Advanced Marine Structures
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Lecture - 3
Compliant Type Structures

Today, we will discuss in the third lecture on advanced marine structures, some details about complaint offshore platforms, which are another classical type for marine structures which are used for oil exploration.

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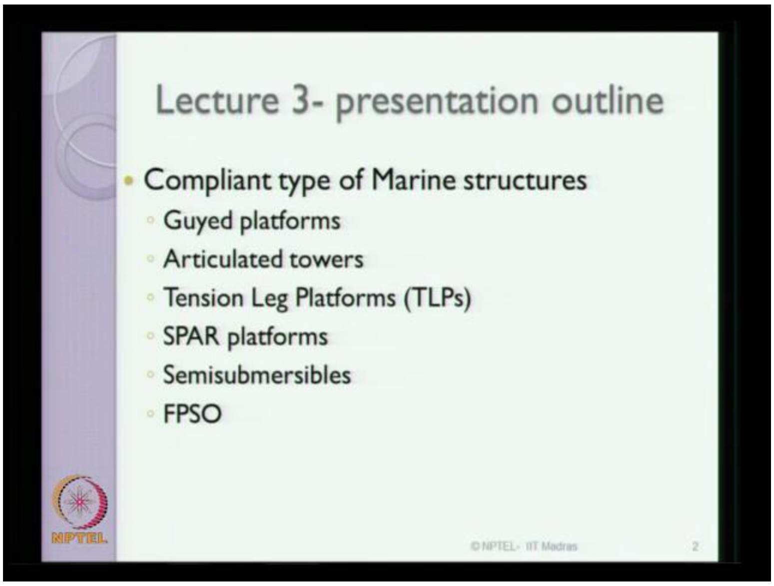

In the compliant type of marine structures in today's lecture, we will focus on guyed platforms, articulated towers, tension leg platforms, SPAR platforms, semisubmersibles and FPSO.

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The word compliant has a specific meaning in the literature, compliant stands for mobility, flexibility or movement; anything which moves is said to be compliant. So, compliant structures are essentially offshore drilling platforms that are deployed in the deep sea for oil exploration. So, we are now moving towards the greater water depths of marine structures compare to that of what we discussed in the last lecture. In the last lecture, we discussed about fixed type platforms, which are meant for shallow and medium water depths, whereas now we are talking about different structural form of marine structures, which are meant for deep waters and ultra deep waters as well.

Compliant structures are generally connected to the sea floor by a mooring system. The mooring system, in general is a taut mooring system. When they are anchored to the sea bed using a mooring cable then one can expect that the system has a freedom to move laterally under the lateral loads or under the excited environmental loads. Now various loads which are exciting this kind marine structure are wave loads, wind loads, current loads etcetera. Under these lateral forces the structure or the platform will have a degree of freedom to move lateral direction.

These structures essentially rely on a restoring buoyancy force. So, the basic principle of design is very simple in this case. I am maintaining the weight of the structure is for lower than that of the buoyancy. Therefore, when the structure is installed in a specific draught at the installer location the upward forces, which are caused by the immersed volume of the members, will exert upward forces on the members, which we call as buoyancy forces. They are proportional to the submerged volume of the members. As the member dimensions or a platform dimensions are very big. The buoyancy force is relatively going to be high.

Now, as the buoyancy force has a tendency to push the structure in upward direction to hold down the structure, I use cables or tethers or tendency or simple mooring lines to hold down the structure in position. Therefore, the structures essentially depend on the excessive or the restoring buoyancy force to maintain the stability under the lateral movements.

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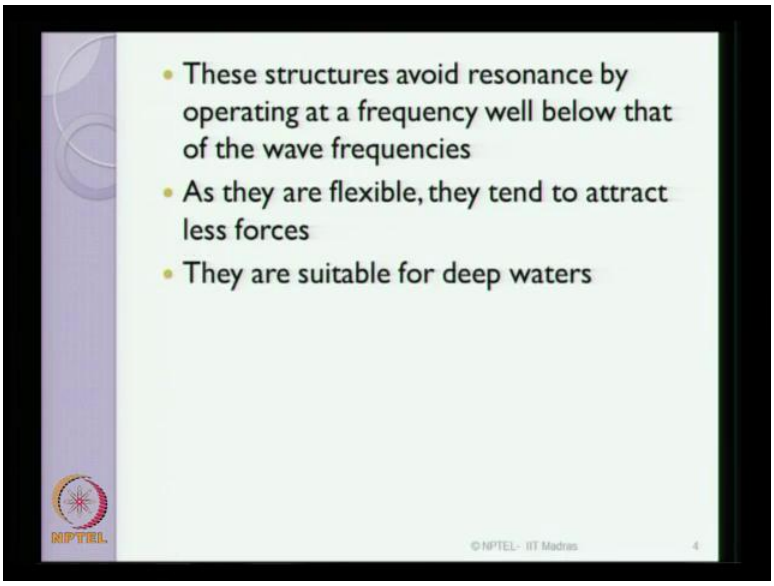

These structures actually avoid resonance, because the operating frequency of these kinds of systems is differently located in band width of that of the wave frequencies. As they structures are flexible they generate tend to attract lesser forces. They are suitable for deep waters.

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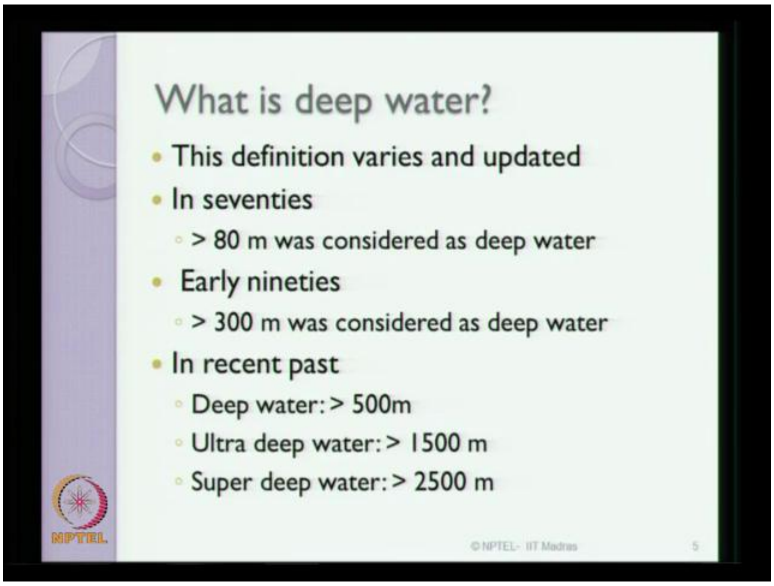

Now the question comes as we understand the water depth, as one of the important criteria for selecting or choosing a marine structure. Then lets we quickly understand what is mean by deep water? The definition of deep water varies and periodically updated. For example, in seventies the water depth higher than or greater than 80 meters was considered as deep waters. In early 90’s, the definition of deep water moved from eighty meters to three hundred meters. Now, in the recent past we simply say deep waters are water depth exceeding 500 meters and ultra deep waters are water depth exceeding 1500 meters and super deep waters, where the water depth exceeds 2.5 kilo meters.

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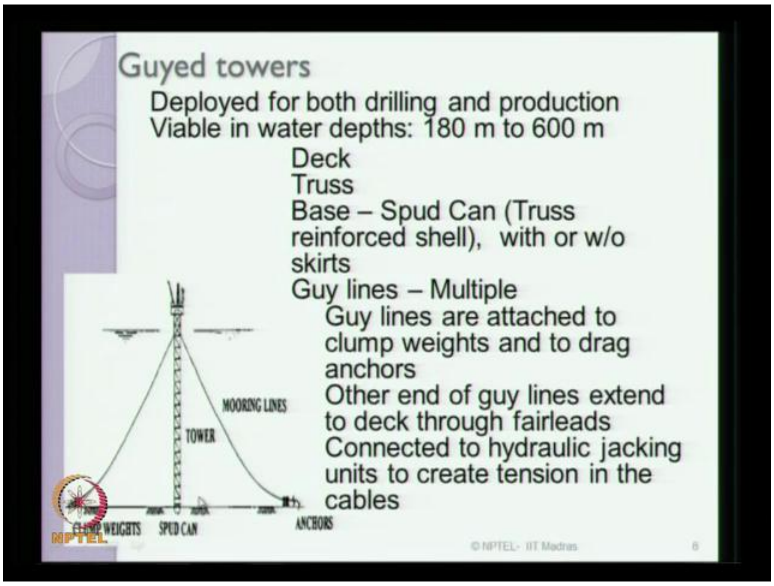

One classical marine structure, which is meant for medium and deep water depths, is what we called guyed tower. Guyed tower is generally deployed for performing both operations namely drilling and production as well. Guyed towers are found to be suitable for a water depth varying from one 80 meters to as high as 600 meters. The vital components of a guyed tower shown in the picture, here can clearly show you that is got the classical depth, which houses or facilities that are required for drilling and production as well.

Essentially it has got a tower, which is truss base structural form may root of steel as a primary construction material. Now, the truss supports the deck and the truss is founded to the foundation of the sea bed using Spud Can systems, which we saw in the last lecture. Spud Can offers lot of degree of freedom in terms of its rotation whereas the tower will be only position restrain. So, Spud Can will give you hypothetically a support condition by the name hinged support at the foundation system here. Now, the tower is anchored to the sea bed in addition to the support given by the Spud Can by means of cables, what we call as mooring lines.

This mooring lines essentially of centenary type of profile, which is connected to the tower at the specific point; this point where the mooring line touches or connects the truss system or the tower is call fairly. A point, where the mooring line touches the foundation is what we call as touchdown point. At the touch down point you generally provide anchors and clump weights to fall down the mooring line in position. There is different type of anchors available in the literature. Of course, in this present lecture we will not discuss about the type of anchors and the clump weights as this is beyond the scope of this specific lecture.

So, let us look at the vital components of a guyed towers from this particular slide, it consists of deck it has got the truss system. Of course, it has got the base which is connected to the foundation of the sea bed using a Spud Can system that can be scuds with or without scuds also even can hold down the truss with the foundation system. Now, these mooring lines or otherwise also called as guy lines or guy wires or guy ropes. Generally, they are in multiple dimensions they are multiple in numbers as well located circumferentially along the truss at the fairly junctions. Guyed lines or generally attach the clumpiest and to the drag type anchors.

One end of the guyed line extends to the deck through the connecting point what we call as a fairly this fairly here. The other end is connected to the foundation using what we call as a drag anchor or a clumped. Now, the mooring line which passes through the fairly will be then connected to hydraulic jacking system on the deck, where required tension on this line will be applied here. So, the tension on the mooring line can be adjusted depending upon the water action or the wave action as depending upon the hydraulic system or the jacking system available on the deck itself. So as you can understand from here.

Ladies and gentleman, this system is highly compliant or has a freedom to move in the lateral direction under the action of the wave or wind that is why we call this kind of structural system as compliant towers or compliant systems.

