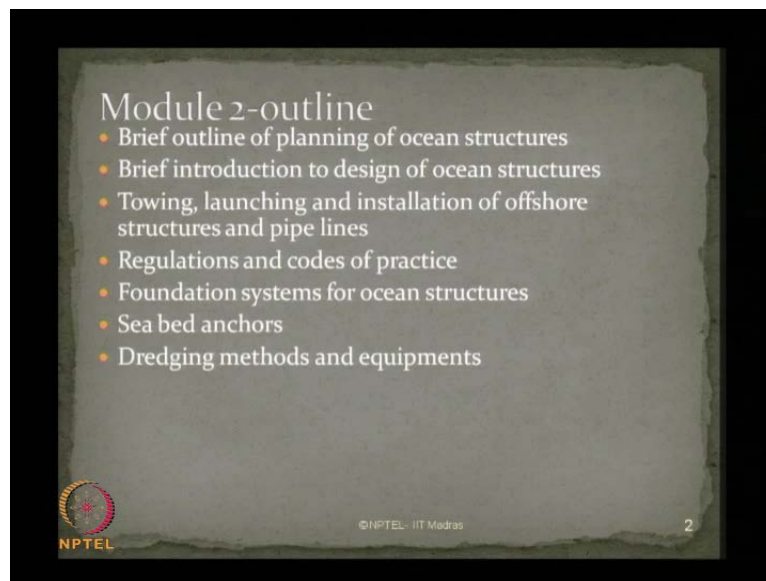


Ocean Structures and Materials
Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

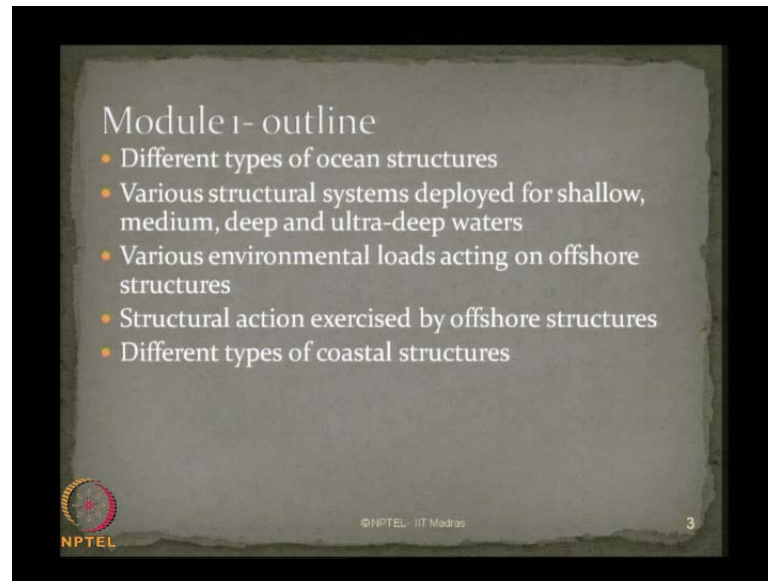
Module - 2
Lecture - 1
Outline of Planning of Ocean Structures

