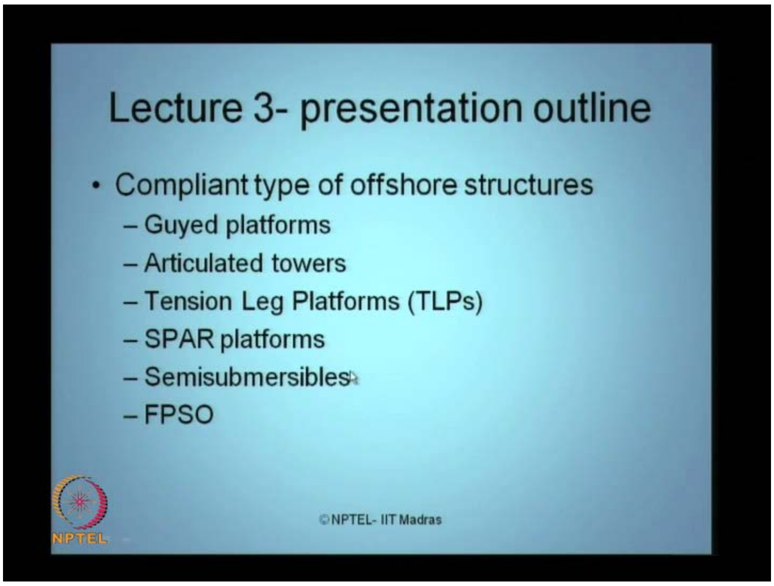
Ocean Engineering
Prof. Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 1
Lecture - 3
Compliant type offshore structures -1

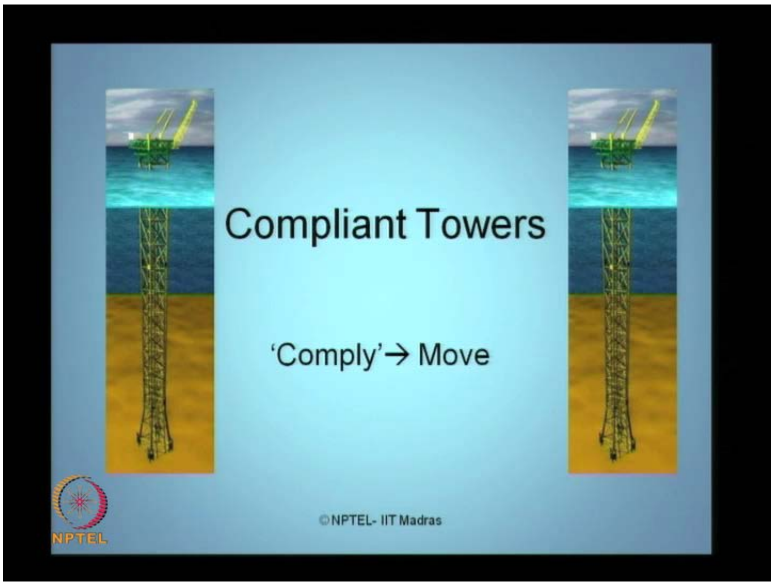
Welcome to the third lecture, on the module on offshore structures and materials. We discussed in the past two lectures in detail, about the fixed type platforms. In this presentation, we will talk about different compliant type offshore structures.

(Refer Slide Time: 00:24)



We would like to cover topics related to guyed platforms, articulated towers, tension leg platforms, abbreviated as TLPs, SPAR platforms, semisubmersibles and FPSO, very briefly. In the next lecture, we will discuss about semisubmersibles and FPSO, and drill shapes, more in detail.

(Refer Slide Time: 00:58)



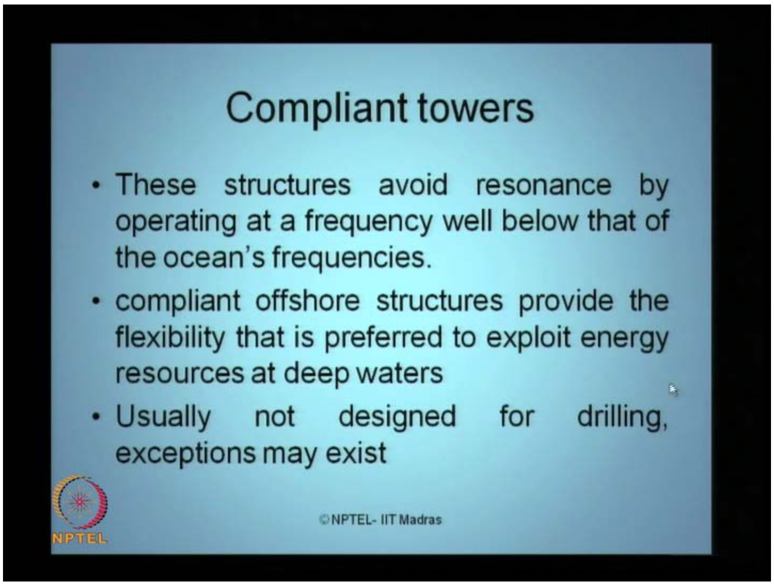
What do we understand by compliant structures? I want to draw your attention to the spelling of this term. It is compliant. Compliant means move. So, exactly the term compliancy is associated to those kinds of structures, which has a capability to move along with the external forces acting on the structure. So, compliancy induces flexibility to the structure, because as the structure becomes flexible, the structure starts responding to the external forces, in the same direction as that of the force being applied.

(Refer Slide Time: 01:46)

Now, what are the different kinds of compliant structures or compliant towers? Compliant offshore structures are essentially drilling platforms that are deployed, in deep sea for oil exploration. The previous types of plate forms where meant, for shallow or medium water depth. Whereas, the current type of complaint offshore structures are essentially designed for drilling, especially in deep sea. They are connected to the sea flow, by allowing them to move freely under the action of current waves, and wind; which is the lateral force exiting the structure. Obviously, the method by which, these complaint structures are attached to the sea flow, has got to be different from that of the fixed type structures. As we recollect, in case of fixed type structures, they are found to the sea floor, either by piles or by gravity based structural system or by spud cans.

While in complaint type of offshore structures, they are also connected to sea flow, in an intelligent way, which enables them to move freely, under the action of lateral forces. These structures, therefore, strongly rely on a restoring buoyancy force, to maintain the stability, after any lateral movement occurs on the structure. So, the restoration of compliant structures, are essentially and basically, from the buoyancy force, which are acted up on the structures.

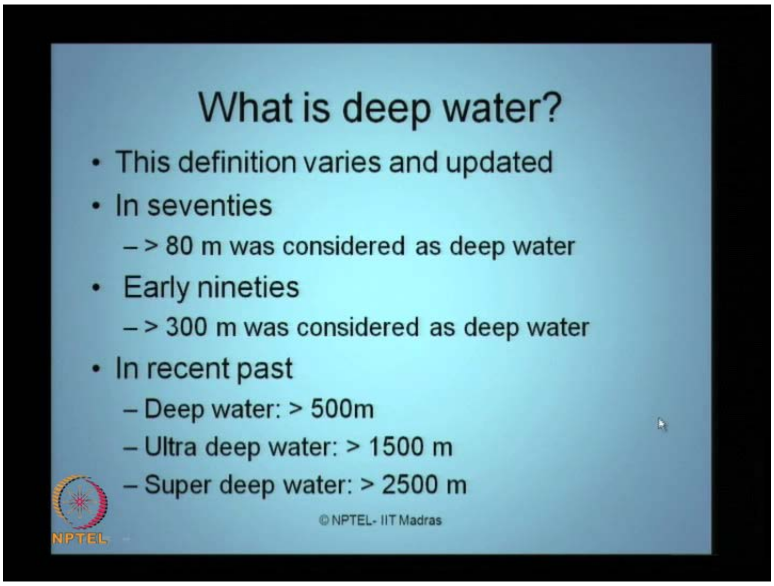
(Refer Slide Time: 03:39)



These structures avoid resonance by operating at a frequency well below that of the ocean wave's frequency. This is considered to be, one of the greatest design advantage, of compliant type of offshore structures. Because the operational frequency of, the fundamental frequency of these structures, are well away from the band of operational frequency of the water waves, therefore, these structures do not resonate under the external action of environmental loads. Compliant offshore structures provide flexibility, which is preferred to exploit energy at deep waters.

On the other hand, if looking for any structural system, which has got to install in deeper waters; ladies and gentlemen, you will remember that, as the water depth keep on increasing, the cost of fixed type of offshore structures; especially still jacket structures, gravity based platforms go very high, and the cost grows exponentially high, when you take these kind of structures, to deeper waters, whereas compliant offshore structures, where the virtue of the design, imparts, lot of flexibility to the system. Therefore, these are one of the most preferred structures to exploit energy at deeper waters. Usually, they are not designed for drilling, but exceptions may exist.

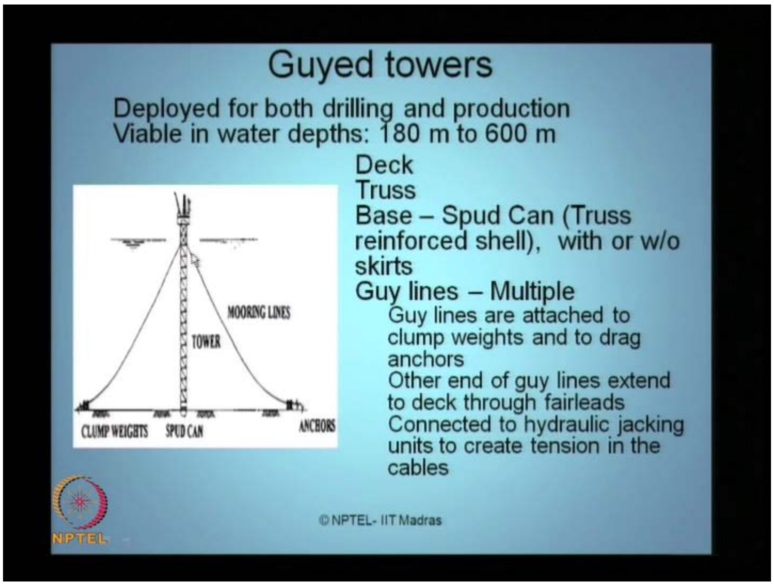
(Refer Slide Time: 05:22)



Now the fundamental question comes is, what we understand by deep water? It means, what would be the criteria, to call water as shallow, medium, or deep waters. Now, obviously, this definition keeps on varying, and they are updated in the literature. In 70s, people said, any depth more than 80 meter was considered as deep waters. Whereas, in early 90s, people said, more than 300 meters, can be called as deep waters.

Now, based on the recent past, of statements in the literature, we say, any water depth exceeds 500 meter is assigned as deep water, in the literature. Any water depth, greater than 1500 meters is referred as ultra deep waters; whereas, water depth exceeding 2500 meters are referred as super deep waters, in the literature.