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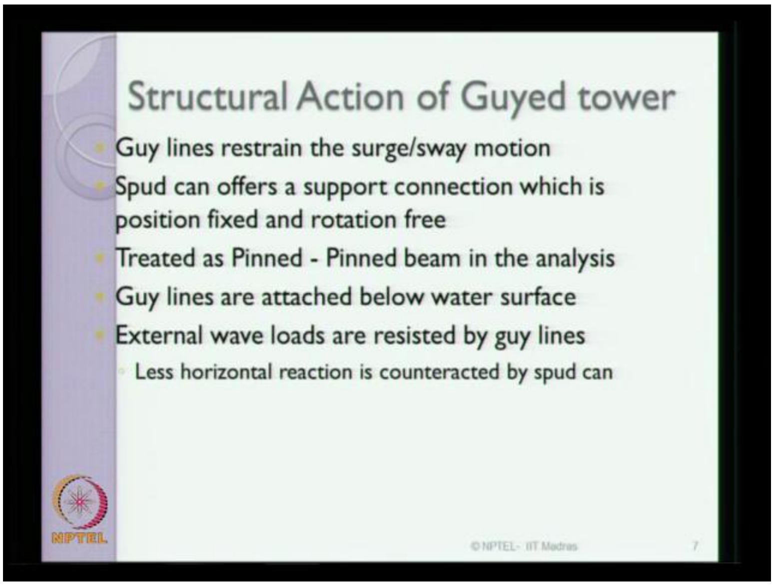

If you look at the structural action offered by the guyed tower under the lateral loads; guyed towers essentially restrain the surge or the sway motion, which is applied or which is caused by the action of the wave or wind on the tower. The Spud Can which is located in the bottom of a support connection, which is offering what we call a position fixed connection, but rotation is said to be free. So it is treated in analysis as pinned beam for the structural analysis purposes. The guyed lines are attached below the water surface the external wave loads are registered by guyed lines as well. The less horizontal reaction, which is a component of the guy line, will be counteracted by this Spud Can in terms of its resistance.

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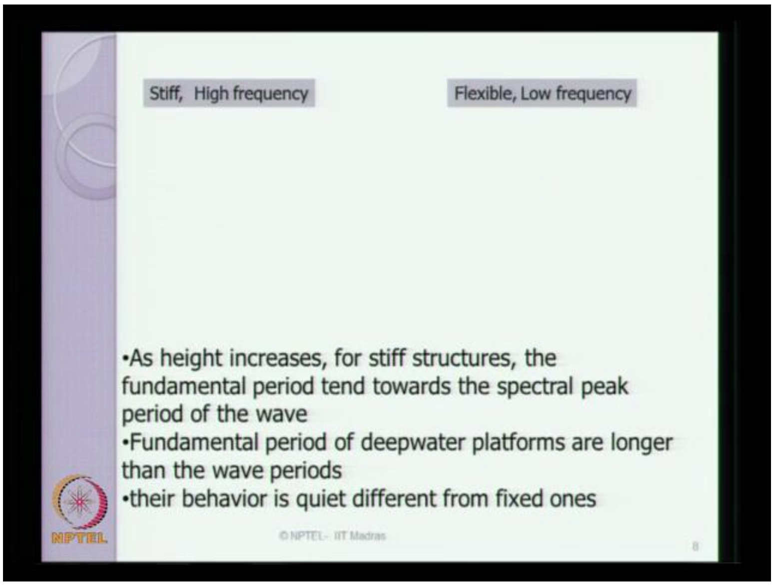

Let us quickly look at the frequency band at which these kind of compliant towers operate.

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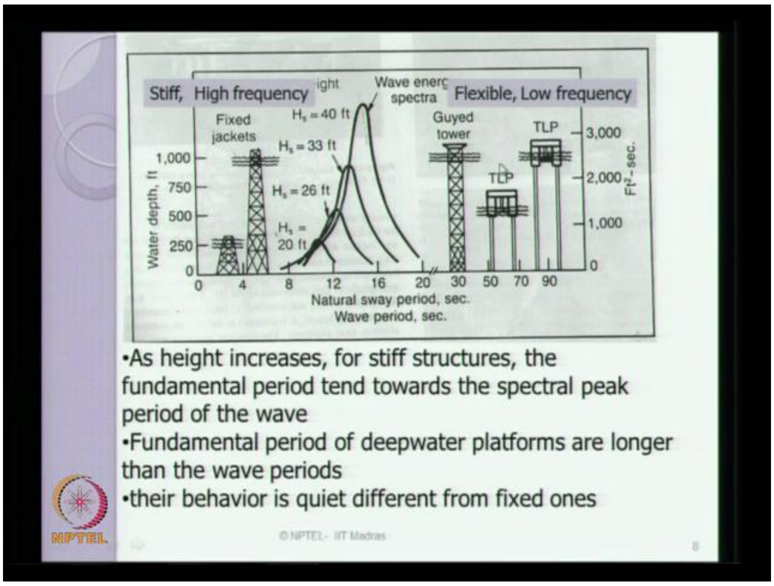

Now, if you look at this figure shows on the y axis water depth in feet where as in the x axis the natural periods in seconds as well as the wave periods. Now, as the wave periods or the natural periods are lower, we have stiff type of structure, which have got lower natural period; on the other hand they have got very high structural frequency or the natural frequency.

So, fixed jackets gravity way structures, which we saw in the last lecture, do have high frequency and we call them as stiff structures and they located fall below this band; whereas look at the flexible system like in the current lecture the compliant structure have larger period natural periods varying somewhere from 20 or 25 to as high as hundred. As the period goes high the structural system becomes highly flexible, because of its low frequency.

So, the guy tower which is one of the kind of the compliant system of marine structures is located in a band width away from the top the fixed type structures. Now the classical band width at which the wave periods at in a common given sea state vary somewhere from 6 seconds to around 20 seconds. So, intelligent thing you can see the selection of a structural system in terms of flexible degrees or generally designed in such a manner that the structural frequency or the period of such structures or variable away from the band of the operational sees states.

So, on the other hand ladies and gentleman by the virtue of design general the structural form or the geometric form of the marine structures or design structural manner that they do not resonate at the fundamental frequency with top that the excitation wave frequency. So, there is a classical point which like to ask me is that what happens in case of wind forces. Because, wind is a low frequency phenomenon I have a structural system having so very low frequency.

So, is this kind of structure sensible to wind forces? Will talk about this in a separate lecture in same module, where we explain the environmental forces acting on these kinds of towers or flexural members. So, what we understand from this slide is that as the height of tower increases or on the other hand as the water depth increases people generally moves from a stiff system to a flexible system.

Because, the fundamental period of the flexible system shift from lower value to a higher value, the fundamental period or what we call flexible system or deep water platform are longer than that of the critical wave periods, which are generally operational where these kind of structures are install. You should also appreciate that the marine structures of flexible nature do behave differently in the dynamic perspective in comparison to that of fixed type marine structures.

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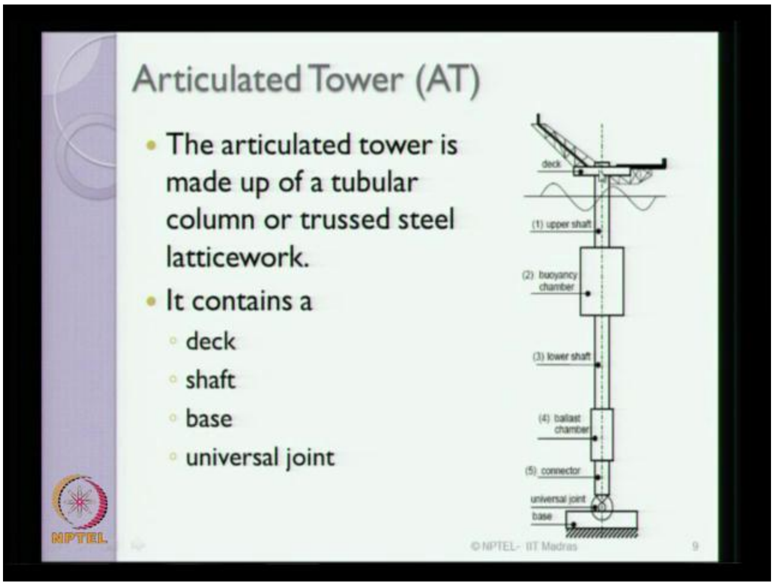

The second classical type of compliant system what we have in the literature is articulated towers. You must have seen this kind of platforms or understood these structures in a different course during your under graduate or post graduate program. But, still it will be interesting for us quickly to review, how the structural action of an articulated tower behaves under laterals loads. The sketch, which shows here, is a schematic view of an articulated tower. It consist of a classical depth, which has got different arrangements and the flat bone, the crane, the derrick etcetera, which all are required essentially for an operational platform in off floor.

Essentially, instead of the tower as you saw in the previous case it is replaced by shaft which is divided into three components: the upper, the lower and then the connector part of the shaft. The upper shaft and the lower shaft are separated by means of a chamber, which we call as a buoyancy chamber, which is approximately located about one third of the top height of the water depth, where this platform are installed. Now the interesting component or the vital component of the platform is what we call as an articulation joint or a universal joint or a ball joint.

That is why this kind of platform is name as articulated tower. Articulation is nothing but, a hinged joint which gives position restrain to the tower, but the rotation is set free. This is similar to what kinds of arrangement being made in Spud Can foundation system of a guyed tower. So, the articulated tower is made up of a tubular column or trussed steel lattice work; it contains a deck, a shaft, a base and a universal joint.

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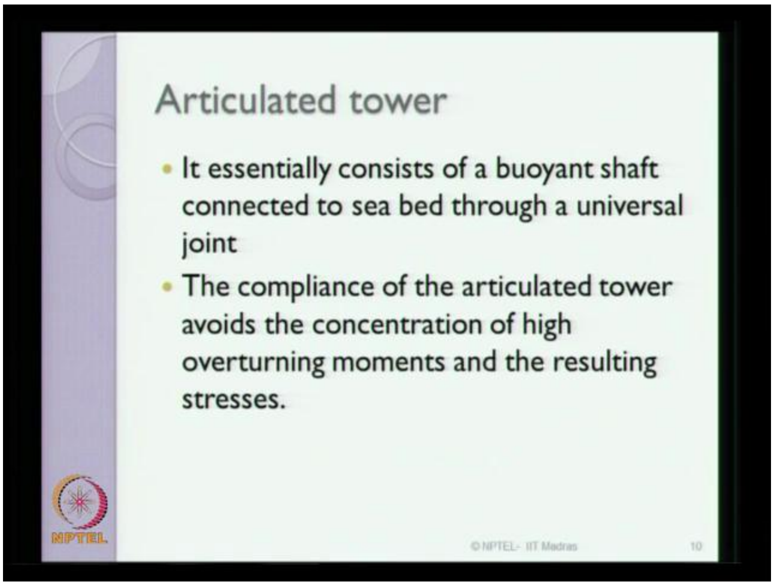

These towers essentially consist of a buoyant shaft, which is connected to the sea bed through a universal joint. The compliance of an articulated tower essentially avoids the concentration of high overturning moments and result in lowest stresses on the member as we all understand. When the connection point of the tower with that of foundation is made to be hinged, the moments at the bottom of this or the footing of this tower is essentially or practically zero. Therefore, the stresses on the members acted upon the lateral forces on these members or phenomenally reduced, because of the presence of this kind of degree of freedom or because of the freedom given to the lateral moment of the tower under the forces exerted on the tower.