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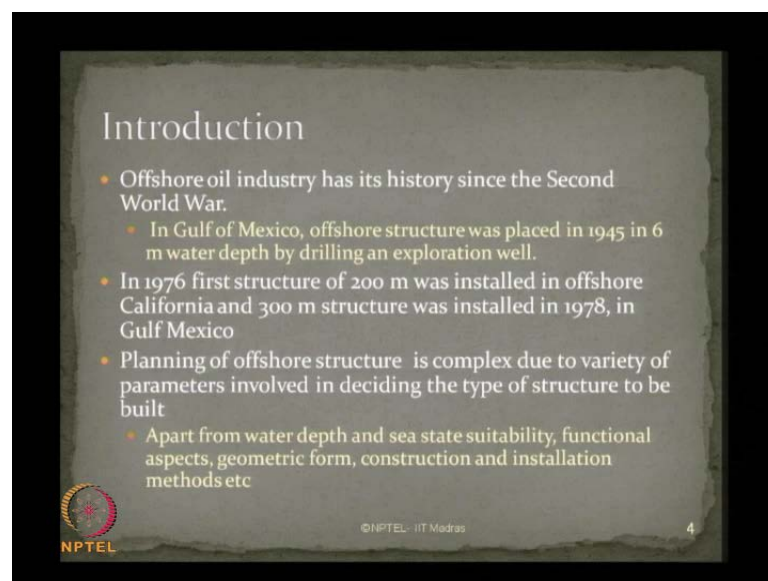
Ladies and gentlemen, welcome to the first lecture on the second module for the course on ocean structures and materials under the braces of NPTEL, IIT, Madras. I hope you have followed the lectures on the first module. In this set of series in the second module, we will look at the following topics. We will speak about brief outline of planning of ocean structures; we will talk about brief introduction to design of ocean structures; we will also speak about towing, launching and installation of offshore structures and pipelines in this lecture schedule. We will talk about regulations and code of practices involve in construction and design of offshore structures. We will speak about different kinds of foundation systems for ocean structures. We will also speak about seabed anchors, dredging methods and equipments in this module.

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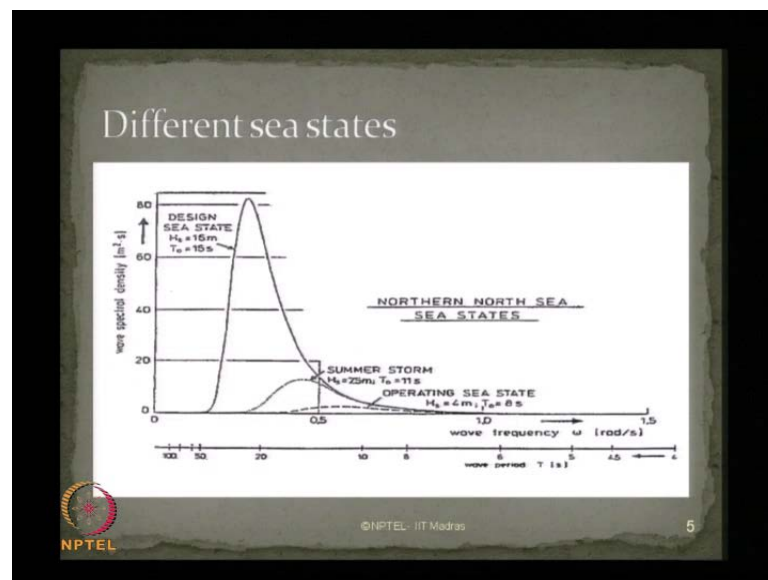
For the benefit of the viewers, let us also look into the outline of module one which we have completed so far. We discussed about different type of ocean structures in module one. We learnt about various structural systems that are generally deployed for shallow water, medium, deep and ultra-deep waters in sea. We spoke about various environmental loads acting on offshore structures. We understood structural action exercised by different ocean structures. We also studied different types of coastal structures in detail in the last module.

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In the present module, in this lecture one of module two, we will speak about introduction, planning and guidelines of offshore structures. Ladies and gentlemen, offshore oil industry has a very old history since the Second World War. In Gulf of Mexico, offshore structure was placed in position in 1945 in just at 6-meter water depth by drilling an exploration well. Followed by which, in 1976, the first offshore structure of 200 meter depth was installed in offshore California and 300-meter structure was installed in 1978, in Gulf of Mexico. The planning of offshore structures is actually a complex procedure; the main reason is, because of variety of parameters involved in deciding the type of structure to be constructed. Apart from the water depth and sea state, suitability functional aspects, geometric form, construction and installation methods keep the selection of structures as a very complex policy in deep-sea systems.