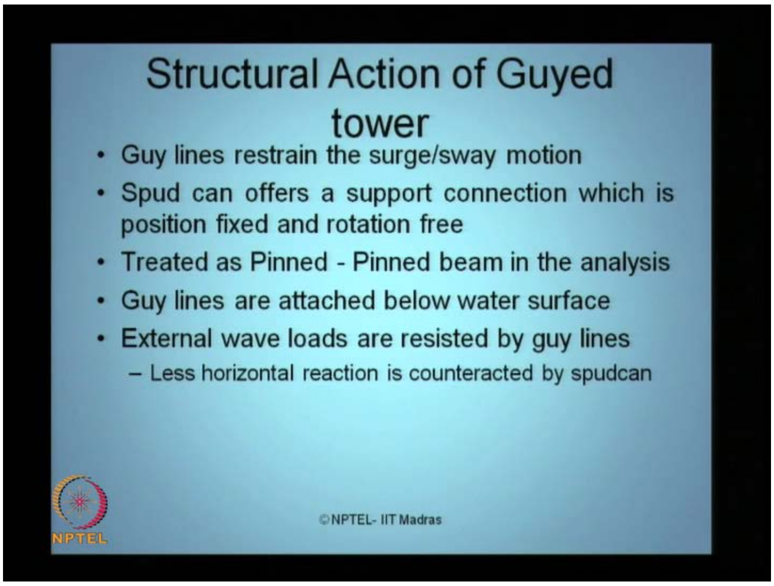
(Refer Slide Time: 06:30)



Let us look at, first type of the compliant structures, which we call as guyed towers. Guyed towers are essentially compliant type of platforms, which are deployed for both exploit drilling and production drilling. Generally, these kinds of towers are deployed in water depths, varying form 180 meters to 600 meters. The essential components, as seen in this figure, of a guyed tower are, essentially the truss system, which you see here. The base, base attached to a spud can; in the last lecture, we have already discussed about the spud can system; and, the type of foundation which has been used for spud can, in case of jack up rigs. These spud cans and the base, can be without, or with skirt files. Essential component of this is what we call, as a mooring line or to be very specific a guy line.

Guy lines are actually attached to the clump weights; and then to the drag anchors. To hold these guy lines, formally to the sea flows. Other end of the guy line, one end of the guy line is attached to the clump weight; and further attached to drag anchors, as you see here. Whereas, the other end of the guy line passes through a point call a fairlead. So, the point which connects the guy line on the tower is what we call as fairlead. The point which connects the guy line, to the sea flow is what we call, is a touch down point, where we put lot of clump weights; and then drag anchors to hold these guy lines, down to the sea flow. Now, once these guy lines are connected to the tower, to the top side through the fairleads, the top side will have complicated hydraulic jacking units, through which tension will be created in these lines.

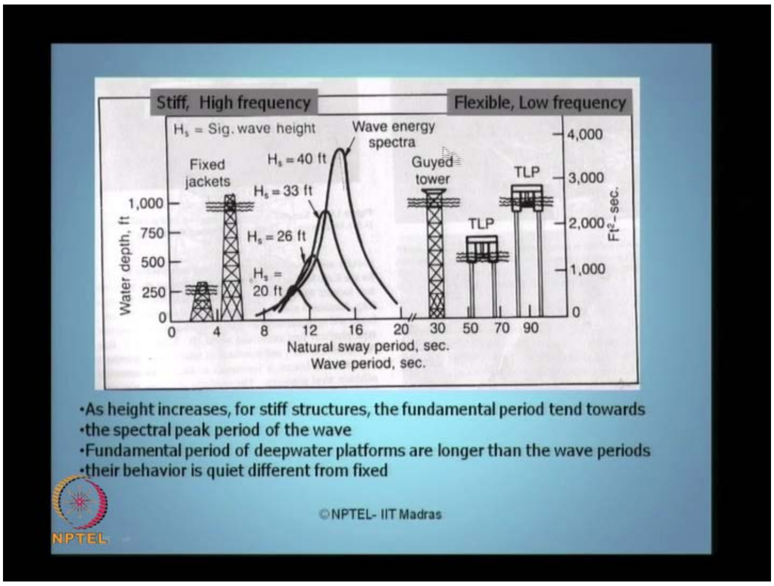
(Refer Slide Time: 08:56)



Let us look at quickly, the structural action of a guy tower. Guy lines, as you see, restrain the surge or sway motion imposed on the tower. The spud can offers a support connection, which is position fixed; but rotation wise, it is free. So, on the other hand, the central tower, of a guide tower, is fixed in position to the foundation point; but it has freedom to rotate in 360 degrees. That is the type of compliancy, what this tower offers. It can also swing, or it can also surge and swing at the pined junction, or the pined point, at the foundation. In the analysis, guy towers are treated as pinned, pinned beam for structural analysis purposes.

Guy lines are attached much below the water surface, to the tower. The external wave loads are resisted by the guy lines. Now, because of this reason, less horizontal reaction is counteracted by the spud can. So, the spud can offers only stability against lateral sliding. It has no job to resist any lateral forces coming on the tower. Because all lateral loads cost, because of waves or winds, will be resisted essentially by the tension enforced on the guy lines.

(Refer Slide Time: 10:40)



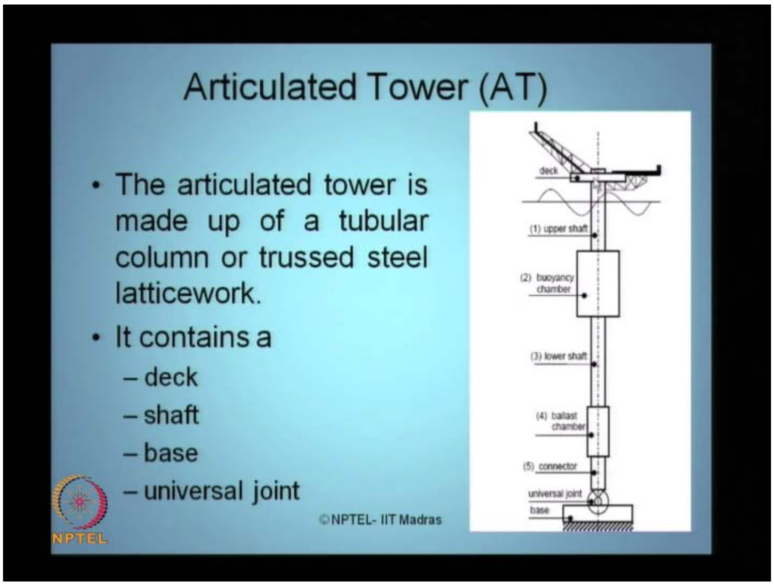
Let us quickly see, this figure to understand, where are different kinds of platforms located in deep waters? If we look at this figure, which is plotting, the natural sway period in seconds, or the wave period in seconds, with respect to the water depth in feet; we can see here, the fixed jacket structures or the steel jacket platforms, which has the natural period, closed to around 4 to 7 seconds; considered to be very stiff, because of high frequency. Ladies and gentlemen, you can understand that, the time period, what we see here, is inversely proportional to the frequency. So, for a lower time period, we have a very high frequency. When the frequency goes higher, the structure is called as stiff. So, fixed jacket structures, or fixed platforms, which are having very high stiffness, have low natural period. And generally, they are deployed, at locations where, the depth can be close to be around, let us say, 200 meters.

As you go ahead, in case of larger time period structures, as I said in the beginning, these structures have high degree of flexibility. So, the moment I say, high degree of flexibility, they should have very low frequency. For a lower frequency, the natural periods will be very high. For example, for structures which are compliant in nature, whose natural time periods are very high, from a range of 30 to about 110 seconds, these platforms will be having very high natural time periods, and low frequency.

Now, interestingly, by the selection of the design, whether compliant towers with high time periods, or fixed structures with low time periods, do not intermit in the operational range of wave period, of a sea sit. Offshore structures of design, in such a nice manner, do not resonate at any point of time, with the external load acting on the structural system. So, as the height increases, for stiff structures like fixed jackets, the fundamental period have a tendency to move towards the spectral peak.

Therefore, I do not prefer to have a fixed structure with greater water depths, because as the water depth increases, the height of the structure will go larger and larger; and the structural height goes increasingly larger. Then the structure time period will start moving towards the spectral peak period, which initiates the probability of resonance. Therefore, the fundamental period of deepwater platforms, like compliant structures, have very long periods, compared to the wave periods. And they, their behavior therefore, are quite different, with that of fixed type of offshore structures.

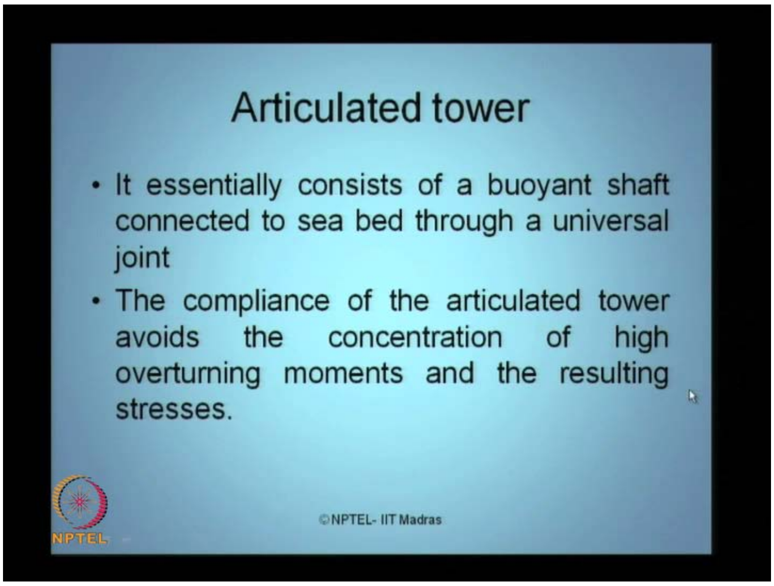
(Refer Slide Time: 14:19)



The second category of complaint structures is, what we now see, is called articulated tower. Articulation is a term related to rotation. Rotation is always given, if you have a hinch. So, articular towers, are those towers which are connected to the sea bed, through a hinch, we call technically this hinch as universal joint. So, universal joints offer position restrain, but no restrain against rotation. These are the vital components of an articulated tower.