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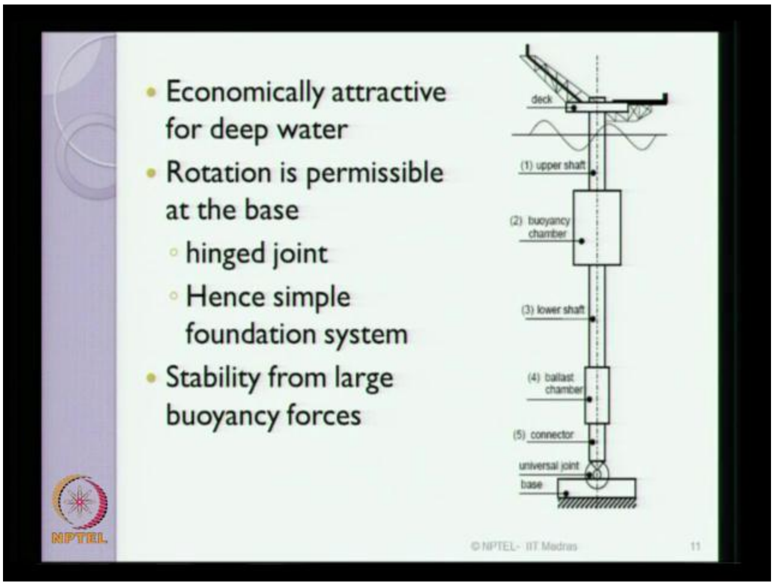

Articulator tower has been seen as economically attractive structures for deeper waters. The rotation of the tower is permissible at the base, because a joint is hinged. Therefore, interestingly ladies and gentleman, the cost of this structure becomes phenomenally reduced, because foundation system of this kind of towers becomes highly simple. It is also understood that these kinds of towers stay or have very high degree of stability because they arise from large buoyancy forces created from the last in the buoyancy chambers.

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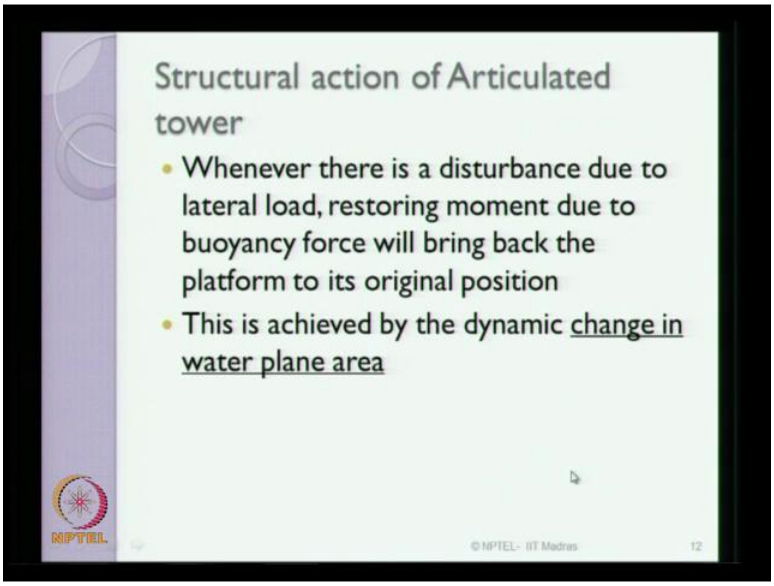

Let us quickly look at the structural action of this kind of structures; whenever there is a disturbance acted upon the tower due to lateral loads. The restoring moment due to buoyancy force will bring back the tower to the original position. As you understand from this figure very clearly, the tower is subjected to the lateral action. The tower will get inclined, because of this there is a variable submergence effect happening on the large size of these members, which are alter the buoyancy and that buoyancy force will cause a restoring moment about the bottom of the tower, which brings back the tower to the normal position. So this is centrally achieved by what we call the dynamic change in water plane area, otherwise we address this as variable submergence effect of the member.

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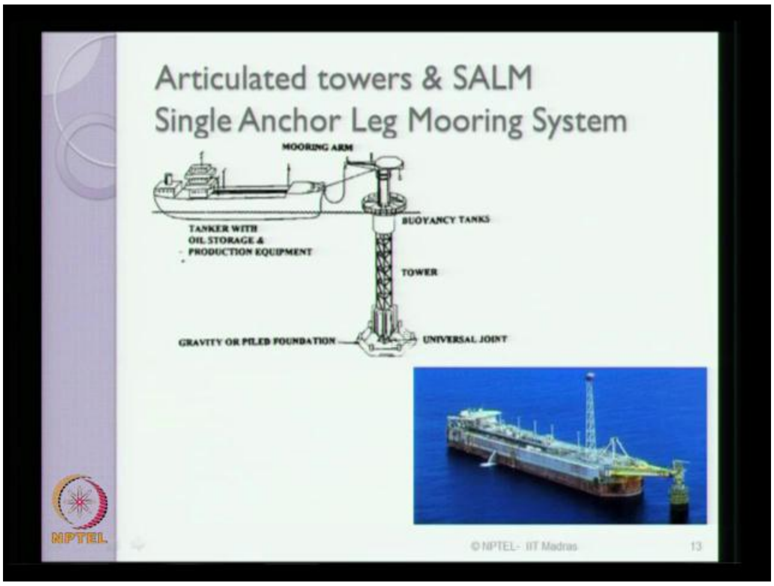

The practical examples of these kinds of towers are seen in the literature. Articulated towers and single anchor leg mooring system, essentially these kinds of towers are used for anchoring systems in the sea. You can see this real photograph of a single anchoring leg mooring system, which anchors a drill ship at a specific position at a depth of above thousand meters. A conception figure of this is drawn here as AT shown as the connection point of mooring system for a tanker with an oil storage platform, which also houses production equipment.

This is what we call as a mooring arm, which holds the tanker to that of the tower and now you can very clearly see the buoyancy tanks, which are essentially component of restoring the action of this tower under the lateral forces and the tower in this case is a lattice truss work and you got universal joints at the bottom.

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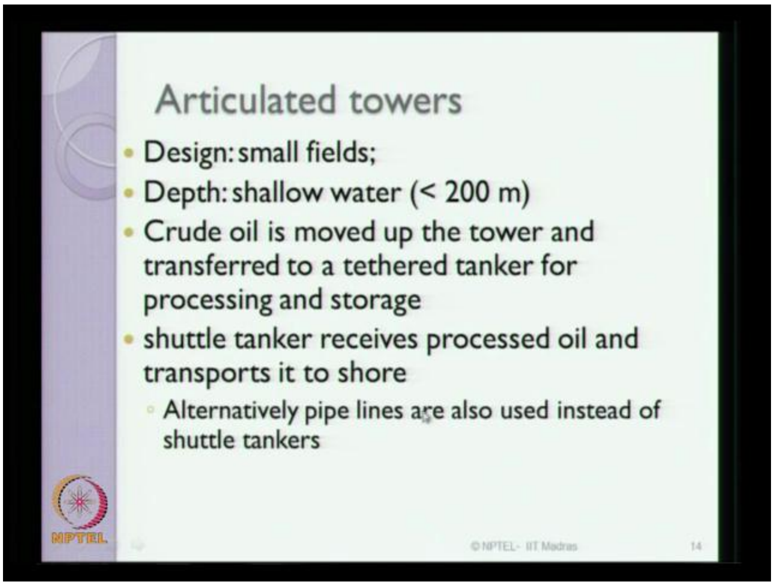

Essentially, articulated tower designed for very small fields. They successfully operate in shallow waters, which is less than 200 meters crude oil is generally moved up the tower and then transfer to the tether tanker for processing and storage. So, ATs are never used for the continuous production there used as either a storage tanks or used as mooring anchors. A shuttle tanker then receives processed oil and transports to shore. Alternatively, one can use pipe line also to do.

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This is the another classical figure, which anchors a drill ship or a storage vessel to that of a mooring system, which is a single leg anchor mooring system, which is an articulated tower which is a classical example of a marine structure.

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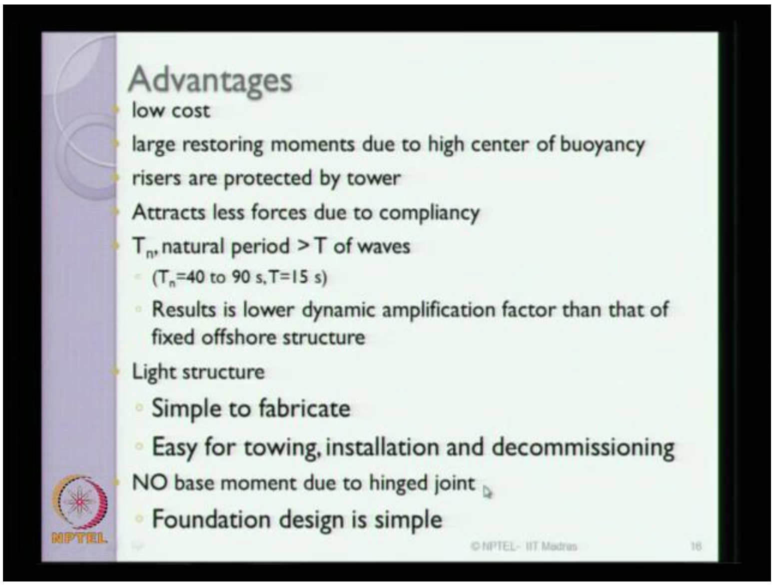

These kinds of structures have salient advantages. They are very low cost. The large restoring moments due to high center of buoyancy, it offers a very good resistance, risers a protected by tower. It attracts lesser forces due to compliancy the natural period of the towers are much larger than that of the waves. Approximately, they vary from 40 seconds to 90 seconds whereas the dominant wave periods at which these structures operate vary from 10 seconds above 15 seconds. Therefore, they result in lower dynamic amplification factor, which is in comparison to that fixed structures are significantly lower.

The structure ladies and gentleman, in overall is very light in weight. Therefore, is very easy and simple to fabricate. It is very comfortable and convenient for towing installation and as well as decommissioning this kind of towers. Most importantly, as there are no base moments generate it due to the hinged joint the foundation design of this kind of structures is relatively simple.