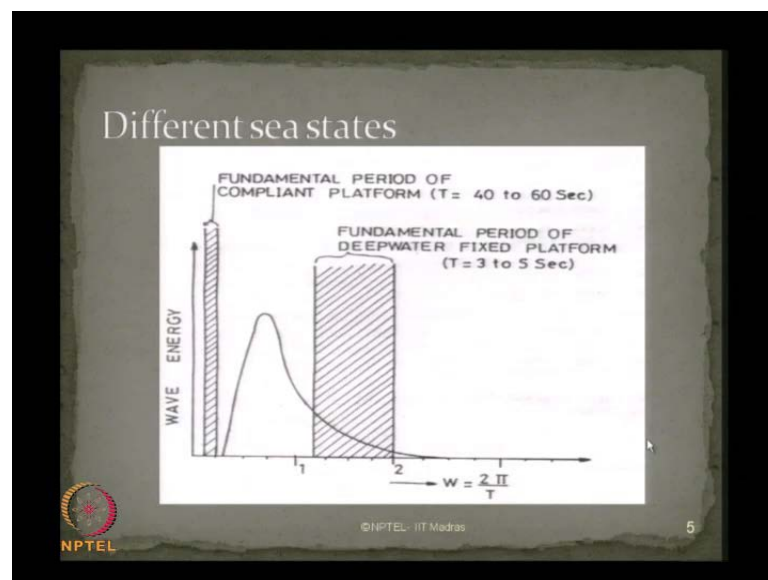
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If we generally look at the different sea states where the structures are deployed, the figure what you see in the screen will show you, the different kind of sea states where they generally deployed. This is a typical curve will shows the northern North Sea states. The x-axis of the curve plots different wave periods in seconds, varying from 4.54 to that of 100. Whereas, the wave speed density or the wave spectral density is varied in the y-axis from 0 to 80. If you look at the wave frequency which is again plotted in the same figure, the wave frequency is vary from 0 to 1.5 radians per second while the wave periods vary as a reverse of this in this order.

Now the design state of significant wave heights 15 meter and about T_z 15 seconds which is the $T_z = 0$ crossing wave period lies somewhere around here in this region, for which a spectral has been shown. Whereas, if we look at the sea states where the summer storm generally occur in gulf northern sea state which has got H_s and T_z as 7.5 meters and 11 seconds. You have the curve, which is plotted here as it is. And of course, the operation sea state in northern sea which has H_s as 4 meter and T_z - 8 seconds looks like this on the same scale. So, there are different sea states varying from 15 meters 15 seconds, 7.5 meters 11 seconds, 4 meter 8 seconds in Northern North Sea states which has been shown here.

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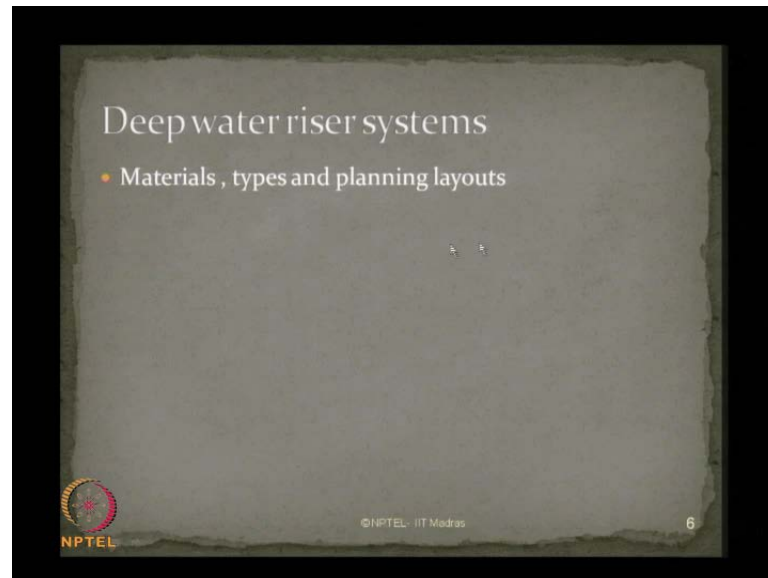


So, generally offshore structures are planned to deploy in different sea states as see in the figure, where the spectral density varies drastically respect to one sea state with that of the other. Alternatively, if you look at the type of platform which is to be installed in the sea states, then the fundamental period of complaint type platforms vary from 40 to 60 seconds, which has been shown in the wave frequency here at a lower frequency. Whereas, the fundamental period of deepwater fixed platforms, which vary generally from 3 to 5 seconds has been shown in this range here.