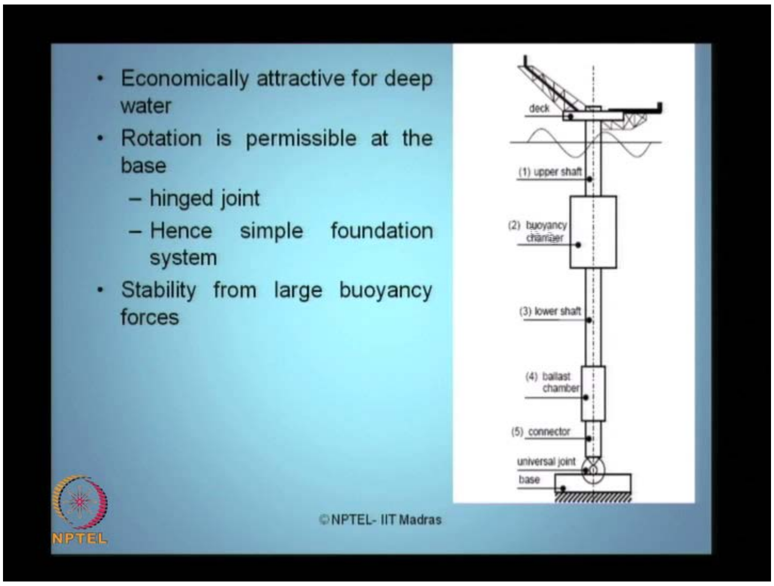
Starting from the deck, we have a helipad; we have a top side detail of this; you have a grain drag on a flair bone; we have got a central column which contains upper shaft, and lower shaft. The buoyancy chamber is located usually at one third height of the central shaft, from the mean sea level. The ballast champers is located at one third height, from the bottom on the central shaft. These are the connected pieces, which connects the ballast chamber, or the central shaft to universal joint. And the universal joint rest on a base piece, which is further connected to a sea flow. So, articulated tower is essentially made of, a tubular column or trussed steel lattice work. The central shaft can be a single tubular column, or it can be a trussed type structural system. So, essential components of an articulate tower can be, read form this figure as, the deck, the shaft, the base, and the universal joint.

(Refer Slide Time: 16:22)



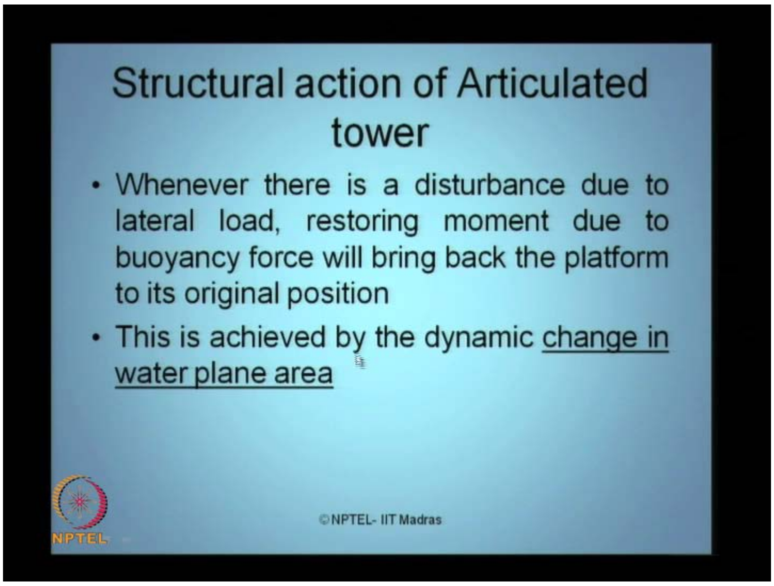
It essentially consists of a buoyancy shaft, or a chamber, connected to the central shaft, which is further connected to the sea bed, through a universal joint. The compliance of the articulated tower, avoids concentration of high moments, at the bottom. And also shifts, the resulting high stresses caused because of the action of external forces.

(Refer Slide Time: 16:47)



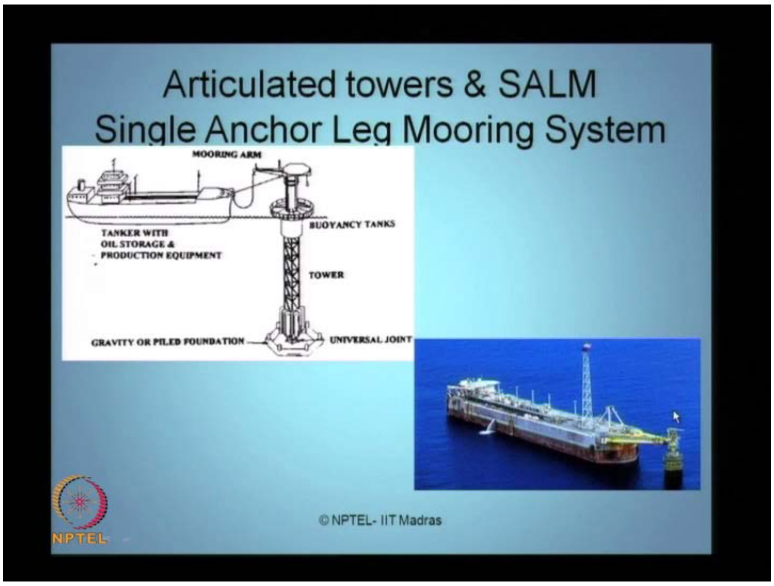
Economically, these structures are attractive for deep waters because the universal joint enables rotation or hinch moment above this point. Practically, when the inch moment occurs about this point, as an engineer we can easily interpret, that the moments of these towers, caused because of the lateral force, above this point, practically will be 0. So, the rotation is permissible at the base, because the base joint is hinch joint. Hence, since there is no rotation, or there is no moment caused because of the external loads, at this point, I can go for a very simple foundation system. These kinds of towers have higher stability, because of large buoyancy forces. We have got a very large buoyancy chamber, attached to the central shaft of this tower, which is located at upper one third of the tower, form the mean sea level. This ensures, lot of buoyancy forces acting on this chamber, which will apprise the tower, in case of action under external loads.

(Refer Slide Time: 18:07)



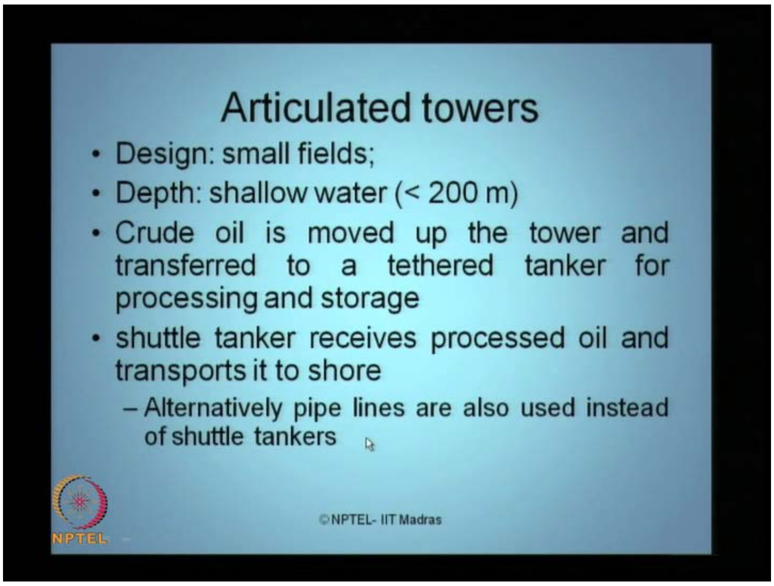
Let us quickly look at, the structural action of an articulated tower. When the tower is disturbed by the lateral load, the restoring moment due to buoyancy force will bring it back to its original position. This oscillation takes place, about the inch, which is the universal joint at the bottom, which enables extraordinary amount of rotation possible about that point. So, essentially the restoration occurs, because of the dynamic change in the water plane area of the buoyancy chambers.

(Refer Slide Time: 18:47)



This figure shows a schematic view, of an articulated tower, which you see here; which is actually used, for anchoring the ship, or a tanker, which is used for oil storage and production systems. The tower has a helipad; it has got a crane derrick; it has got an operational flow; it has got a very large buoyancy chamber; the central shaft is a lattice tower, as we see here; and there are universal joints, which connects, this tower to my foundation system. The real photograph of, the single anchor, leg mooring system, a single anchor leg mooring system, which we call, in the literature as SALM, is shown here. This is my drill shape; this is being used for drilling production and equipment etcetera. Now, this drill shape has to do dynamic positioning; and that positioning of station keeping is achieved by holding it, by hungering it, to a system, which we call as an articulated tower.

(Refer Slide Time: 19:59)

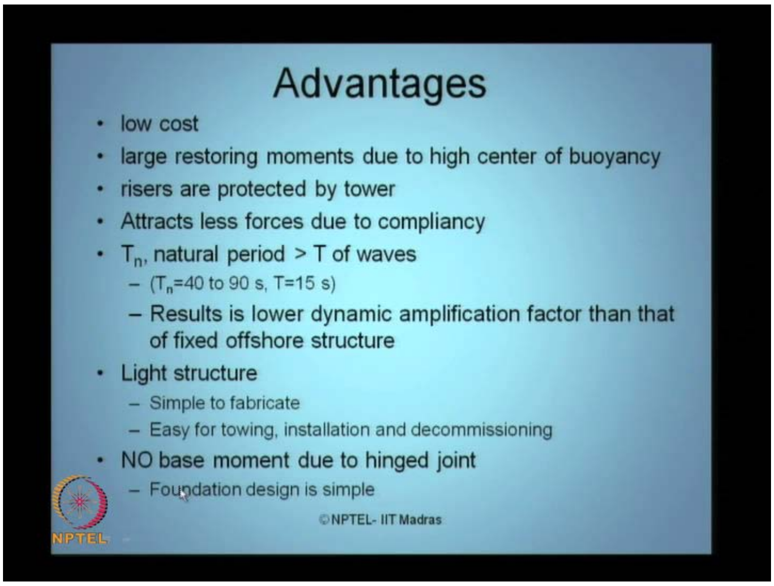


If we look at the design concept of articular tower, these are actually made for very small fields; they are made for shallow waters, which is less than 200 meters; the crude oil is moved up the tower, and transferred to a tethered tanker for processing and storage, because articulated towers, expect the bouncy chambers, do not have large space for storing the excluded crude oil, which is taken from the drilling rises. The shuttle tanker, which receives the processed oil, further transports it to the shore; alternatively in certain cases, instead of shuttle tankers, people use directly pipe lines to transfer, the processed oil from the platform.

(Refer Slide Time: 20:48)

These are very clear photographs, on a sea state sick's, which anchors, tanker; which is essentially used for transporting the explored oil, from the platform to a different location. So, this is the single leg, anchor leg mooring system, which is used essentially to hold the ship in position, at a specific location.