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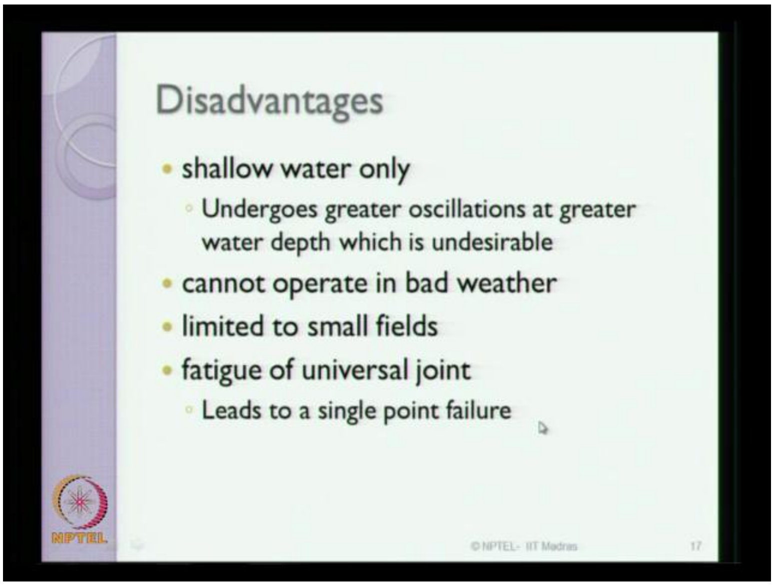

Of course, there are some couple of demerits these kinds of towers they can operate only at shallow waters, because they undergo greater oscillations and greater water depth, which is not desirable as per the structural act of the platform is concerned. These towers cannot operate in bad weather, because of the fundamental reason the restoration time given or taken by the tower is phenomenally high to bring back to the original position under the lateral forces. They are limited to very small fields the fatigue of universal joint is seen as the one of the important criteria failure for this kind of towers, because these towers lead to what we structurally understand as single point failure.

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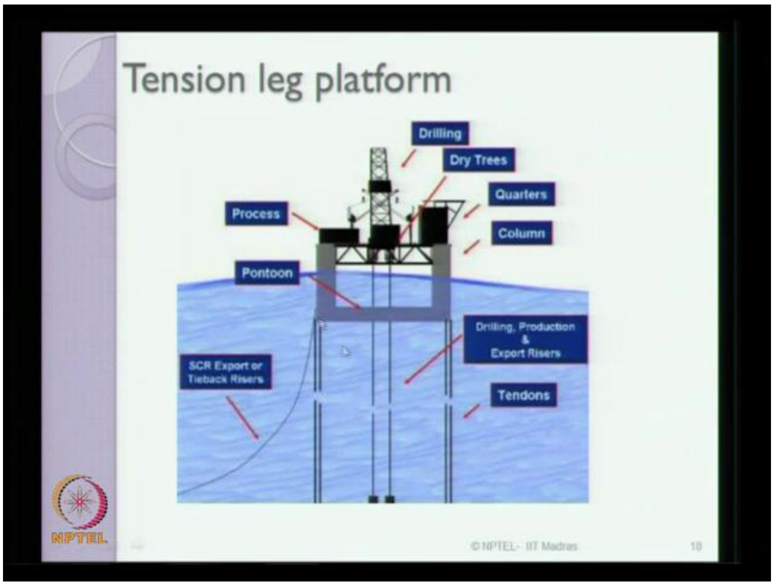

The next variety of marine structures, which are meant for oil exploration in deep waters, is what we call as tension leg platforms. Again this is a floating buoyancy high result structure, which is anchored to the sea bed using cables or tethers. Now, these cables are technically called as tendons, what to see here are all production and drilling risers they are also used for exporting oil or gas from the production well to the top the shuttle vessels the drilling unit or the drilling derrick is located on the top side. On the top tire of the platform the entire operational drilling takes place above the water level.

We call them as dry trees there are living quarters, which holes are available the house people working on boat the process plant, the mechanical equipments, the drilling equipments, the production facilities are all located on the top side above the water level the entire unit is, what we call technically as dry trees. It is comprising of pontoon members and columns is very large diameter, typical diameter of this members vary from 12 meter to 16 meter external and the thickness can vary from 150 millimeters to as thick as 300 millimeters.

The size on this platform generally varies from 17 meters in plan of one side to top 110 meters. So they have very large volume submerged volume which has got a very high buoyancy force when exerted the upward force by the submerged volume of these members. As the buoyancy force phenomenally high the platform will have a tendency to push off from the installed location and these pontoons will try to pull them down, which will always remain in tension that is why this platform is named as tension leg platform.

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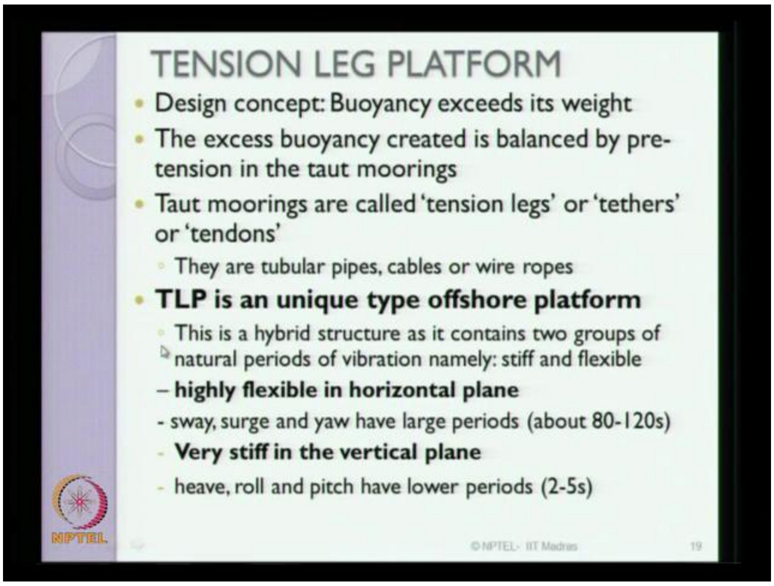

If you look at the design concept of this kind marine structure essentially and fundamentally the buoyancy of these kinds of platforms exceeds its weight. Because of the excess buoyancy there is an unbalanced created, which will be compensated by the pretension in the taut mooring supporting the platform. The taut mooring lines are called as tension legs or some time tethers or sometimes the literature refers them as tendons. They are nothing but, tubular pipes or cables or wire ropes of very high tensile tens steel. TLP, therefore, say very unique type of an off shore platform is a hybrid structure, because this kind of platform has two groups of natural periods.

One group will be having a period which is related to a stiff degree freedom the other group will have very high flexible period. On the other hand, certain degrees of freedom in this kind of platform will have very large period. For example, such sway and yaw motions have a very large time period whereas the other degrees of freedom namely heave, roll and pitch has low time periods and uncertain stiff degrees of freedom. Therefore, one can say ladies and gentleman the platform is highly flexible and complaint in horizontal plane, because the periods of such sway and yaw vary anywhere from 80 to 120 seconds.

Whereas the platform remains very stiff the vertical direction, because heave period is the vertical moment of the platform is as low as 2 seconds vary from 5 seconds. Therefore, the platform has got a hybrid combination of flexible and stiff degrees freedom in built in only one type of structure. Therefore, we say this kind of marine structures are unique type in the design in the literature.

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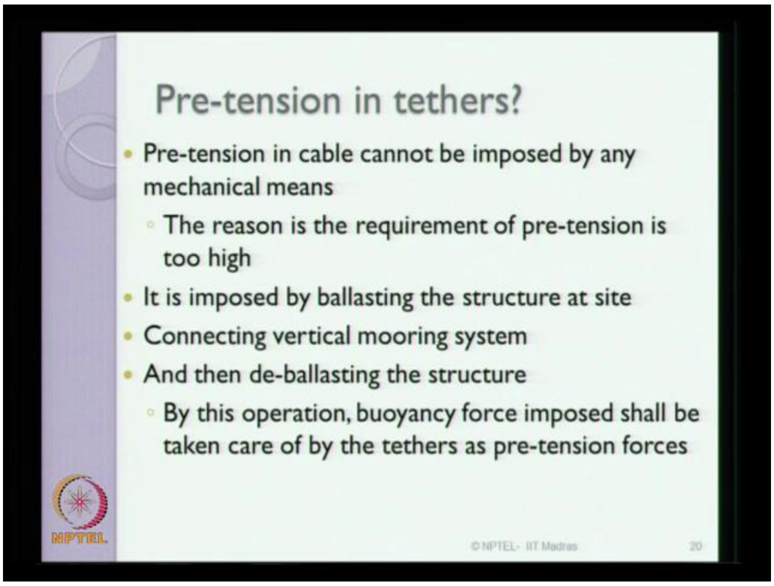

No one can wonder what you understand by pre-tension in tethers, how are the imposed? Pre-tension in the cable cannot impose by any mechanical means; because the value of the pre-tension requires the counter act the buoyancy force exerted on the members is phenomenally high. Therefore, it cannot be imposed by simple technique the reason is essentially the pre tension value is very very high.

So, then how it is imposed so it is imposed by simple technique when the platform is moved to the side then members are actually ballasted at the side, when you put the ballasting on this members of pontoons and columns, which are hallow inside the member will start sinking buy increasing the drought on the members. As the member start sinking the tethers will be connected to the sea bed, which are flexible which will not be thought move once the tethers are properly connected to the sea bed, then they are deballasted. As they deballasted the platform will have the tendency to move up, because of buoyancy force and since the tendency are connected to the members they will try to pull down the platform.

That is how the unbalanced tension that is unbalanced force between the wave and the buoyancy is transferred to tethers by way of simple ballasting and deballasting at site. So they connected by what we call as the vertical mooring system. Once you deballasted the structure by this operation the buoyancy force or the unbalanced forces will be actually imposed on the tethers and what we call as initial pre-tension in the tethers.

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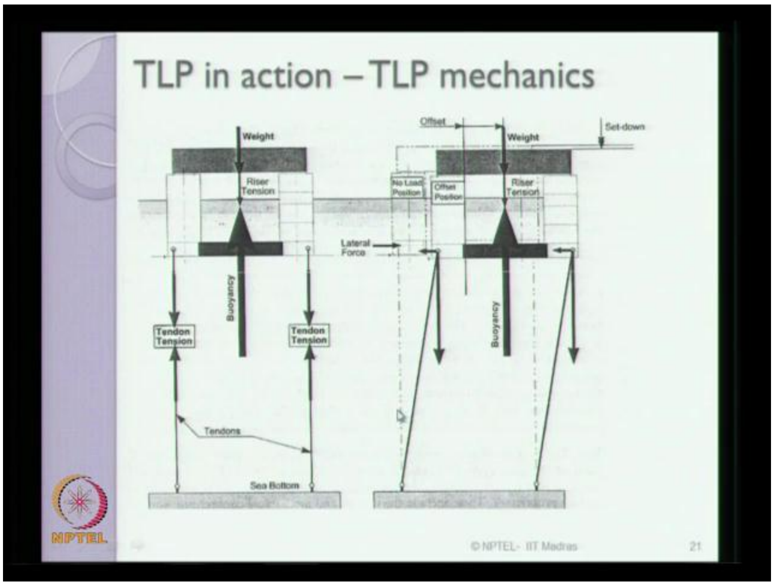

So this is a very interesting figure, which shows you the TLP mechanics when the TLP is in position under the static action. When no lateral load is hypothetically acting on the member then the tendency will remain vertical straight and of course, they will be all pre-tension, because I told you already the buoyancy force exceed the weight phenomenally high. Therefore, to pull them down I need tension in the cables or in the tethers. Now when under this when this platform is subjected to a lateral action because of the forces you can see the platform has a compliancy that is the platform starts moving in the lateral direction.