Now if you look at the input spectrum for which the structure set design, the input spectrum is again super imposed on the same region, where the fundamental period of complaint structure and deepwater platforms or fixed type platforms has been shown.

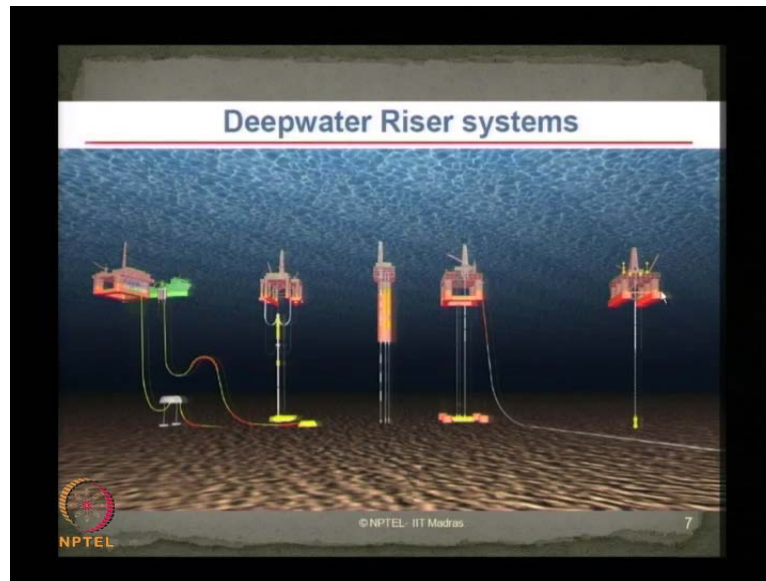
Now on the other hand, alternatively in the y axis, if you see the wave energy or the concentration of wave energy is on the y axis where the complaint structures have been installed or the region where the periods of complaint structures are focused; the wave energy is higher compared to that of the fixed platforms, where the wave energy is relatively lower.

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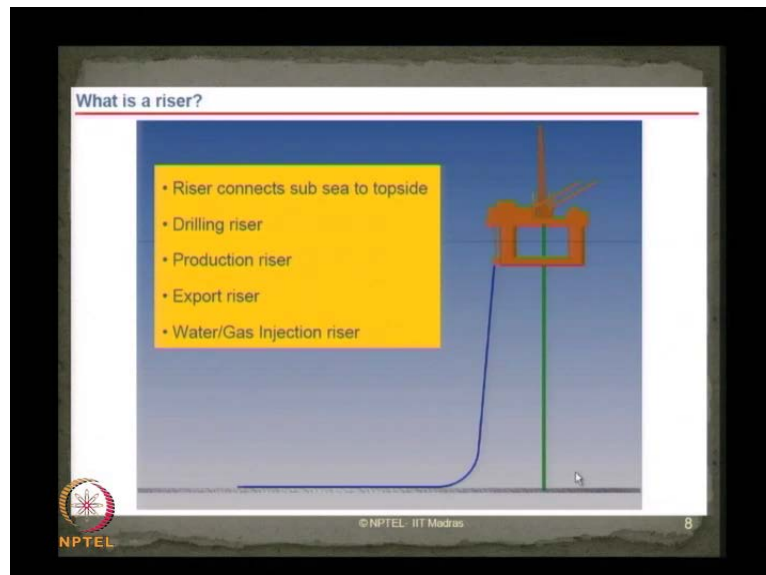
Now, to understand different planning guidelines which are referred to that of deep water systems. One must realize deepwater riser systems, which are important in my discussions here. There is a correction here, one-minute, deep water. So, let us look at different deepwater riser systems as we are now going to discuss. Let us quickly see the different kinds of material, types and planning layouts, which are connected to deepwater riser systems.

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The deepwater riser system as you see in this figure varies from different kinds of platform as you see here. Ladies and gentleman, depending upon the base of understanding in lecture number 5 and 6 in module-1, you will be able to name at least few of these platforms which has been shown here.