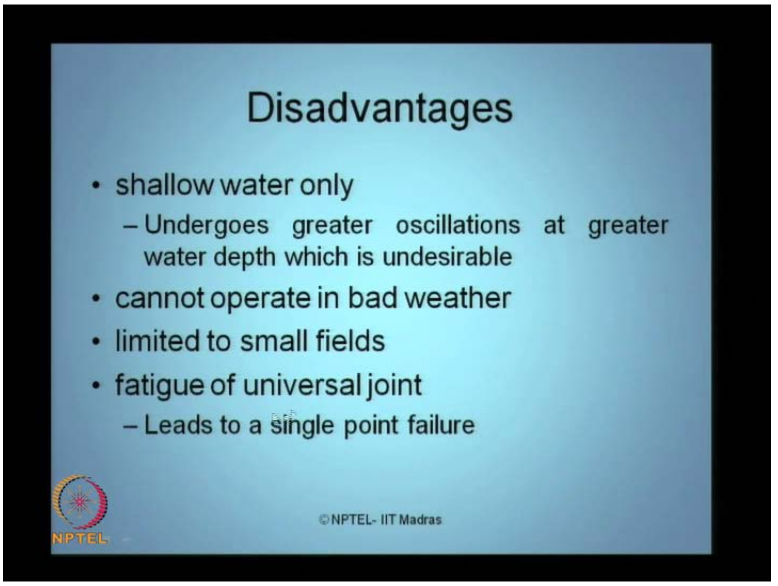
(Refer Slide Time: 21:18)



AT's have lot of advantages. It is essentially a very low cost structural system. It has large restoring moment capacity, due to high center of buoyancy. The risers are protected by the tower, form the external loads. It attracts less force due to its compliancy. The natural period of these towers is larger than that of the waves. For example, they are in the range of, 40 to 90 seconds; where its typical period of a wave is around 15 seconds, in an operational sea sate.

The main advantage of this shift of natural period, with that of the wave period is, that results in lower dynamic amplification factor, than that of a fixed offshore structure. The structure is very light. As a result of which, it is very easy and simple to fabricate. It can conveniently tow it down, to the side installed. And further more advantageously, we decommission it, whenever, we want to remove it, from the installed location. As, the structure is supported by the universal joint at the bottom, the universal joint does not accept, or generate any base moment. As a result of which, the foundation design is very simple for articulated towers.

(Refer Slide Time: 22:51)

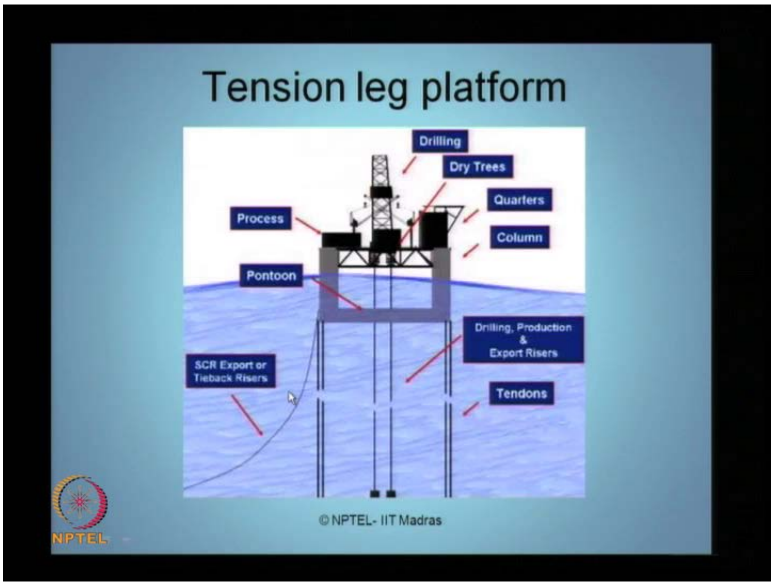


Of course, AT's have few demerits. It can be used only for shallow waters, because it undergoes greater oscillation, when you try to use it, for higher water depths, which is undesirable, in case of operational sea states.

Articulate towers cannot operate in bad weather. Because in bad weather, may be a strong surge, or huge hurricane wind, may cause lot of oscillation, to the buoyancy chamber; which will result in, quick restoration of the platform; which will cause, lot of uncomfortable surge sway and yak moments, on the platform. So, therefore, they cannot remain in operation, in case of bad weather. They are limited to very small explicative fields only.

The most important undesirable feature, of an articular tower is, the fatigue of the universal joint. As we see, and understand, the restoration of an articular tower is essentially from, the movement of the universal joint at the bottom. Because of the constant rotation happening at hinched joint at the bottom, this will lead to, what we call as a fatigue failure of the joint. The universal joint is a very important, vital component of this tower. Therefore, its leads to, what we so call as a structural engineering, as a single point failure. Any structural geometry, which initiates or proms, a single critical point, catastrophic failure is always a dangerous design. It is not preferred, as a good design, in structural engineering, whereas articular towers have this, as one of the serious disadvantage, for its application.

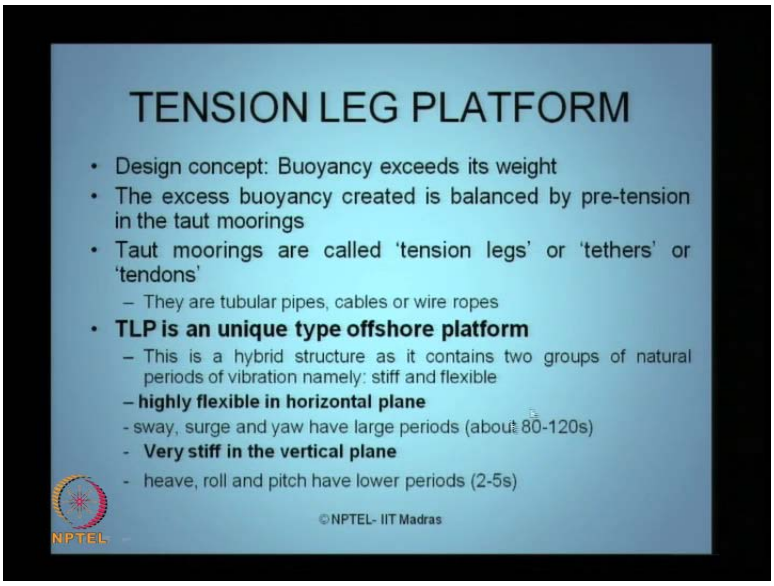
(Refer Slide Time: 24:48)



The third kind of platform, what we see, in the compliant type offshore structures, is tension leg platform, abbreviated as, TLP.

The photograph what you see here, is a sketch diagram, of a typical tension leg platform. I want you to draw your attention, to various parts, or components of a TLP. The top side is as common as, you saw, in other kind of offshore structures, whereas, TLP essentially, is this part; and the further down part. So, TLP essentially has columns, which are vertical, usually cylindrical in shape. And the bottom member is what we call as the pontoon member. They hold super structure, is anchored to the sea bed, using cables. These cables are technically called as tendons, or tethers. As these cable hold down the structure, this is called tension leg platform.

(Refer Slide Time: 26:00)



The design concept of a TLP is basically very simple. It is designed with excess buoyancy, in comparison to its weight. Obviously, when you got a platform, whose weight is much lower than the compared buoyancy force, exited to by the water body, on the platform, the platform will have a tendency to be pushed up by the water forces, when it is installed. So, the buoyancy force exceeds its weight; obviously, this buoyancy force which is exceeding the weight will be counteracted, by imposing, what we call as a pre-tension, in the mooring systems. Since, all my mooring systems will be in pre-tension, I call this platform as, tension leg platform.

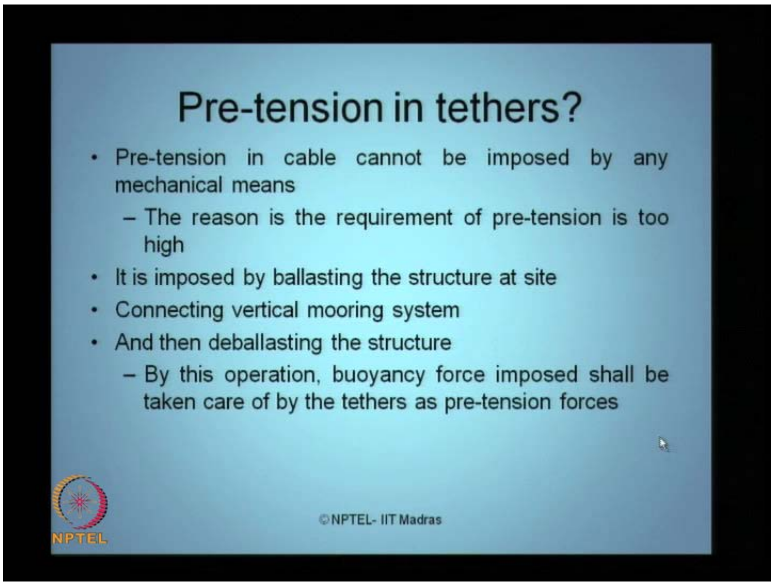
The taut moorings system, or otherwise called in the literature as tension legs, tethers or simply tendons. Structurally, they are tubular pipes; they can be even, set of cables, or simple wire ropes.

TLP is a unique type of offshore platform. Ladies and gentleman, this is the only type of an offshore structure, which is hybrid in nature. What we understand by hybrid structure? Hybrid structure is a classical example of having two classified groups of natural periods of vibration. Suppose, if a structural system has two distinctly different groups of natural period, I call the structural system, as a hybrid structure. In the design and development of offshore platforms, TLP is completely unique because of this characteristic. This has got two groups of natural periods. One is what we call as the stiff period; other is what we call as a flexible period.

The TLP is a structure, which is highly flexible in horizontal plane. For example, look at the degrees of freedom of surge, sway and yaw. I understand, all of you will recall, the degrees of freedom by their names; for the sake of learners' knowledge, let we repeat it very briefly again. Surge and sway, are the displacement degrees of freedom, along x axis, and along y axis. It is very easy to remember, sway, as the last letter y, so sway is a displacement degree, along y axis. Alternatively, surge is the displacement degree, along x axis. You may wonder, what is the displacement degree, along z axis? Heave, is the displacement degree, along z axis. Rotation, about x axis, is what we call, as roll. Rotation, about y axis, is what we call pitch. Rotation about z axis, is what we call yaw. So, there are 6 degrees of freedom associated with an offshore platform. Out of which, I am classifically grouping, two degrees of freedom, or two natural periods separately.

So, surge sway and yaw, which all motions, which can be seen in horizontal plane, have very large period. It means, they are highly flexible in the horizontal plane. Whereas, in the vertical plane, that is, the heave response, which is the motion of the platform, along z axis. The rotation of the platform about x and y axis, have very low periods; it is means they are stiff. We can easily anticipate, the response of a TLP, for a lateral force, can be very large in flexible degrees of freedom; whereas, very small in stiff degrees of freedom. So, this is a hybrid combination of two classified groups, of natural periods; and, that is the uniqueness, for this platform.