If I call this as my wave direction then this is what I address as surge motion, I technically call this moment as an offset and relatively platform moves towards right or towards left. Depending upon the wave direction the platform will also have a tendency to have a immerse members volume much larger. So the platform will have what is called as set down effect. Because of this set down effect there is a change in tension happening in this tethers and the horizontal component of this change in tension will counteract the lateral load which is acting on the member. So, interestingly the members or the forces acting on the member is partly counteracted by the horizontal component of this tethers and the angle of this shift generally varies anywhere from 2 to maximum 7 or 10 degrees in order.

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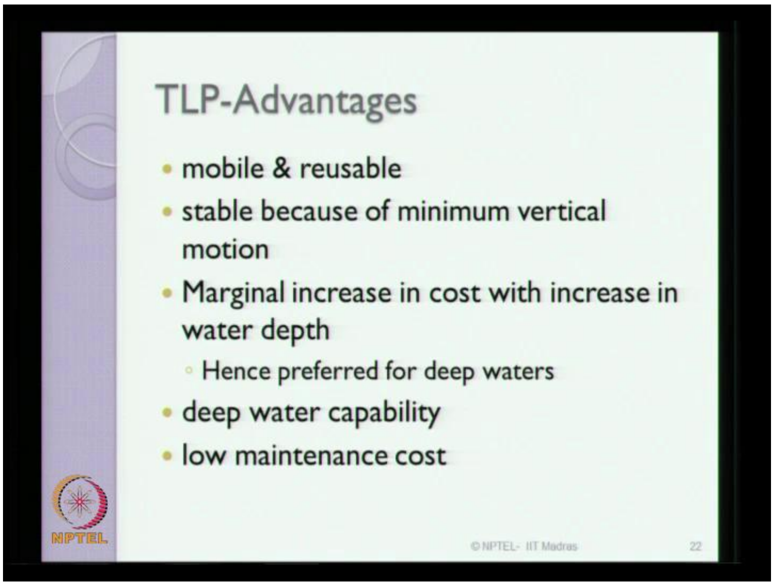

There are classical advantages of this kind of marine structures, they are highly mobile and reusable; they are very stable because a minimum vertical motion as you understand heave degree of freedom is highly restrain. There is marginal increase in cost as you move this platform to greater water depth. Hence, these kind of marine structures are highly preferred and deploy in deep waters as well as in ultra deep waters. They have a very low maintenance cost because the immersed member cross section or the member dimensions or the number of members immersed in water is far lower in comparison to a fixed type structure or a gravity based platform or even an articulated or a guyed tower. Here only, one part of the column and pontoon members are immersed in water therefore becomes low maintenance cost.

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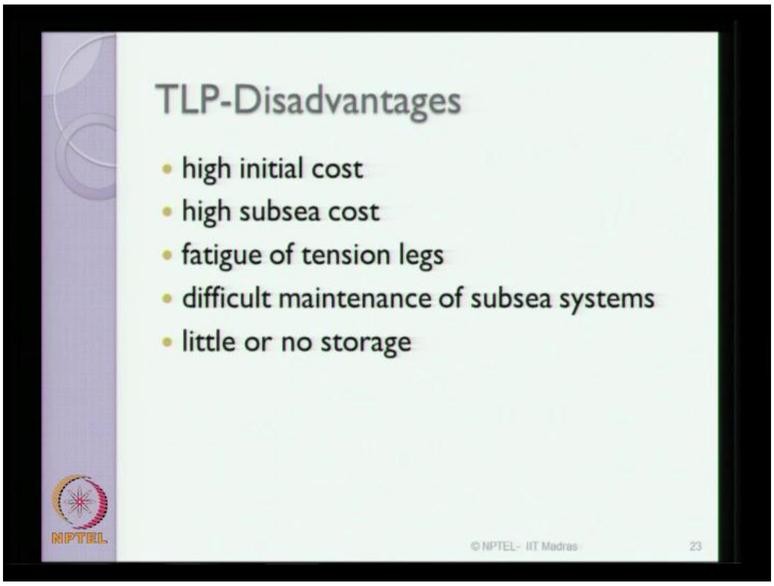

There are of course, sudden demerits of these kind of structures they have got a very high initial cost because commissioning, towing, launching, directing and making it enable for production of a TLP is a very complicated task and it request not a special work force. Therefore, these kinds of structures have very high initial cost. They also have what we call as very high subsea cost. Interestingly, the tension in the tethers leg or the legs keeps on changing continuously, because of the dynamic action of the wave or wind and that result in fatigue in tension legs.

Alternatively, in literature people have felt the there is a serious difficulty of maintaining the subsea systems associated with TLPs. They have little or practically no storage they are meant for production and exported drilling as well. But, essentially they meant for production platform but, they do not have a storage facility as high as you see in GBS or in jacket structures.

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There are many TLPs installed around the world North America owns fifteen of them, whereas Europe and Africa shows two of them each. There are total about nineteen TLPs currently executed successfully deployed around the world. Interestingly, ladies and gentleman you will see the united state of America accounts for 80 percent of TLPs deployed in deep sea.

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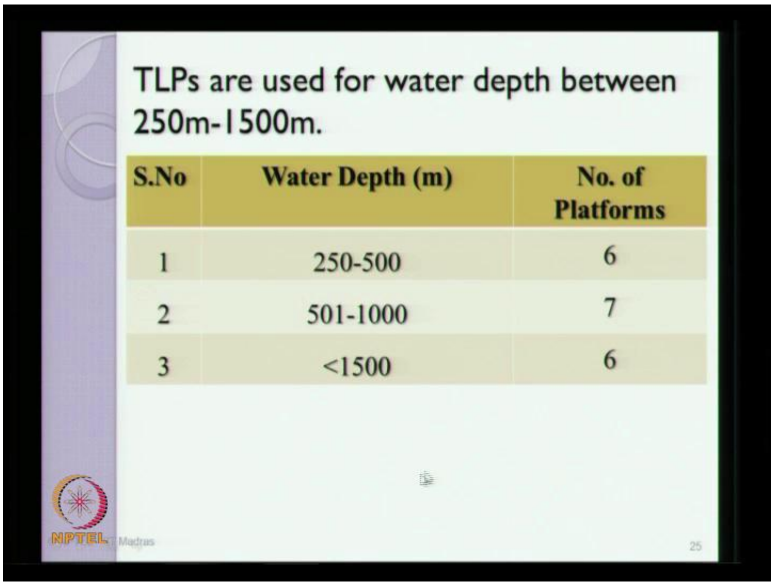

TLP is a generally recommended and used by people in water depth varying from 250 meters to as deep as 1500 meters. If you look at the classification of the TLP based on the water depth you got six number of platforms between the depth of 250 to 500 hundred meters, whereas seven numbers from 501 to 1000 meters and as high as six numbers the depth goes to 1200 or let say less than 1500 meters. So people have not attempted to deploy TLP at a depth greater than 1500 meters; then one should understand what should be the structural form when you keep on moving the water depth from 1500 meters onwards.

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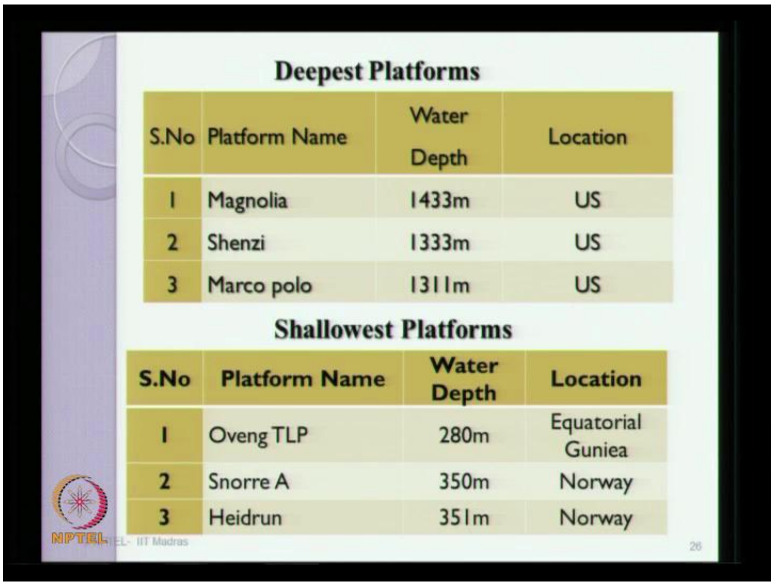

For stastical information, lets quickly see the deepest TLPs installed is magnolia TLP, which is about 1.43 kilometer water depth in united states and the shallowest platform is in equatorial Guniea which is Oveng TLP which is as low as 280 meters.

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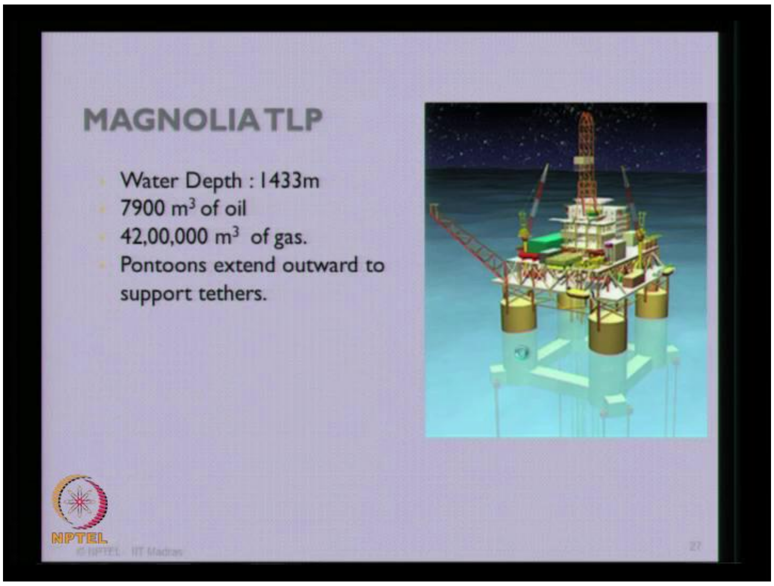

The magnolia TLP is a bigger it is so which you see here in the right hand side of the slide, at the water depth of 1433 meters; the production capacity is about 7900 cubic meter of oil, which amounts also equally 4200000 cubic draws per day. The pontoons are extended outwards to support the tethers. You see here the tethers are not exactly below the column members the pontoons are projected outside and all the four leg and then the tethers are connected here is an interesting system, which has got a more structural advantages, which will not be discussed as scope of this lecture.

