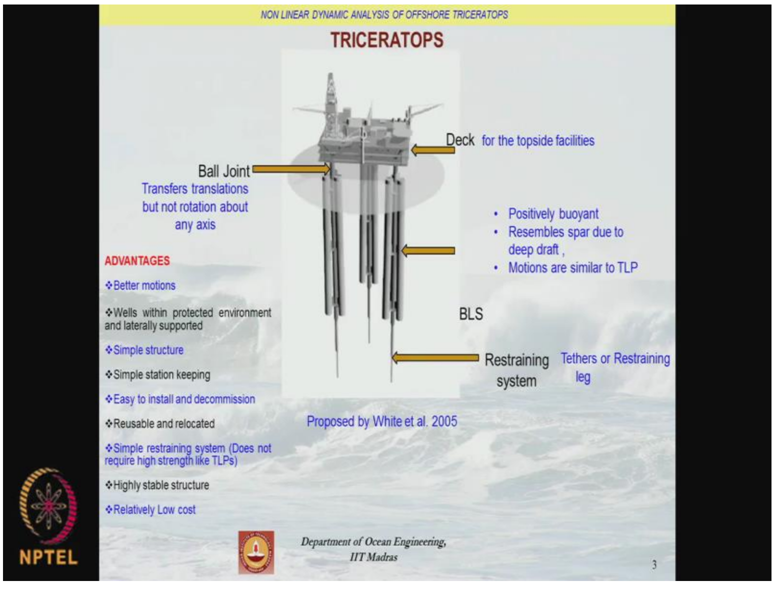

Please pay attention to the figure shown on the screen, triceratops is a conventional idea conceived by white et al in 2005, consist of a deck with all topside facilities. The ball joint is present between the deck and the buoyant legs usually buoyant legs are the single cylinder, it is an set of 3 5 7 cylinders which are interconnected; however, each leg stay in isolation, they are not interconnected therefore, each set of legs have freedom to respond to the wave action independent of the influence of other legs on the deck.

So, ball joints transfer only translational motion, but no rotation. So, there are specific advantage derived from triceratops geometry, better motion characteristics, wells are protected within the buoyant legs and they laterally supported, relatively a simple form of geometry, good station keeping procedures, easy to install and decommission the platform, highly reusable and relocated, simple restraining system does not require a high tether tension as in the case of tension leg platforms, very high stable because positively buoyant system, relatively low cast because installation and decommissioning is very fast with a lowest possible downtime, it is a positive buoyant system therefore, resembles spar due to deep draft and motions are more or less similar to that of a tension leg platforms. So, it delays advantage of both set of deep water platforms namely tension leg platform, under spar platform.

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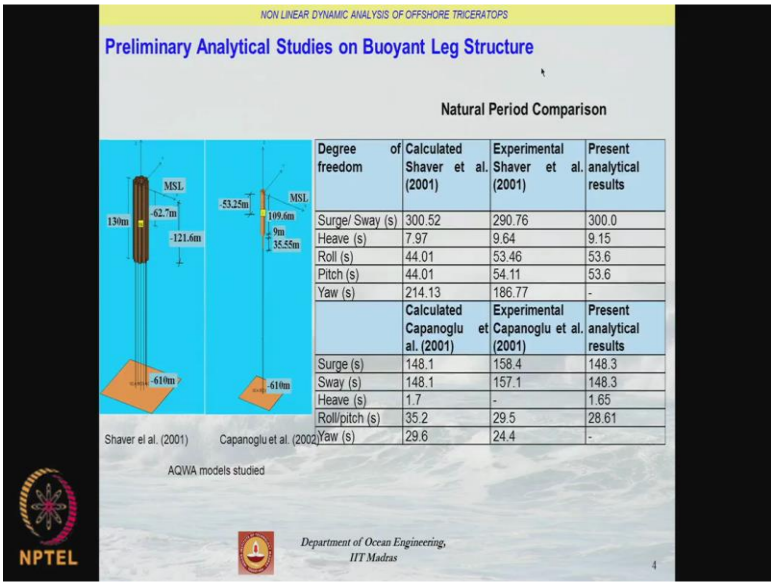

A typical study which has been conducted to compare the preliminary analytical studies results are shown here.