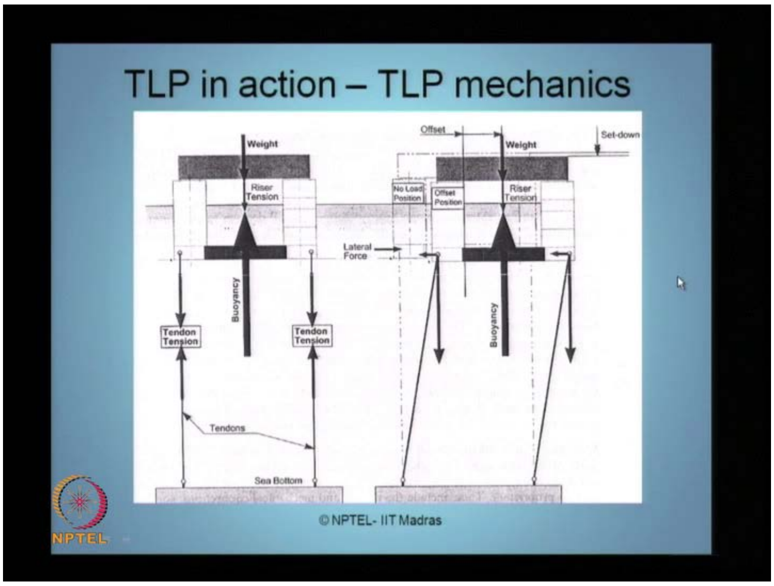
(Refer Slide Time: 30:17)



Now, as we understand, how the system is designed by the excess buoyancy. I would like to have, a pre-tension enforced on the tethers, to counteract this buoyancy force. Now, the question comes, how do I induce pre-tension in tethers, at greater water depths, in sea, during installation? As you understand, pre-tension of the cable cannot be imposed by any mechanical means. The reason is, the requirement of pre-tension is very high, in terms of its magnitude. For example, it is as high as 8000 kilo Newton. So, this kind of pre-tension on cables cannot be induced by any mechanical means on a platform, which is floating, or which is getting installed, in deeper waters.

Then how this pre-tension of the very high magnitude is induced, in the tethers? It is imposed by ballasting the structure at site. So, what I do is? The column and the pontoon member will be filled up with ballast material, which will counteract the buoyancy force. So, the cables attached to the pontoons and columns, which I call as tethers, will be slackened. This tethers will be connected to the foundation, anchors, once I deballast the system, as the weight is removed from this columns and pontoon chambers, the structure will restore its buoyancy force, which will be transferred indirectly, as attentions to the tethers. So, the connected vertical mooring system will get a transfer of this buoyancy force, as a pre induced tension, when the structure is deballasted.

(Refer Slide Time: 32:05)

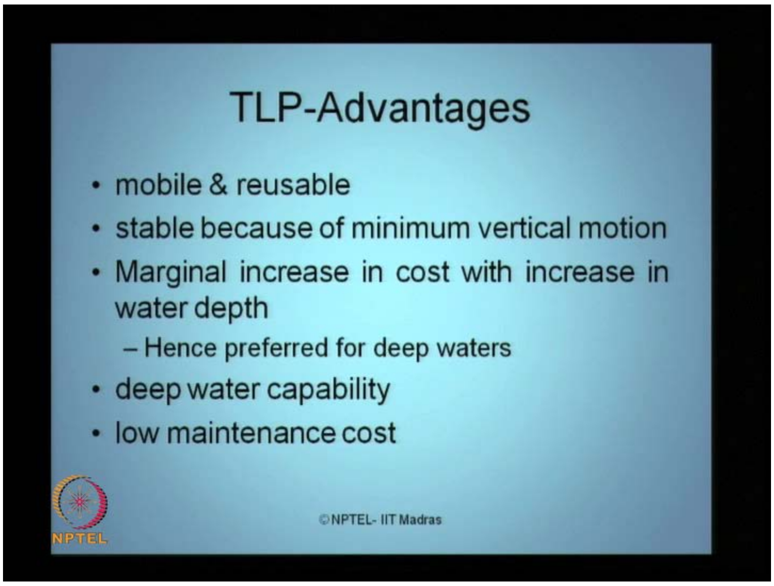


This is a conceptual figure of a TLP, what we call TLP mechanics. This is a structure, and idle location, where these are the points at which these tendons are anchored to the sea bed. This is a buoyancy force, which is acting, in the direction, opposite to the gravitational force of the weight; and we understand, because of the symmetric design of the platform, the buoyancy and the weight will be co-linear and co-planar, with respect to the vertical plane, where they are acting. Now, under the equilibrium condition, when the buoyancy exactly equal to the weight, the platform remains vertical, as it is. And these cables will be always induced in tension; they will never get slacked, we called them as, top mooring systems. That is why they are called tension leg platforms.

When the platform is subjected to a horizontal force, or lateral force, by wind or wave, then the platform sway or surges, along the x or the y axis respectively. When the platform moves to my right, as we see in this figure, there is a small set down effect happening in the heave direction. So, this set down effect, changes the buoyancy on the column, and the members here. That will induce, or that will change the pre-tension available in the cable. They will have two components- horizontal and vertical. The vertical component will get added, to the weight to counteract the buoyancy; whereas, the horizontal component of the large pre-tension, will counteract the lateral force acting on the system; it means these cables are able to counteract the actual lateral force, subjected to the system.

All these members, which you see here, do not contribute directly to restore, the lateral force action caused by wind or wave. It is only the component of very large pre-tension, which counteracts lateral force, through which the platform is brought back to normal position, as you see in the left side. This mechanics is what we call, TLP mechanics. There are two important terminologies, you must understand. The movement of the platform, under the lateral force is what we call as an offset; the movement of the platform in the vertical direction is what we call as set down; whenever there is an offset, set down is automatically generated. So, heave is very strongly coupled with surge and sway, degrees of freedom; that is the integral design, of this kind of platform. We call this structural action, as so called, TLP mechanics.

(Refer Slide Time: 35:06)

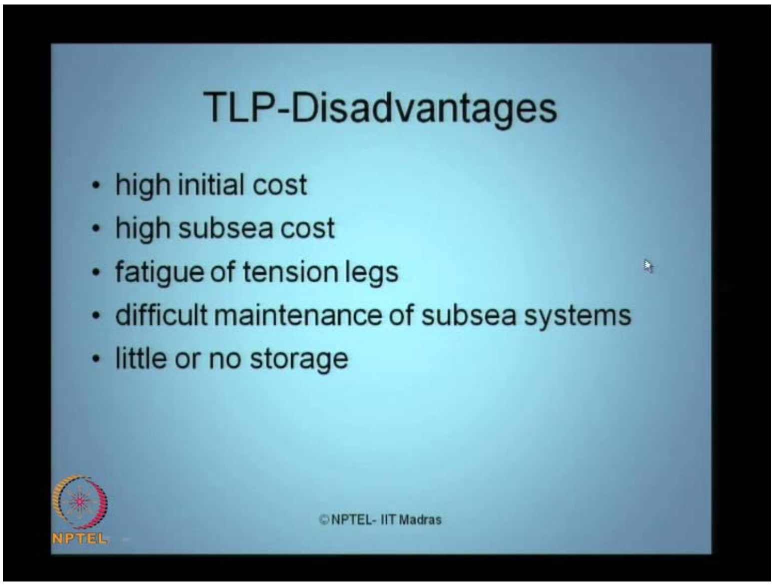


TLP posseses lot of merits, as offshore platforms. They are highly mobile, because you see, once you release the free tension, in the cable, by again ballasting the structure, the cables get slaked. Therefore, we can easily remove the cables from the foundation system, will be self buoyant, and can start floating the TLP. So, it is very highly mobile; it can be very highly reusable.

It is stable, because of minimum vertical motion. I told you, in the heave degree of freedom, the structural period is very low, and is very stiff. So, minimum vertical motion causes lot of comfort ability, for people working on board. We call that as highly stable system.

It has a very marginal increase in cost, when increase the depth of installation. Because the member dimensions, and the member sizes, and the platform dimension, remain more or less same, for even deeper waters;. because the whole platform, has to be designed, with a very excessive buoyancy only. So, therefore, these kinds of structures are highly preferred for deep waters. So, they have a deep water capability. They have a very low maintenance cost. Then we may wonder why TLP is not, frequently built?

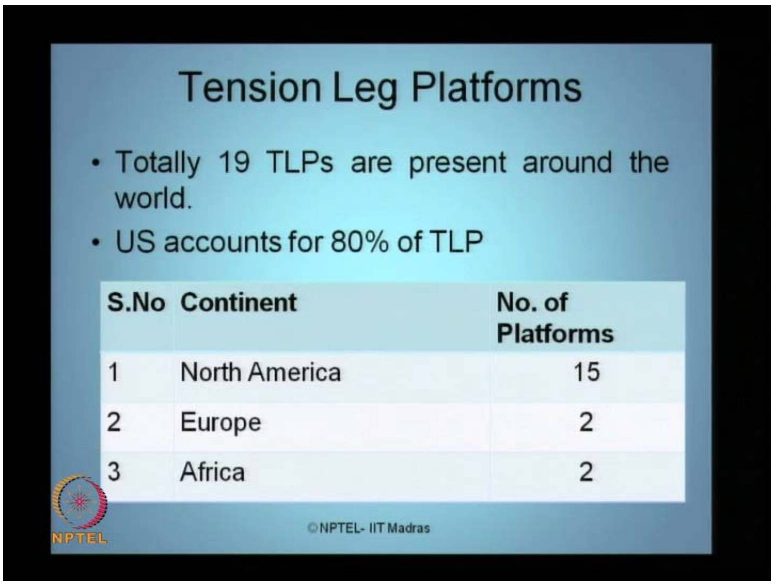
(Refer Slide Time: 36:33)



There are problems associated, which we call them as demerits of TLP. It has got a very phenomenally high initial cost. And the majority of the cost goes to the subsea cost. The installation, commissioning of the TLP, added depth of greater waters, is very expansive. Thirdly, as an, in the structural engineering point of view, fatigue induced on tension legs; as you see, initially, the tension legs are induced free tension, but this tension induced in the tethers, we keep on dynamically changing, resulting from the motion of the platform. Therefore, the change in tension induced in the legs, will result in what we call fatigue, to these tethers. That is one of the serious problems, because there are many incidences, where TLP has plugged off, because of, failure of tethers.