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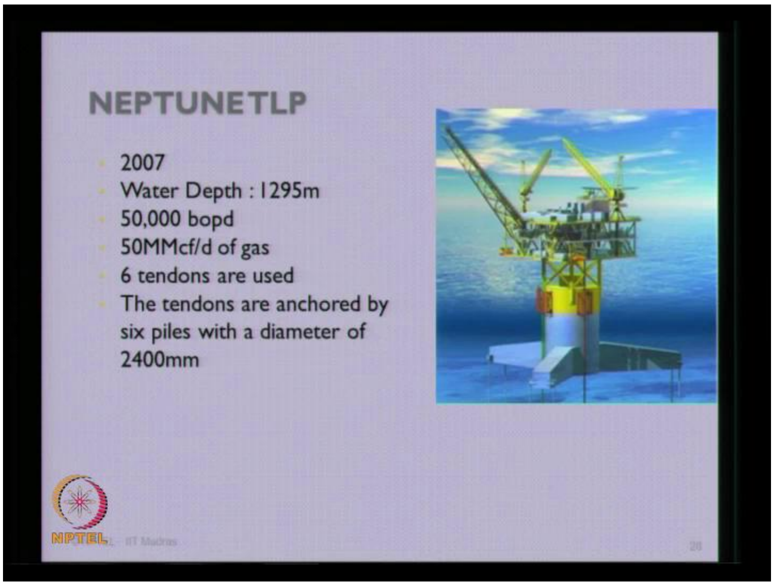

Another alternative TLP is a Neptune TLP. The photograph you see here is a Neptune TLP constructed in 2007 at a depth of 1295 meters capacity of 5000 bopd, is has got 6 tendons as you see in the picture the tendons are anchored by six piles to the diameter of about 2400 millimeters.

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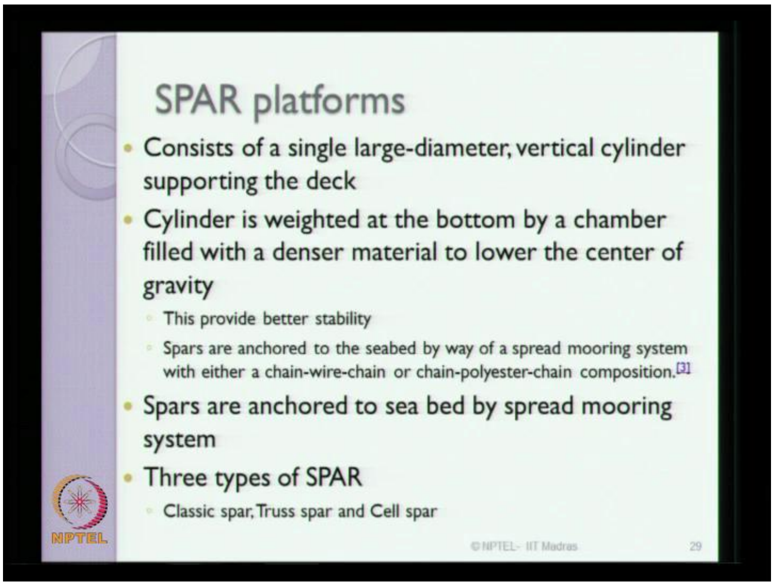

The next classical variety of marine structures which are meant for production in deep waters is SPAR platforms. It consists of a single large diameter vertical cylinder, which supports a deck. The cylinder is weight at the bottom by a chamber will be a dense material to lower center of gravity from the top towards the base, because this provides a better stability for the platform. Spars are anchored to the sea bed by means of what we call as a spread mooring system. This can be either a chain wire chain or chain polyester chain composition. Spars are anchored to the sea bed by spread mooring system most commonly there are three kinds of spars or types of spar: the classic spar, the truss spar and the cell spar.

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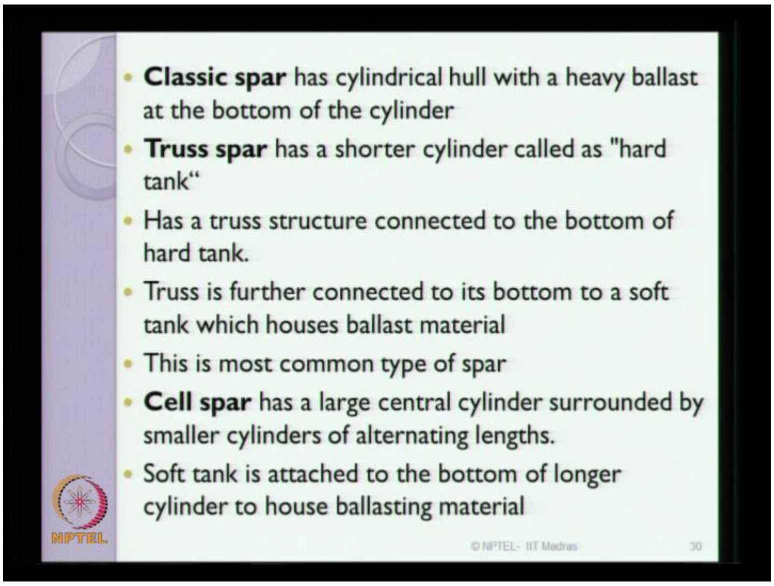

The classic spar has a cylindrical hull with heavy ballast at the bottom of the cylinder. The truss spar of the shorter cylinder, which we call as hard tank in the literature it is got a truss structure connected to the bottom of hard tank. Truss is further connected to the bottom to a soft tank, which houses the ballast material. This is one of the most common types of spar deployed in deep waters. Cell spar has a large central cylinder surrounded by small cylinder of varying length. The soft tank is attached to the bottom of longer cylinder to house the ballasting material.

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Totally, there are about seventeen SPAR platforms deployed in the world sixteen of them surprisingly are located in United States. There are three classical spar, thirteen truss spar and one cell spar so far installed.

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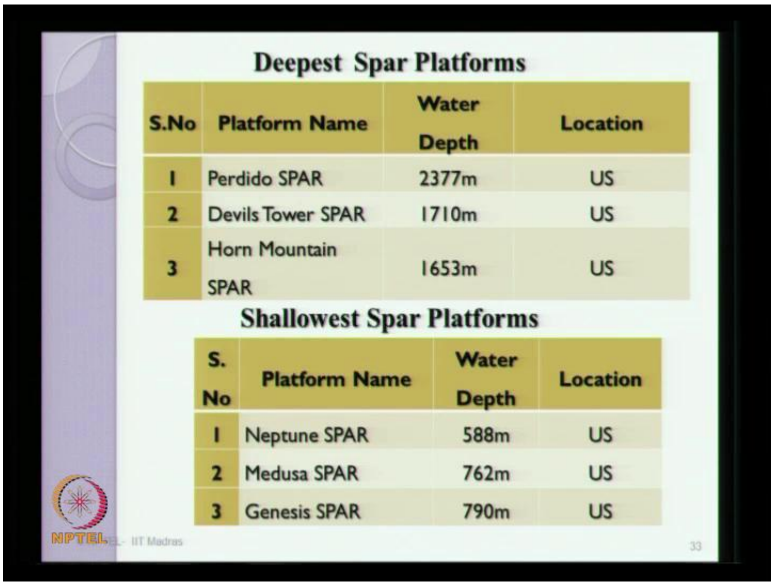

Deepest Spar Platforms

S.No	Platform Name	Water Depth	Location
1	Perdido SPAR	2377m	US
2	Devils Tower SPAR	1710m	US
3	Horn Mountain SPAR	1653m	US

Shallowest Spar Platforms

S. No	Platform Name	Water Depth	Location
1	Neptune SPAR	588m	US
2	Medusa SPAR	762m	US
3	Genesis SPAR	790m	US

If you look at the number platform in terms of the water depth being installed, there are about three platforms installed from a depth of 750 to 1000 meters from 1000 to 1500 meters, eight numbers and 1500 to 2000 meter water depth four numbers. And I have got one spar platform installed at a depth more than 2000 meters statistic importance deepest spar platforms is perdido SPAR at 2.377 kilometer depth in United States, whereas the shallow spar is Neptune spar at a depth of 588 meters located again in United States.

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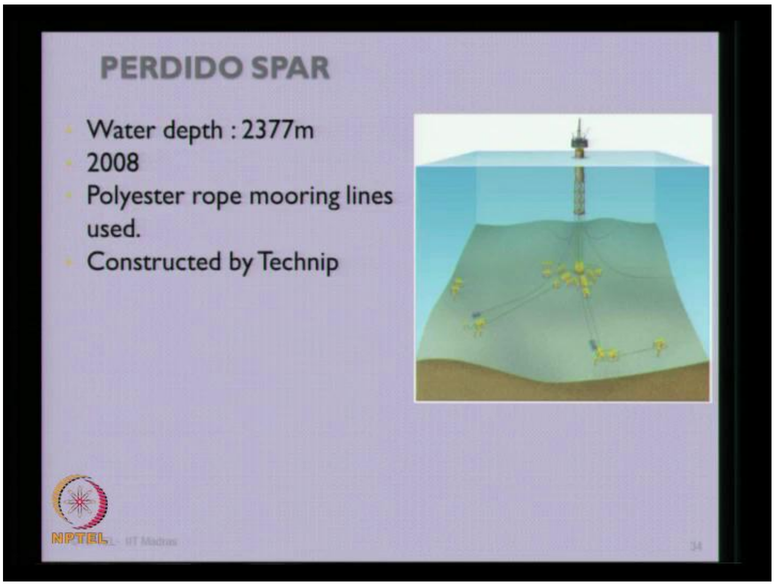

The perdido spar is a very interesting spar, which you see in the right side here it essentially installed at a depth of 2.377 kilometer in the year 2008. It consists of polyester rope mooring lines, which is essentially a new attempt made to anchor this kind of spar to the sea floor. It is constructed by a company by name Technip located in US.

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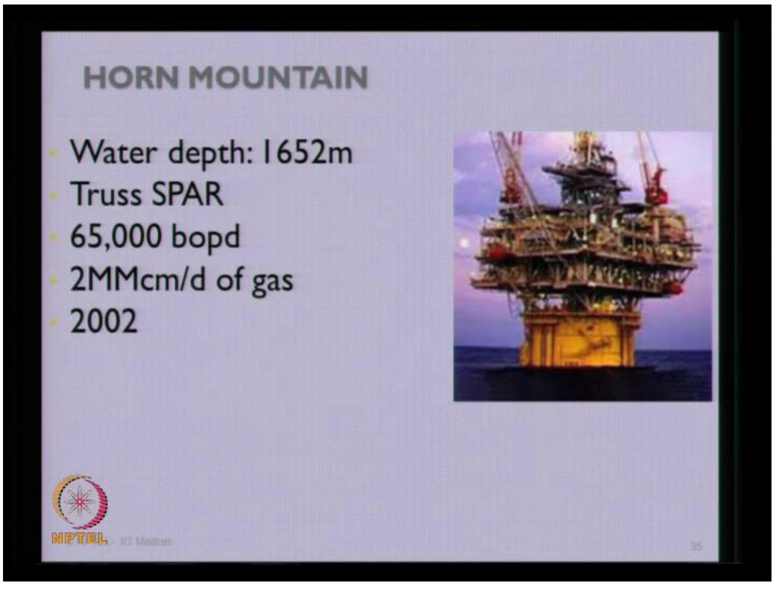

Horn Mountain is another spar, which has got a very complex top side detail, as you see in the photograph installed depth of 1652 meters. It is a truss spar type and it is having a production capacity of 65000 bopd constructed in the year 2002.