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Let us fundamentally ask a question, what do you understand by a riser? Riser actually is a structural member, which connects the subsea to the topside. So, the subsea to the topside is a riser. There can be many risers involved some are meant for drilling, some

are meant for production, some are meant for export risers, some of them for injection risers as a process for exploration. There is something called what are the factors driving the design of risers - the floater type, the floater motions, the water depth, the environmental conditions and the design pressure and temperature are important critical factors which initially drive the design of the risers in deep-waters.

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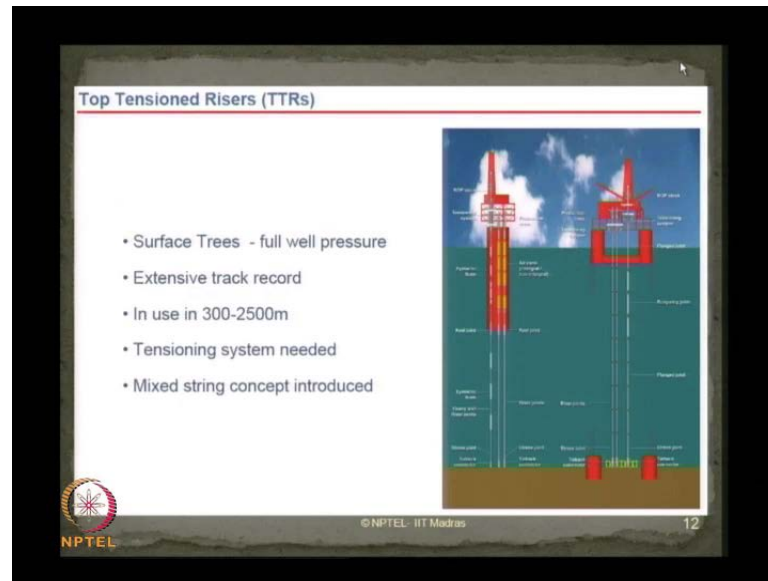
If you look at the deepwater developments in general, there are different kinds of risers which has been provided for different kinds of platforms, which is been housed. This is what we called as an FPSO, which the ship shaped floating system is also meant for explored drilling. You can also linked the platforms like TLP's, TBP's and SPARs which are also meant for production and exploration drilling combined with the top different kinds of platforms together on the same sea state. So, if we look at deepwater developments in general there are many complexities involved in planning these kinds of installations and operations in deepwater.

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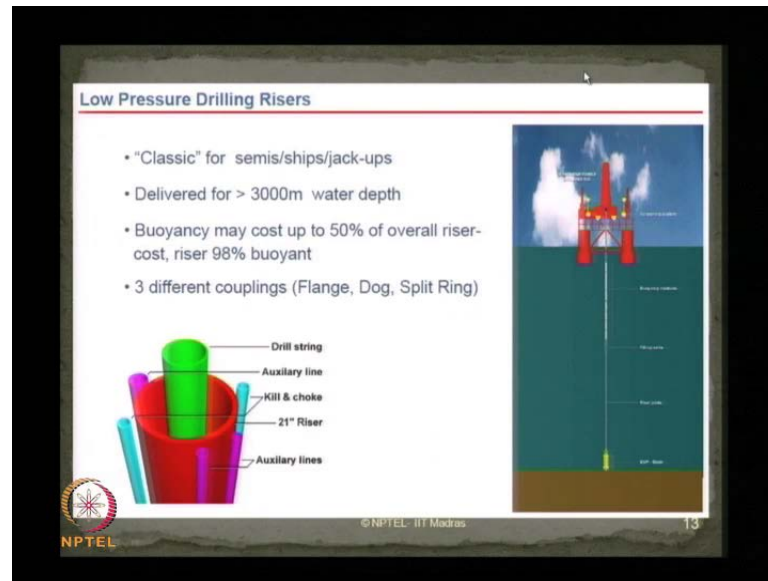
To understand them in detail, the foremost question comes, what are the types of risers which are generally involved in deepwater systems. Talk about drilling risers; typically they are top tensioned risers which is called as TTR in the literature. Production risers are generally a flexible risers, steel catenary risers, they can be hybrid riser towers they can also be single hybrid risers, which is otherwise called SLOR or you can also have grouped SLOR. So, look at the export risers they are similar to that of production risers and these are the different types, which are generally used for export risers. If you look at the injection risers, they are also similar to type of production risers as flexible steel catenary etcetera. So, there are different kinds of risers different types they were generally involved. Essentially the drilling risers are of top tensioned risers, which are unique in nature in comparison to other type of risers, which are used for deepwater systems.