If one can look at the experimental investigation conducted by Shaver et al and then the present analytical model what we investigated at IIT madras, for a single buoyant leg structure the periods are really very high in terms of surge sway degrees of freedom, making it highly compliant whereas, in case of heave, roll and pitch the periods are very close; however, they are still higher compared with that of conventional TLPs. So, buoyant leg structure alone has a single standing system is enable to support the exploratory process, because a very high roll and pitch degrees of freedom. So, it is effective that we have to attach buoyant leg to the deck, using some unconventional or a special kind of structural member which isolates the deck from that of the buoyant leg.

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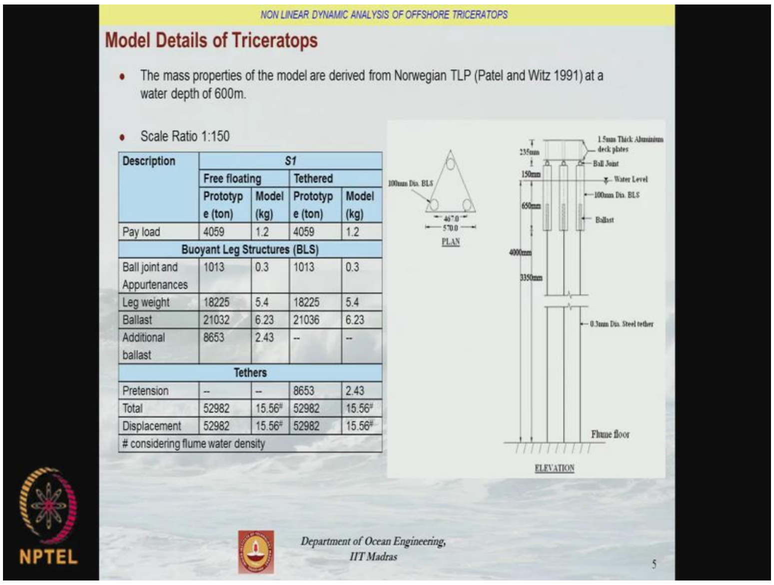

So, now the ball joints are the placed in between the buoyant leg and the multitier deck as an experimental model, and now for the experimental model one can compare the tether and free floating analysis are for the values given on the screen now for its geometric property on a scale of a model at 1 is to 150, which is investigated experimentally at a water depth of 600 meter for a specific prototype whereas, in the moral study a relative scale has been adopted.

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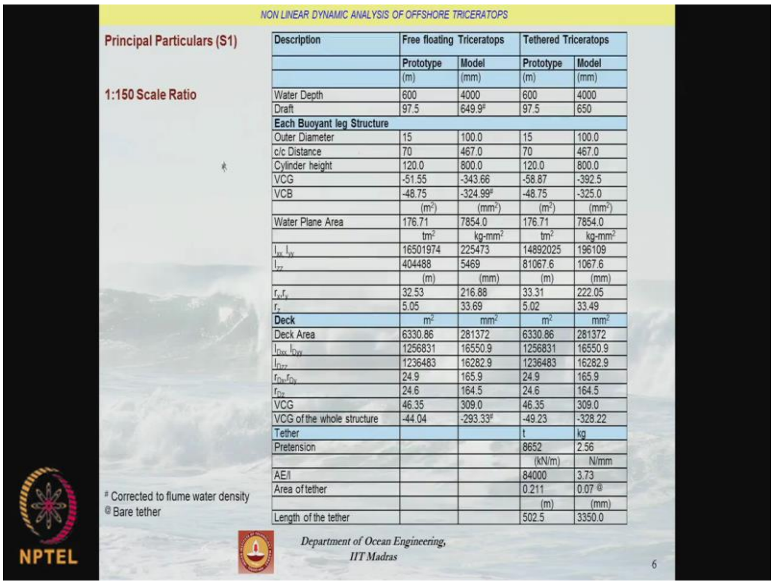

The principle particulars of this particular model, which has been investigated on two issues floating and tethered; for the same water depth, for model as a similar drop the particulars of each buoyant leg in terms of the buoyant legs, the deck and the pretension are available on the screen now.