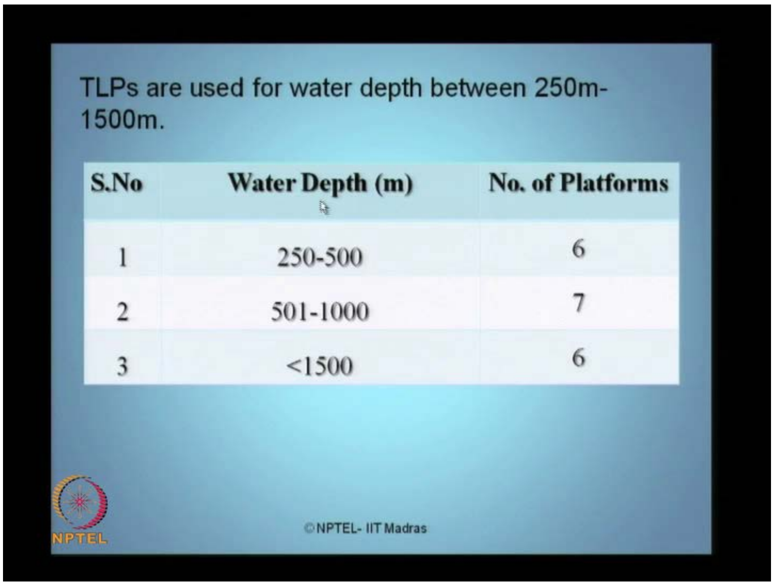
It has got a very highly complicated maintenance for subsea systems. It has practically no storage; if at all, it is achieved, the little amount of storage can come, either from the column member, or from the pontoon members. But that is comparably very less, with respect to that of GBS or a jacket platform, which (( )).

(Refer Slide Time: 37:51)



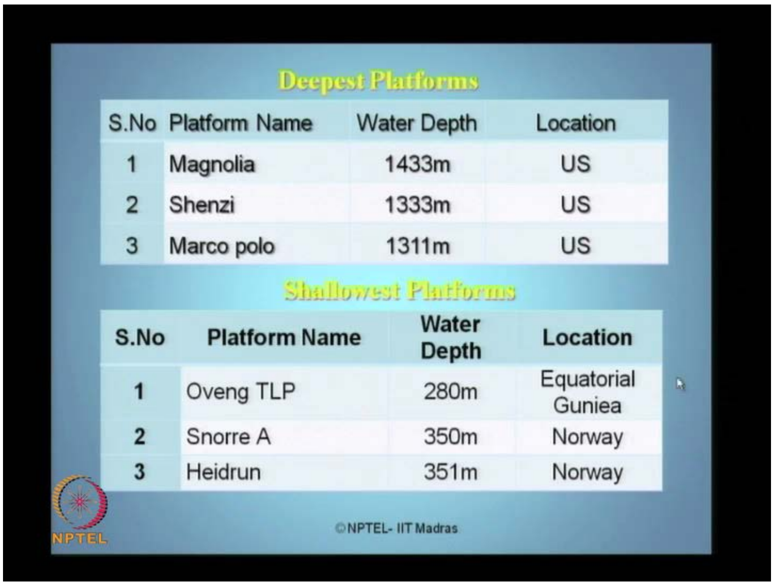
Let us quickly look at the statistics of the TLP's constructed all over the world. There are 19 TLP so for constructed in the world. North America has 15 of them, out of 19; whereas Europe and Africa has 2 of them. So, interestingly United States, accounts for about 80 percent of the TLP installed. As I told you in the interesting lecture earlier, that United States started designing the geometry of the platforms, catering to deeper waters. So, this is one of the very good inventions made in the practical installation of offshore structures in United States, where the platforms have been hybrid designed to captor for exploration in deep sea waters.

(Refer Slide Time: 38:37)



TLPs are generally used from a water depth ranging from 250 meters till 1500 meters. If we look at the statistics between 250 to 500, there are 6 platforms installed; between 500 to 1000 there are 7; less than about 1500, but more than 1000 we have got 6. So, equally larger number of platforms has been installed in United States, had greater water depths.

(Refer Slide Time: 39:06)


Deepest Platforms

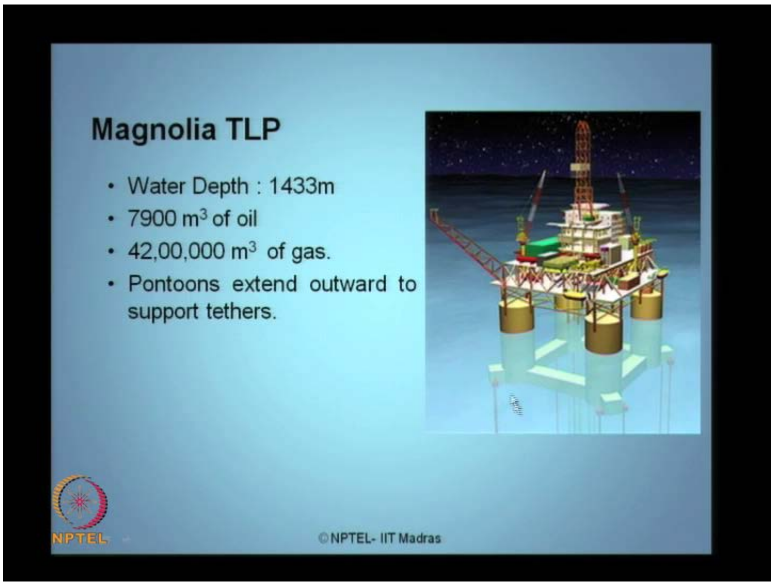
S.No	Platform Name	Water Depth	Location
1	Magnolia	1433m	US
2	Shenzi	1333m	US
3	Marco polo	1311m	US

Shallowest Platforms

S.No	Platform Name	Water Depth	Location
1	Oveng TLP	280m	Equatorial Guniea
2	Snorre A	350m	Norway
3	Heidrun	351m	Norway

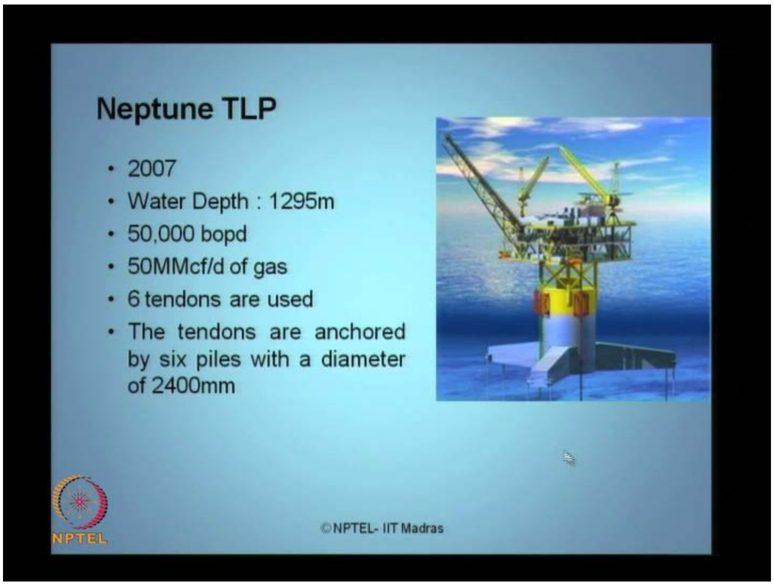
We look at an interesting statics of deepest and shallowest platforms. Magnolia, 1433 meter, stands as a deepest platforms in United States as for now. Whereas, the shallowest platforms are in Norway and Guinea, is about 350 meters.

(Refer Slide Time: 39:25)



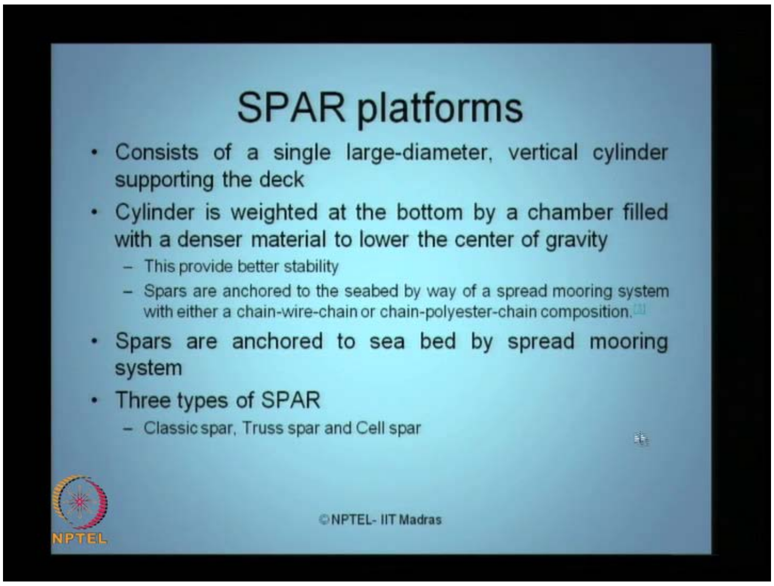
Let us quickly look at the photograph of one of the deepest platforms in United States. Magnolia TLP, operates the water depth of about 1433 meters; capacity of 7900 cubic meter of oil per day; 42 10 power 5 cubic meter of gas; pontoons are extended outward, you can see here, the pontoons are extended outward, to support the tethers. Tethers are not, at the locations where the column members are. So, an interesting phenomenal design by the virtue of which, the depth can be easily achieved, during installation. And the commissioning becomes much simpler, compared to that of tethers, for about exactly, below the columns.

(Refer Slide Time: 40:08)



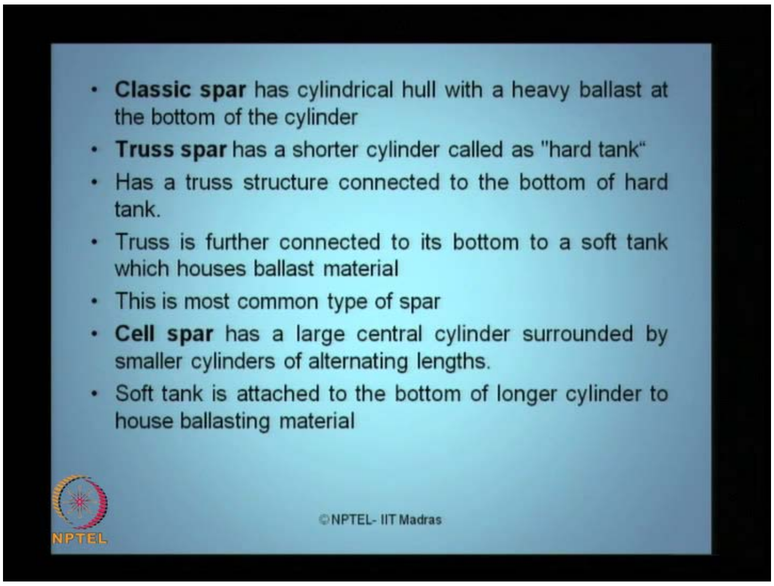
The second one is the classical example of Neptune TLP, constructed in the year 2007; for a depth of 1295 meters; 50,000 bopd; 50 MMcf d of gas; 6 tendons are being used- 1, 2, 3, 4, 5, and 6; that is 3 groups of 2, or 3 of 2 pairs on each leg, being used for holding the TLP. The tendons are anchored by 6 piles with a diameter of 2.4 meter, to the sea flow.