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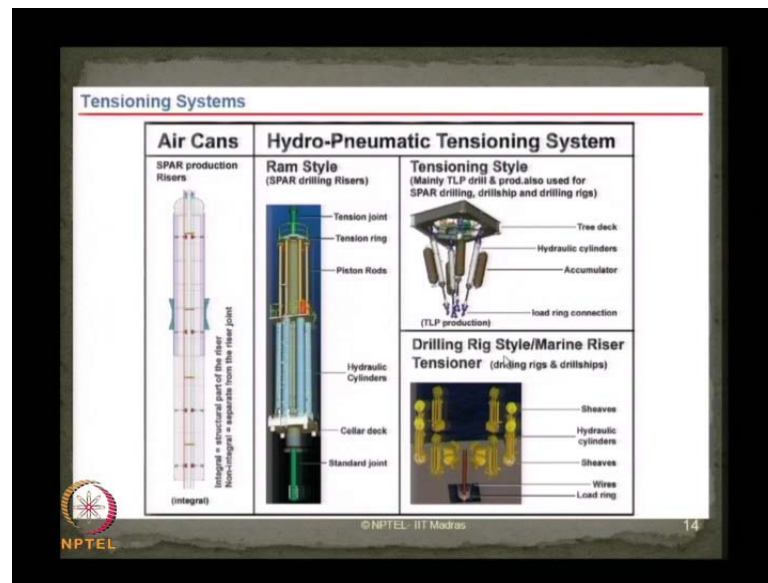
Let us now see quickly, what we understand by top tensioned risers. Briefly associated as TTRs, essentially top tensioned risers are provided with surface trees with full well pressure. They have an extensive track record of being successively deployed in various operational platforms in Gulf of Mexico. They are recommended to be use in a water depth varying from 300 meters to 2500 meter. Obviously, top tensioned risers as the name suggests require a tensioning system which is to be involved or which is to be required to impart tension on the top side of the risers. Now to compensate this alternatively, a mixing string concept of these kinds of risers have been introduced in the design stage of top tensioned risers. The photograph what you see here are two typical examples of different kinds of platforms which are employed in top tensioned risers for production drilling.

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If we look at the pressure involved in drilling risers, if you focused closely on low pressure drilling risers, they are classically used for semi-submersibles, drill ships and jack-up drills. They are generally being used for water depths much more than 3000 meters. Essentially the governing factor for this kind of low pressure drilling risers is that the buoyancy may cost about 50 percent of the overall riser cost, which makes the riser 98 percent buoyant. There are three different couplings, which has been used in this kind of risers, which are otherwise called as flange, dog, and split ring couplings. If you look at a typical cross section of a low-pressure drilling riser, the drill string, which you see here is at the core which has got auxiliary strings or auxiliary lines around it and there are some parallel lines which are otherwise used to kill or choke the well they are called as kill risers. Generally this risers are about 21 inches in diameter and there are otherwise auxiliary lines which are subsequently present along the periphery of the core risers as you see in the figure.

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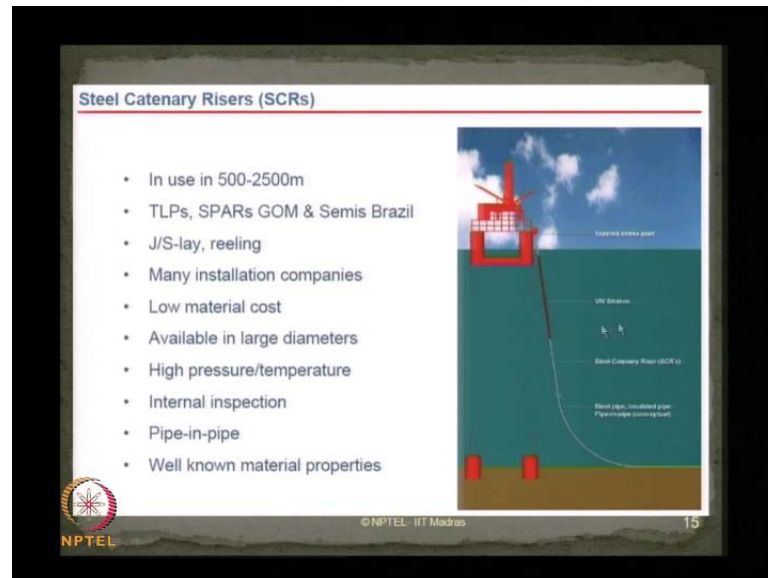