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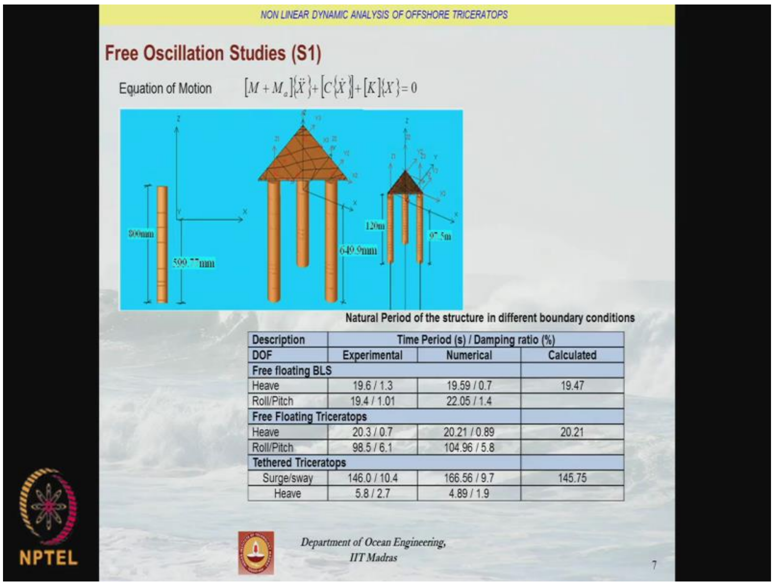

The classically equation motion for free oscillation study will help us the find out the free periods which are seen on the experimental model. One can see here for a free floating system the experimental models show the heave and the roll pitch degrees as see here, where as for tethered triceratops they are showing slightly a very high value compared to a TLP; however, they have a very strong heave resistance system.

So, the platform is heave resistant and vertical plane whereas, the platform remains isolated and very highly compliant in horizontal plane that is in surge spar degrees of motion. So, we have seen that triceratops derive advantages of a TLP under spar. Spar because deep draft system, TLP because tender supported substructure. In addition t derives an advantage because of the ball joints. So, the natural periods or more or less similar to that of a TLP in horizontal plane, ensures the desired compliancy it is stiff in vertical plane by restrict in the heave motion therefore, without compromising the operational advantages, the structural form is conceived which is highly novel.

In the next lecture we will show you some of the results of triceratops under wave and wind action as a sample study which we conducted, we will also talk about one more platform which is used for L and G exploration in the next lecture.

So, friends in this lecture we spoke about classical new generation platform, with a conceived idea on the recent past which is triceratops; we have seen the advantages derived from the existing structural forms, to conceive a new structural form for a triceratops, we have also seen and understood now realize the advantage of tracing a ball joints and isolated a deck from the substructure because the deck isolation enables the deck and the substructure to behave independently on certain degrees of freedom, which are translational which are transfer, but rotational degrees of freedom are not transfer.

So, under rotational degrees of freedom like yaw motion, roll and pitch motion, buoyant legs do not transfer them to the deck whereas, an vertical plane for example, the heave motion or in horizontal plane for example, the surge or sway motion plane, they are transferred ensuring the rigid body connection. Though it is an hybrid system, but the hybrid system is still far compliant with large a periods in horizontal plane and lower periods in the vertical plane.

Thank you very much.