(Refer Slide Time: 40:43)



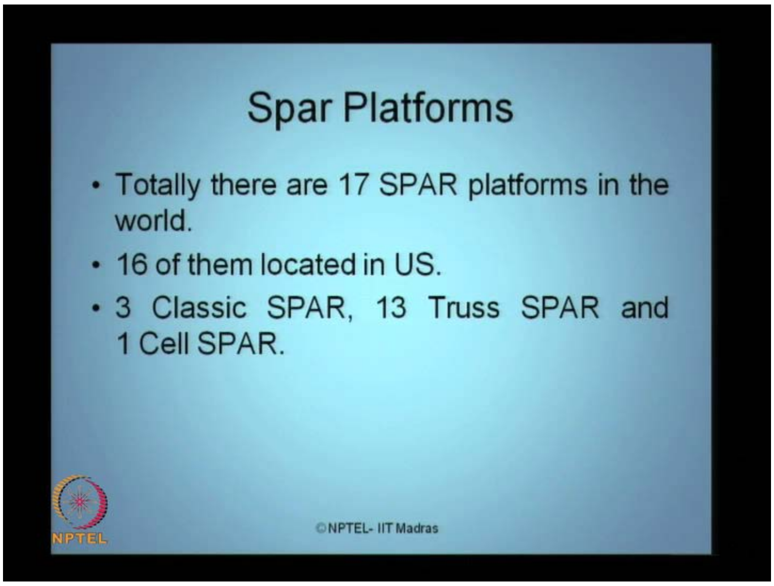
The next category of platform, in complain offshore structure, is what we call as SPAR platforms. Spar consists of a single larger diameter, vertical cylinder, which supports the deck. Cylinder is weighted at the bottom by a chamber, which is filled with a denser material, to lower the centre of gravity. So, this weighted filling, on the central single large diameter column, provides better stability, because the center of gravity is lower, towards the sea bed. Spars are anchored to the sea bed by the way of what we call, spread mooring system. It can be either with a chain wire chain, or chain polyester chain composition. Spars are anchored by spread mooring system. Three types of spar are essentially available in the literature, what we call classic spar, truss spar, and a cell spar.

(Refer Slide Time: 41:46)



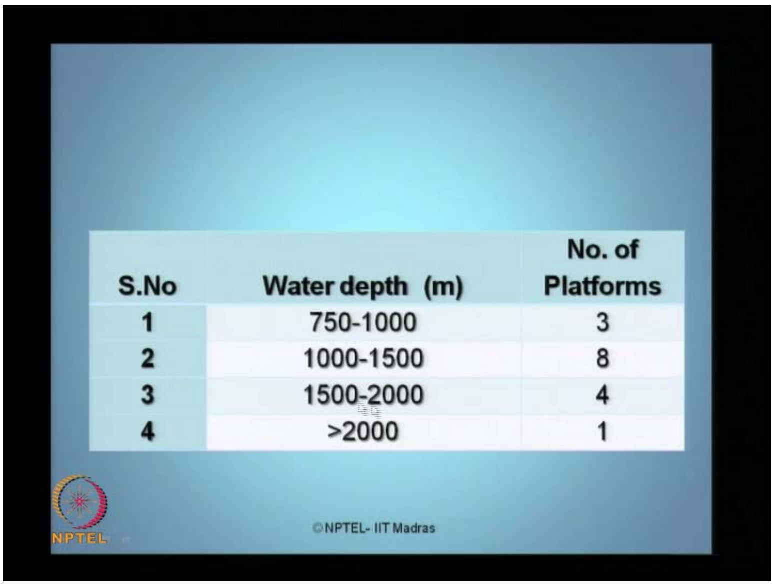
Let us quickly see, briefly, what are these. Classic spar has a cylindrical hull with a heavy ballast at the bottom of the cylinder. Truss spar has a shorter cylinder; we call this as a hard tank. The hard tank will be attached to a truss structure, to which a soft tank will be further attached. The soft tank actually houses the ballast material, which is used for improving the stability, by bringing now, the CG of the spar. This is the most common type of spar being installed in deep waters. The third type of spar is what we call as the cell spar, which is got large central cylinder, surrounded by group of small cylinders of alternating lengths. Soft tank is attached to the bottom of the longer cylinder to house the ballasting material.

(Refer Slide Time: 42:38)



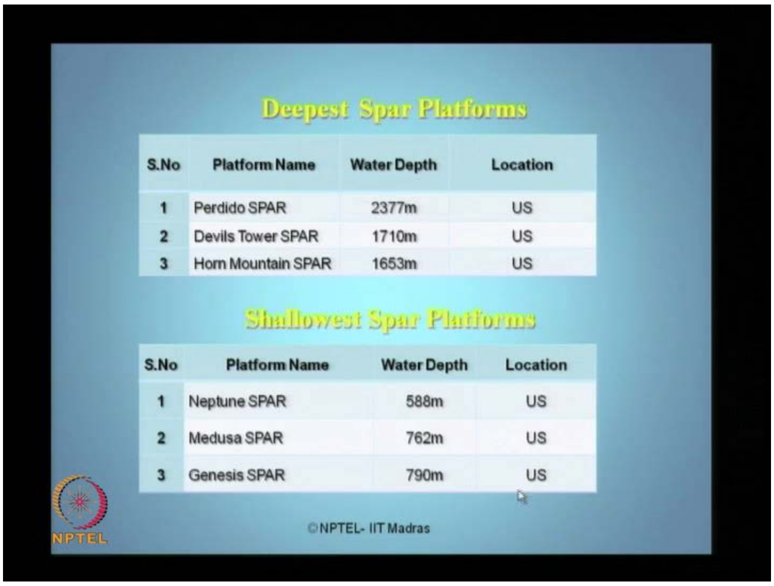
Totally there are 17 spars, constructed in the world. 16 of them surprisingly, are located in the United States. 3 classic SPAR, 13 truss SPAR, and only 1 cell SPAR, so for has been constructed.

(Refer Slide Time: 42:54)



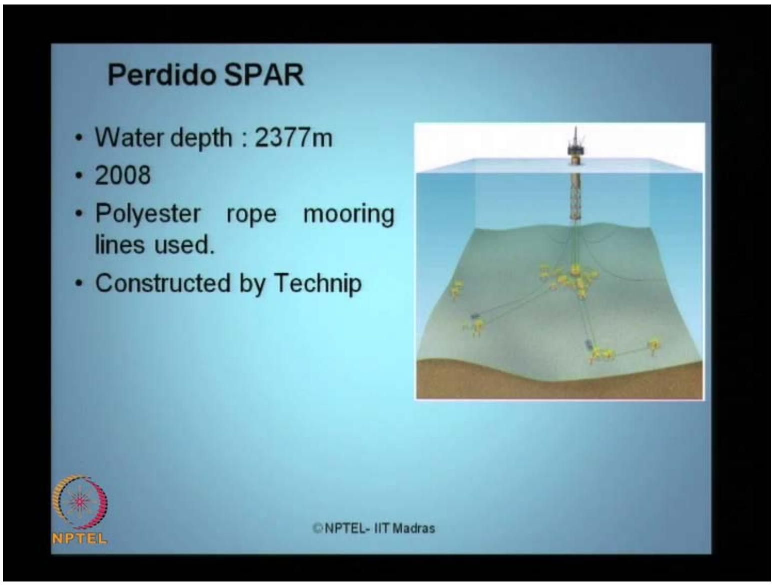
Look at the statistics. Upto 1000 meter water depth, we got a 3 spar platforms; from 1000 to 1500, 8; from 1500 to 2000, 4; and more than 2000, you still have 1 spar platform, which is installed.

(Refer Slide Time: 43:07)



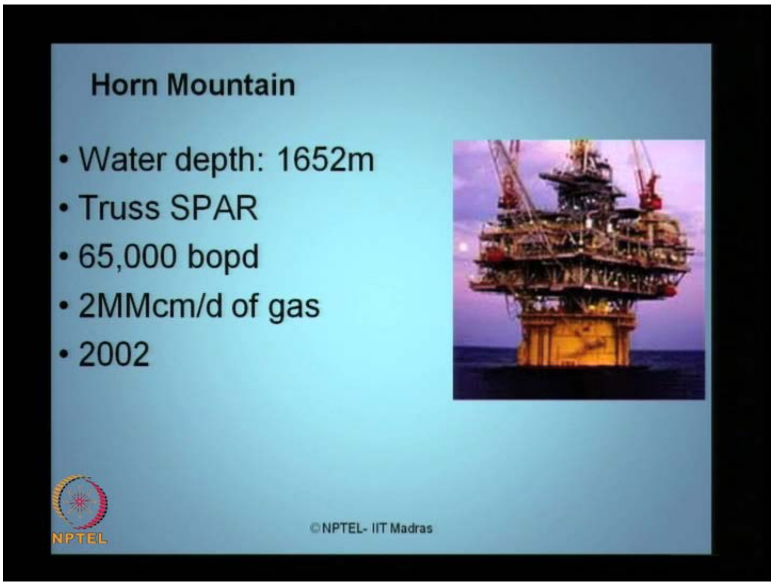
Look at the deepest spar platform. Perdido spar, 2.3 kilo meter deep, located in US. Look at the shallowest platform, Neptune spar about 600 meters again located in US. Ladies and gentleman, interestingly deeper water structural systems, meant for deep sea oil exploration, are essentially focused on the United States only.

(Refer Slide Time: 43:34)



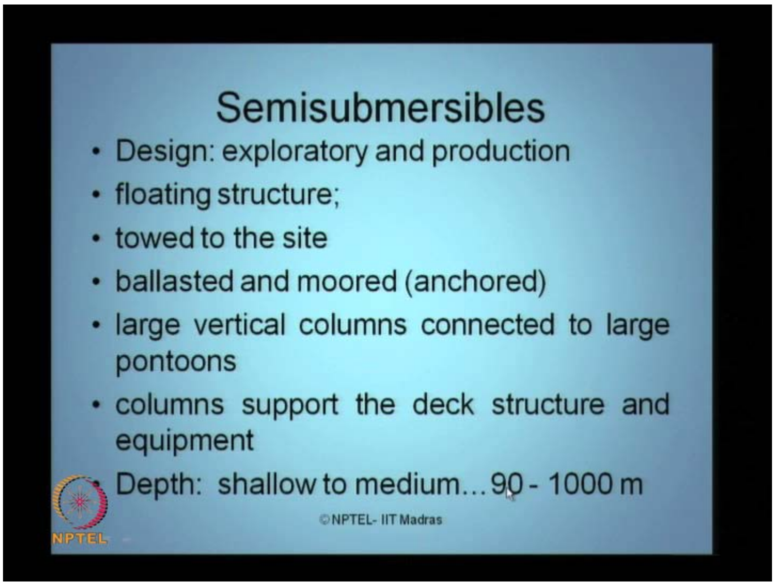
Let us look at the consumption figure, of the perdido spar; is a spar which have the soft anchor and trust of the bottom. The top side as similar to what we saw in other compliant structures. It is installed at the water depth of 2.37 kilo meters; constructed in the year 2008; polyester rope mooring line has been used, in this case; the structure is constructed by a company by name Technip.