If you look at the different kinds of tensioning systems, which are generally deployed for top tensioned risers in production risers of deepwater drilling systems, can have air can system or hydro-pneumatic tensioning system which both are commonly deployed in deepwater rising systems. If we look at air can system SPAR production risers are essentially fall in this category of tensioning systems. If you look at hydro-pneumatic tensioning system, generally they are use also for SPAR as well as for drillship and drilling rigs and as well as for TLP. Essentially the tensioning style is mainly used for TLP drilling and production, which also used for SPAR drilling, drill ships and drilling rigs.

If we look at the Ram style which is one of the hydro-pneumatic tensioning system which is used in case of SPAR drilling risers. It essentially consists of a tensioning joint and the tension ring, and the piston rods circumferencely attached to the casing of the tension ring, which is subsequently connected to the hydraulic cylinders at the bottom, which is housed on the cellar deck and which results in a standard joint as you see in the RAM style connection of hydro-pneumatic tensioning system. Alternatively TLP is used a tensioning style which is slightly different from that of the RAM style, where there is a tree deck on the top which has got hydraulic cylinders placed and mounted in a different angle which is supported by accumulators parallelly attached to this stage of cylinders. They are all connected to a load ring connection which is then further connected to a TLP production riser. We can also see a drill rigs style marine riser tensioner which is

commonly used for drilling rigs and drill ships. You can see here there are different set of sheaves, which are connected to the hydraulic cylinders and then subsequently there are housed on a load ring where this is further connected to my drilling rig system.

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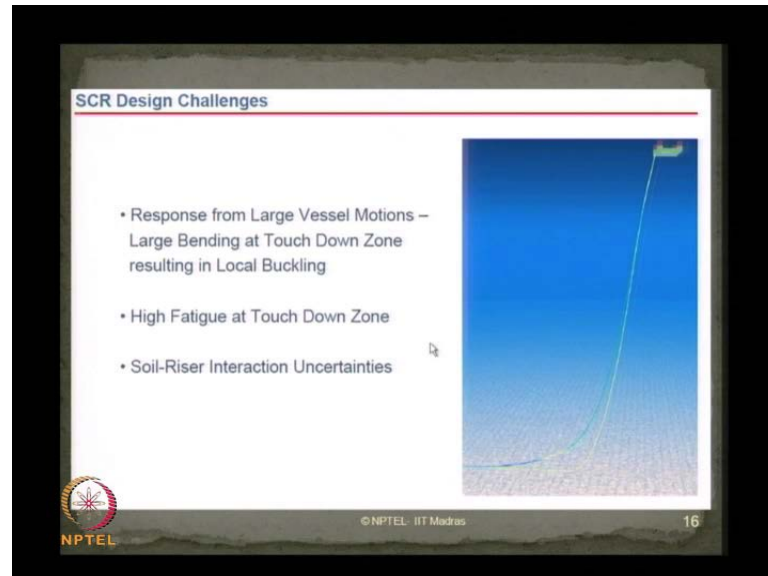


In detail, we look at another type of drilling riser, which is steel catenary riser, which is addressed as SCR in the literature. This is generally connected to that of a TLP where there is a tapered stress joint, which is connected to the top side of the production platform from where the riser is connected to the drilling units. Now there are different VIV streaks because this are the regions where the vortex induced vibration will be severe and this segments of the riser are reinforced by streaks which are called VIV streaks in the design itself. The steel catenary riser essentially consists of a steel pipe insulated pipe or a pipe-in-pipe conceptual system. This is successfully being deployed at a water depth from 500 meters to 2500 meters. They are generally used in TLP's, SPARs in Gulf of Mexico and semi-submersibles in Brazil.