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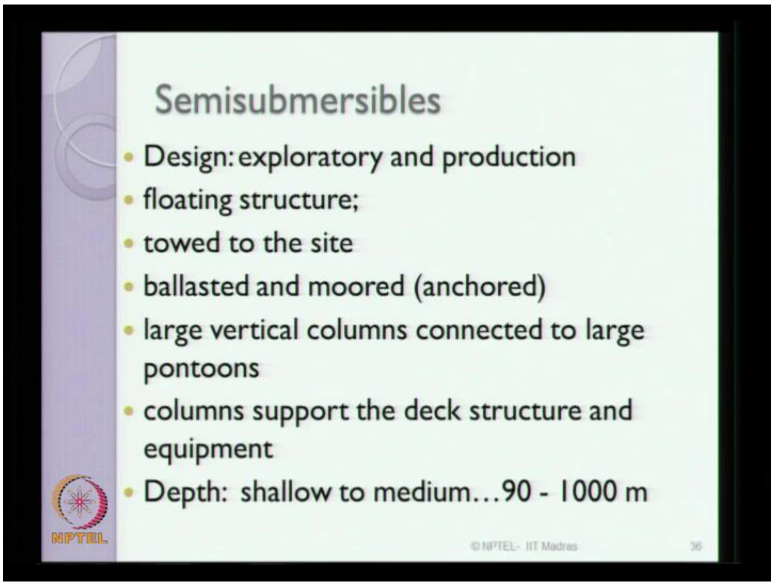

The next type of marine structures which one is interested to know is semisubmersibles. The essential design concept of semisubmersible is meant for exploratory as well as production drilling. It is essentially a floating type marine structure, which is towed to the site then ballasted and then moored or anchored to the site for ocean keeping. Generally, dynamic ocean keeping systems are deployed to whole these kind of semisubmersible in geographic position while production and drilling operation, this is what we call as deepest activated semisubmersibles.

They contain very large vertical columns, which are connected to very large pontoons. The column supports the deck structure and the drilling equipment, which is housed on the top site. It can operate from a varying depth verity of depth varying from shallow to medium as low as 90 meters to as deeper as 1000 meters as well.

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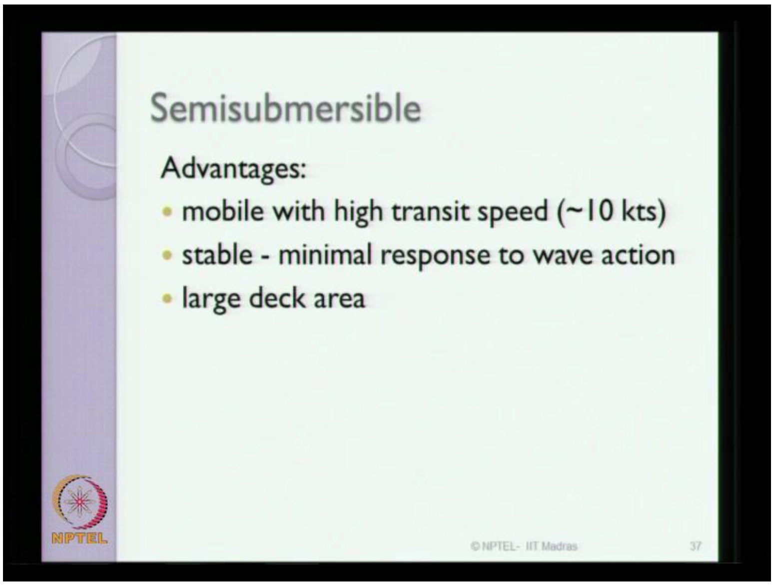

There are classical advantages of semisubmersibles; they are highly mobile, which has got high transit speed varying up to 10 kts. They are very stable offer many minimum response to the wave action.

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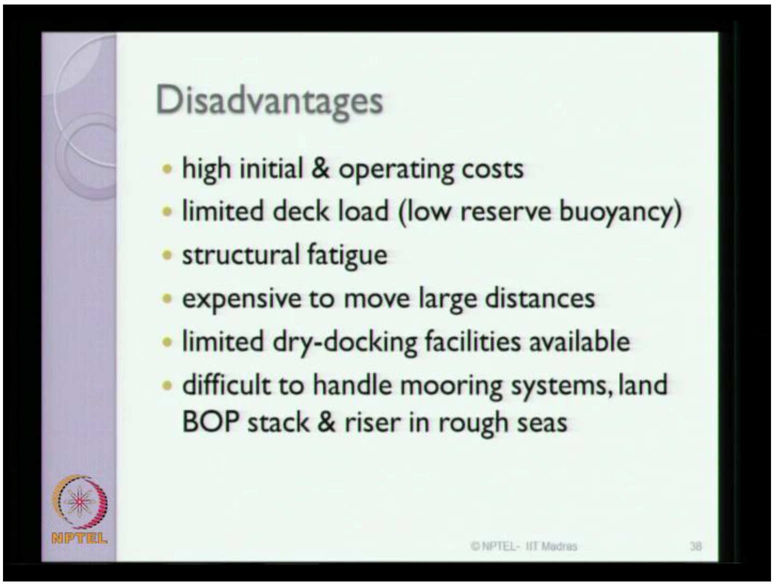

They have a very large deck area, which can create lot of operational advantages. Of course, semisubmersibles have certain demerits they have a very high initial cost and operational cost of semisubmersible are relatively and phenomenally high. They have got a very limited deck load, because the entire structure is same similar to that of or a floating vessel, so the depth load is highly limited and it has got very low reserve buoyancy unlike a TLP.

This kind of structure is commonly subjected to structural fatigue problems; they are very expensive if you want really move semisubmersible from one location to another location. They have a very limited dry docking facility you want really repair and maintain semisubmersibles. It is very difficult to handle the mooring systems associated with semisubmersibles the BOP stack the risers in terms of rough sea states.

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There are total forty eight platforms constructed, which are about 50 percent of semisubmersibles are located in Brazil. So, Europe has got about sixteen numbers, whereas South America as just now pointed out it has got about twenty two numbers, which are house in Brazil most.

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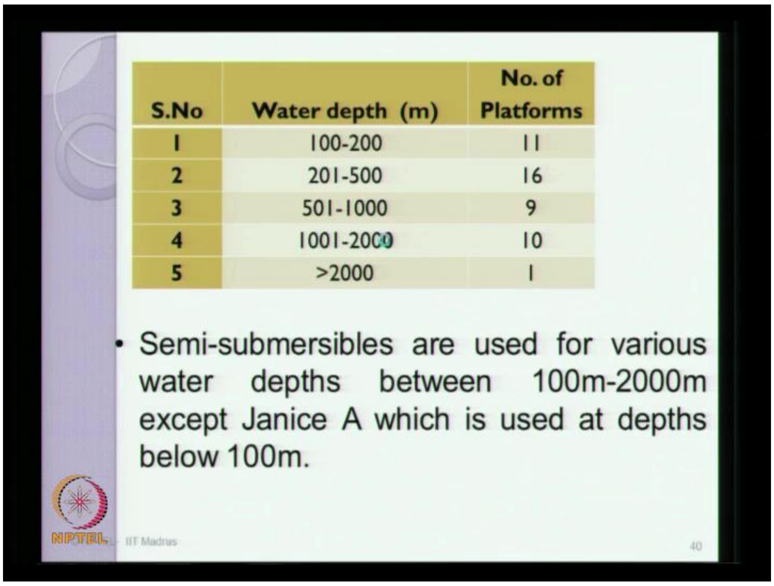

If you look at the water depth level platforms of semisubmersibles operate depth of 100 to 200 meters whereas as high as water level 200 meters you still have one semisubmersible operating but, variety of them operate at from 500 to 2000 about twenty numbers about 40 to 45 percent of them operate at a depth of varying from 500 to 2000 meters.

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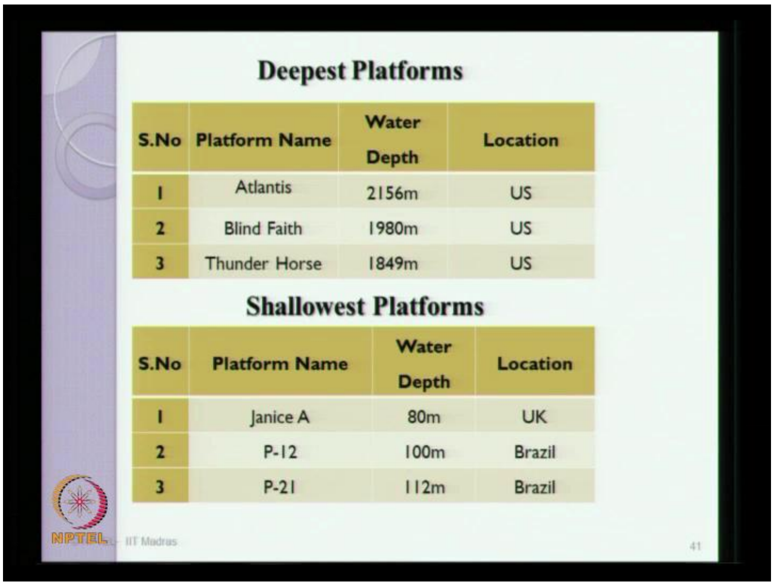

Statistically, if you look at the deepest platform Atlantis semisubmersible is operating at a depth of 2.156 kilometers. The shallow semisubmersibles are in Janice a in united kingdom as shallow as just 80 meters.

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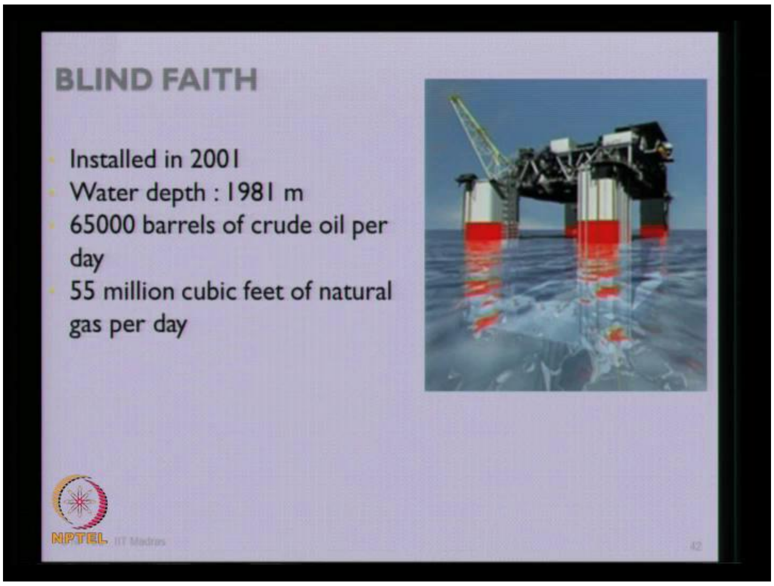

The figure what you see here is a blind faith platform installed in 2001 at the water depth of 1981 meters it can produce 6500 of barrel crude oil per day.