(Refer Slide Time: 44:02)



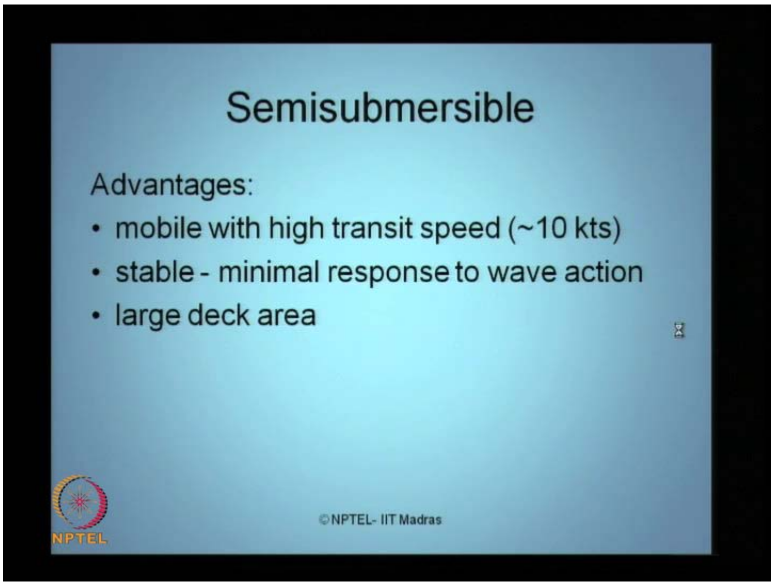
Horn Mountain is another classical example of a spar platform; can see the complicated top side being used in the spar platform. It is situated by the water depth of 1.652 kilo meters; it is the truss spar system; catering to 65000 bopd; 2 MMcm d of gas; built in the year 2002.

(Refer Slide Time: 44:29)



The other classical structure, what we have, is semisubmersibles. I will quickly browse through semisubmersibles on FBSO. We will look into them in detail, in the next lecture. Essentially, semisubmersibles are designed for exploratory and production drilling; they are floating structures; they are towed to the site; they are ballasted and moored, which is anchored to the sea bed, at any specific location; they have a very large vertical columns, connected to large pontoons; columns support the deck structure and the equipment; they generally operate, the water depth from 90 meter to 1000 meters.

(Refer Slide Time: 45:07)

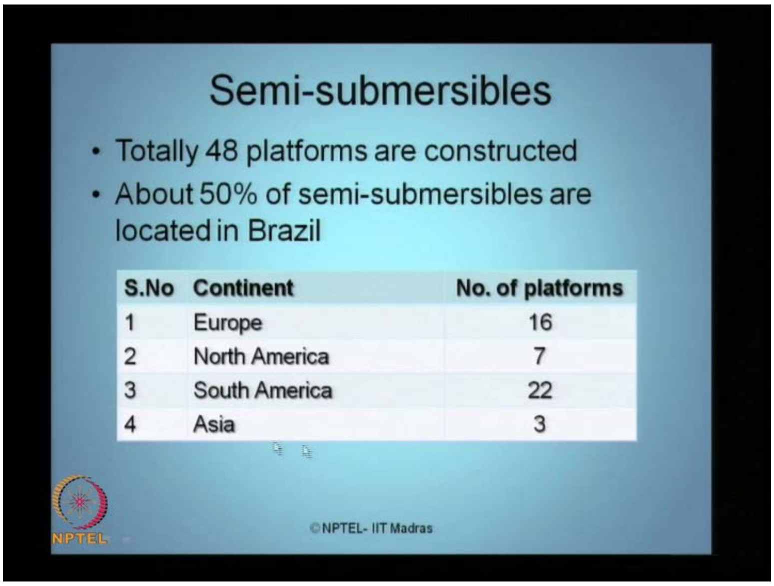


There are many merits of semisubmersibles. Highly mobile; they have a very high transit speed as close as 10 kts; they are very stable; they have a very minimal response to wave action; they have a very large deck area.

(Refer Slide Time: 45:21)

There are demerits of semisubmersibles. They have a very high initial cost, and operational costs are very high. They have limited deck load, actually, because of the low reserve buoyancy. They are generally attacked by, what we call structural fatigue. It is very expensive to flow, or to move semisubmersibles, for larger distances. It is used for limiting dry-docking facilities available. Therefore, maintenance of semi submersibles becomes expensive, because of the limitations in the dry docking facilities available all around the world. It is difficult to handle mooring systems, land BOP stack and riser in rough seas, which are housed on semisubmersibles.

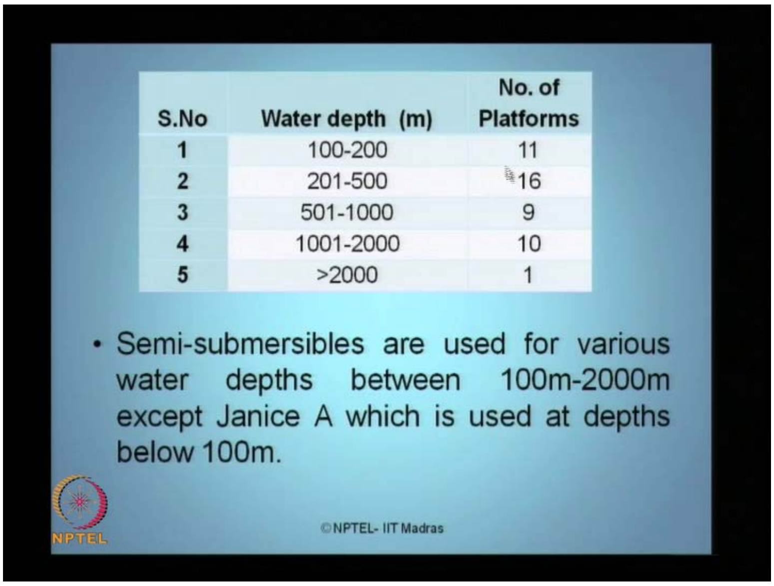
(Refer Slide Time: 46:05)



S.No	Continent	No. of platforms
1	Europe	16
2	North America	7
3	South America	22
4	Asia	3

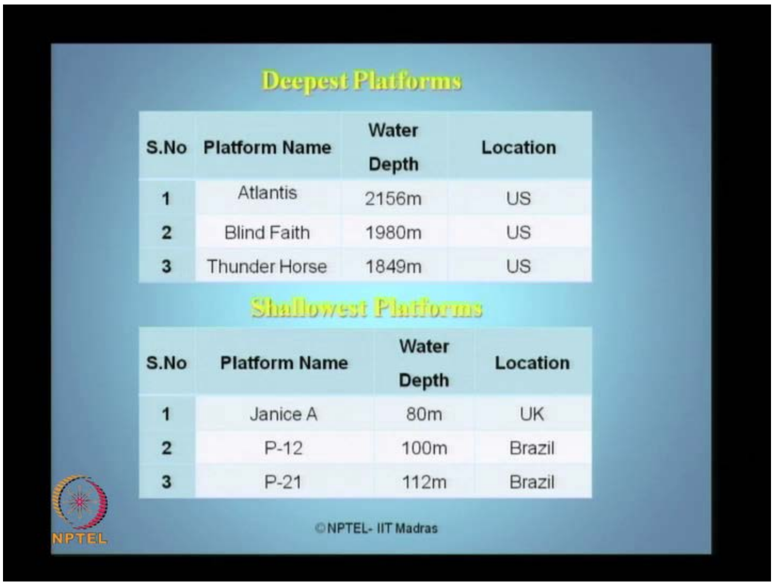
Totally 48 platforms are constructed. More than 50 percent are located in Brazil; Europe has 16; North America has 7; whereas, Brazil, South has 22 platforms of semi submersibles installed; Asia, totally together has only 3.

(Refer Slide Time: 46:22)



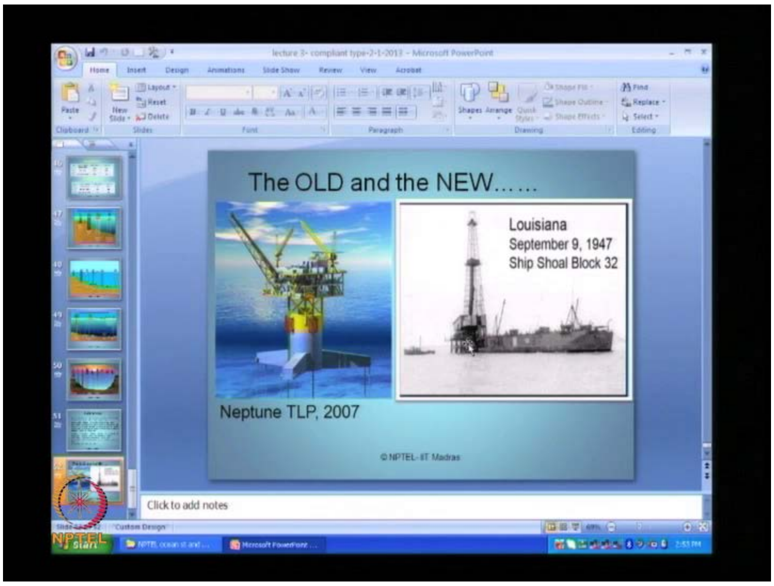
Look at the water depth. More than 2000 meters people have used 1. From 1 to 2 kilo meter deep, people have used 10; of course semi-submersibles are not comfortably used, less than 500 meter water depth, we have got other alternatives structures for this.

(Refer Slide Time: 46:38)



The deepest platform, what we see is Atlantis, located in US; the shallowest platform, what we see, Janice A, located in UK; and Brazil holds, more than 50 percent of semi – submerse population in the world.

(Refer Slide Time: 46:59)



If we quickly compare, the old and the new type of offshore platform, which is been shown in the figure here. For example, Neptune TLP, which is seen on the left side, is attention platform, constructed in 2007. On the contrary, we look at a platform, typically constructed in the year 1947, on September 9. That Louisiana, which is a ship shoal block 2, we can see a (( )) difference between the type of the platform, the geometry configuration, the structural design, the area and depth of the operation, and etcetera. It means offshore industry has grown to grate differences in the past 100 years.

Thank you.