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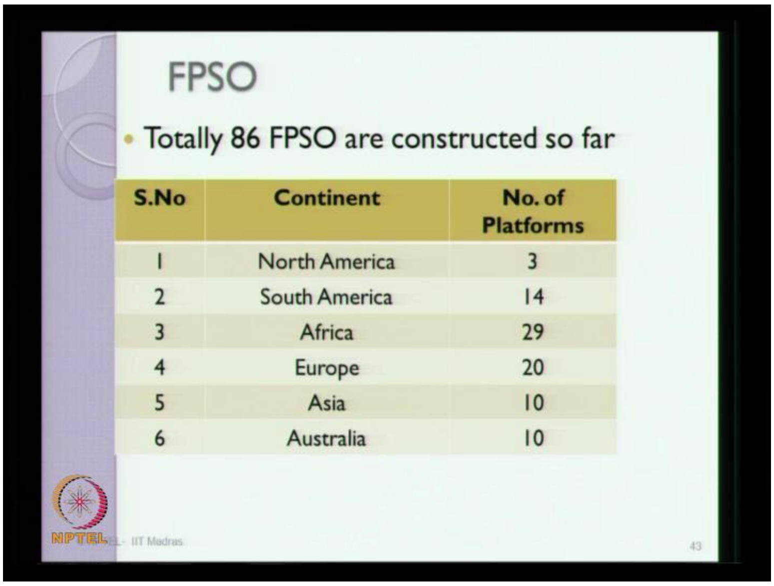

The other kind of platform on marine structure, what you see is floating production storage and off loading facility which we call as an FPSO. South America holds the maximum number of FPSO source as you see in case of United States whereas Europe and Asia and Australia surprisingly holds or deploys lot of FPSO. FPSO ladies and gentleman, is another type of most successful compliant of shore platform, which is used essentially for production of oil from the sea bed, which essentially a floating structure which has got enormous sense significant area of storage and off loading facility as well. Totally about 86 FPSO source are constructed so far.

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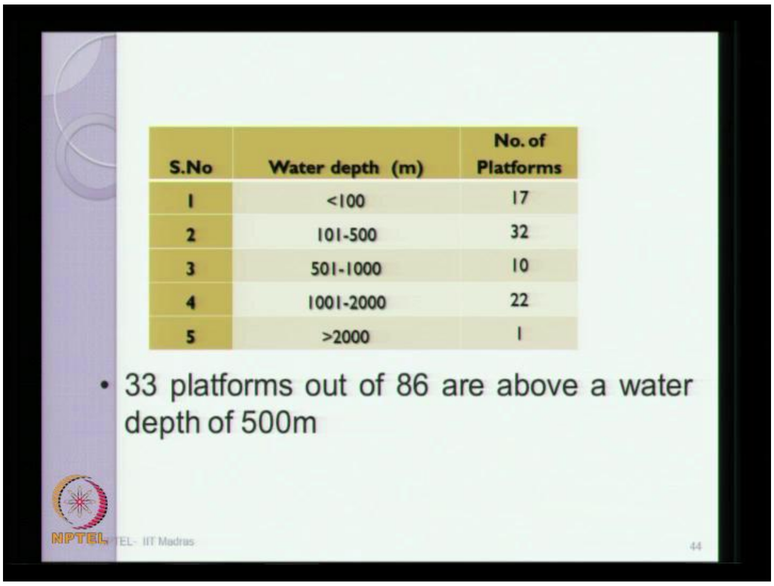

Thirty three platforms of them are above water depth above 500 meters as you see in the table here the deepest platform is in Brazil, which is 2149 meters whereas the shallowest platform is as shallow as 13 meters in Nigeria, which is armada perkasa.

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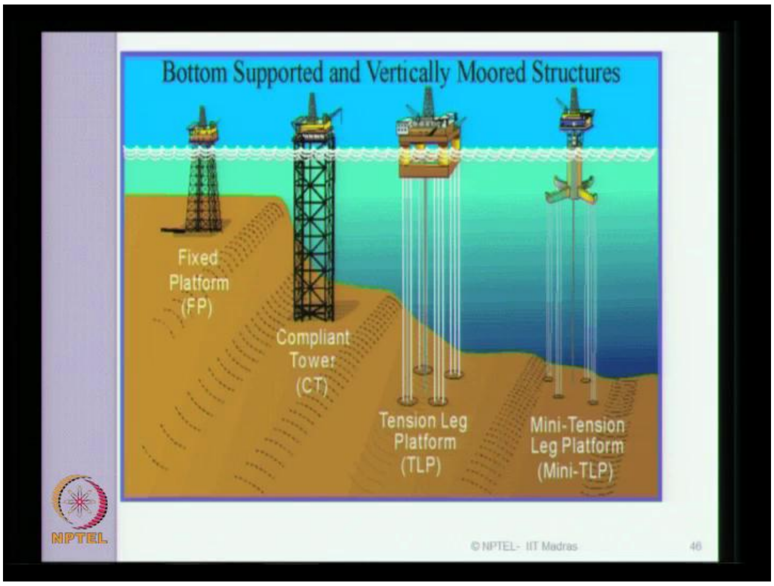

Now, interestingly the conceptual figure here shows how the evaluation structural form varied from fixed type to that of the compliant type. As the water depth of oil exploration keep on increasing from a fixed platform to a compliant power to a TLP to a mini TLP as you see here.

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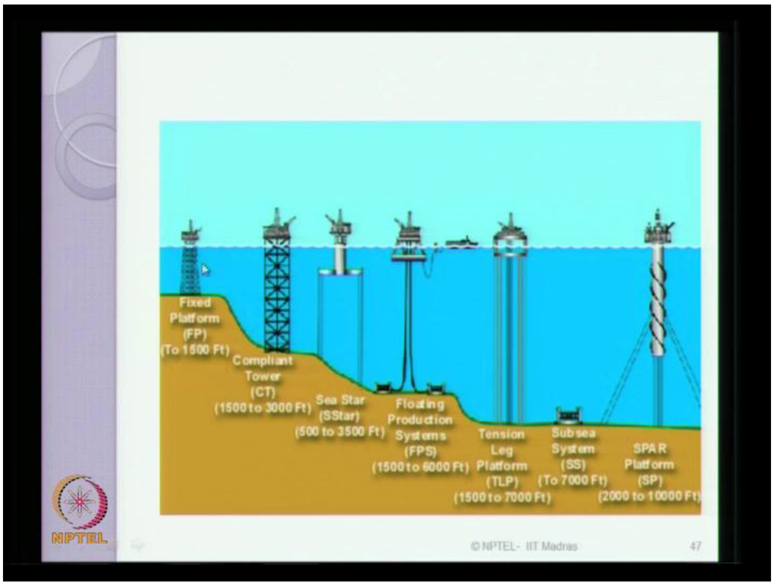

Interestingly, look at the water depth fixed platform where meant for shallow waters up to 1500 feet where as for deep water one can go for spar platforms or a TLPs as you see in this figure.

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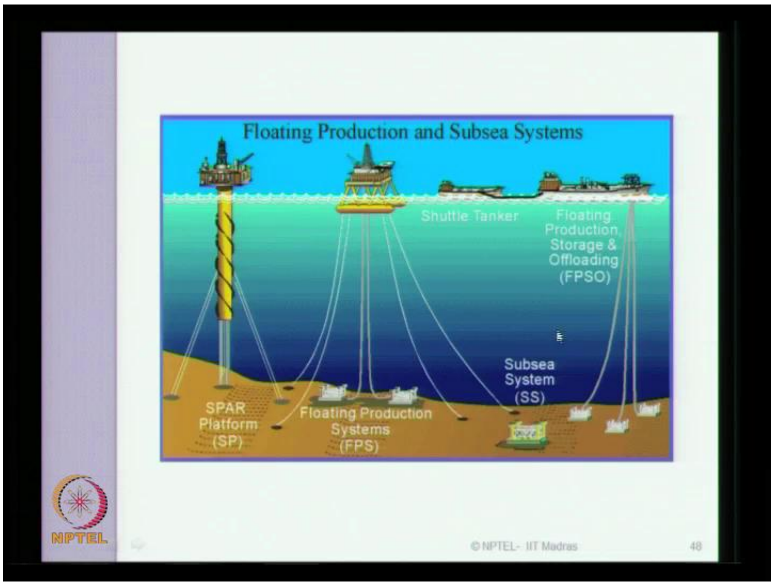

Interestingly, FPSO source are also successful alternatives like you can see here the floating production storage and off loading facility, which is compliant to that of a floating production system, we call as FPSO or alternatively compliant to that of a spar platform in deep water oil exploration system.

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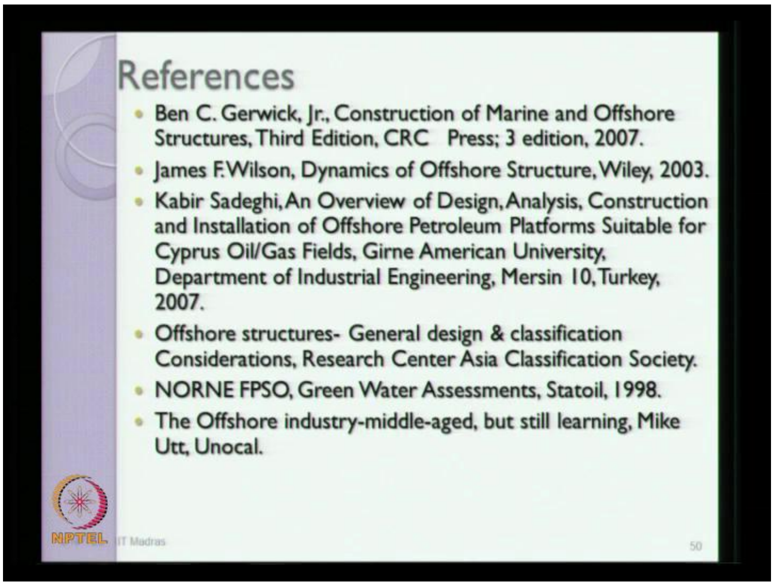

This lecture interesting references, which I want to go through. So, ladies and gentleman kindly go through these references for better understanding in terms of conceptual behavior of this kind of marine structure. In this lecture we covered about different types of compliant type marine structures, which are essentially having structural action because of the structural form based on which they derive structural action or restore the normal sea under the lateral loads.

In the last lecture we discussed about fixed type platforms in this lecture. We discussed about compliant type marine structures compliant stands for flexibility or moment. I hope these lectures have cleared you fundamental structural forms that are deployed for oil gas production system in off shore, which are classical marine structures as saw today.

Thank you very much.