They can be different kinds of laying system like J and S lay system or even by a reeling system. Many installation companies do practice installation of steel Catenary risers as a very interesting methodology. They have a low material cost available also in large diameters, and they can sustain high temperature and pressure, and they can be subjected to internal inspection. Pipe-in-pipe is a very common system of steel Catenary riser which has been commonly deployed, in Gulf of Mexico. They are well known with

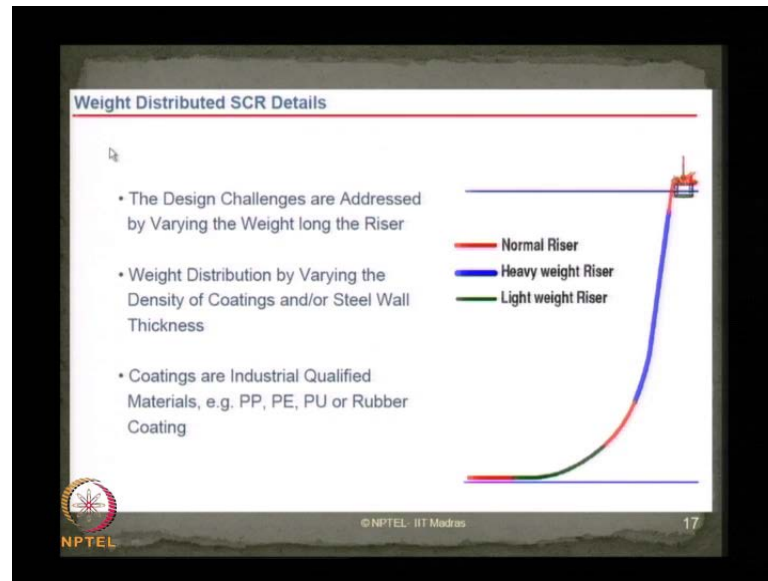
different kind of material whose material characteristics or properties are well established in the literature.

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There are some design challenges related to steel catenary risers, when this kind of risers are attached to large vessels which has got large vessel motions then they result in large bending at the touch down point. Ladies and gentlemen, the point where the riser touches the seafloor is called the touchdown point or the touchdown region. Generally, at the touchdown region, it has got subjected to large bending at the touchdown zone, which results in local buckling of the riser. These risers are also unfortunately subjected to high fatigue at the touch down zone; therefore, they became the critical failure point of these kinds of risers. The soil-riser interaction uncertainties, causes additional complexity and imposes a very serious design challenge to these kinds of risers.

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Therefore, there is something called weight distributed steel catenary riser detail which generally done in case of deploying it to overcome the design challenges what you saw in the last slide. This is the typical case where different kind of weight distribution has been occurred along the profile of the riser. The red color what you see here is the normal riser, which comes from the initial point in the top side to that of the touchdown zone on the sea floor. To this riser at different locations, heavy weights like as you see in blue color or light weights as you see in green color are attached to the riser. The design challenges what you saw in the last slide are addressed by varying the weight along the profile length of the riser.

The weight distribution is generally carried out by varying the density of coatings or even the steel wall thickness of the riser. The coatings are generally industrially qualified material like PE, PP, PU or rubber coatings which are generally and commonly used. These coatings and steel wall thickness of the risers vary the weight along the riser length profile which is otherwise called weight distributed steel catenary risers. These kinds of risers when weight is distributed along the length of the riser are able to overcome few design challenges as we mentioned in the last slide.

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Flexible Risers

- Extensive track record (85% of all dynamic risers are flexibles)
- In use in 2000 m
- Large installation vessel fleet available
- 3 main suppliers
- Easy to install
- Flexible - robust, high dynamics
- Corrosion resistant/reusable
- Pipe-in-pipe/heated under development

Flexible Pipe cross-section layers:

- Carcass
- Internal fluid barrier
- Hoop stress layer
- Tape
- Armour layer
- Tape
- Armour layer
- Tape
- Outer shield

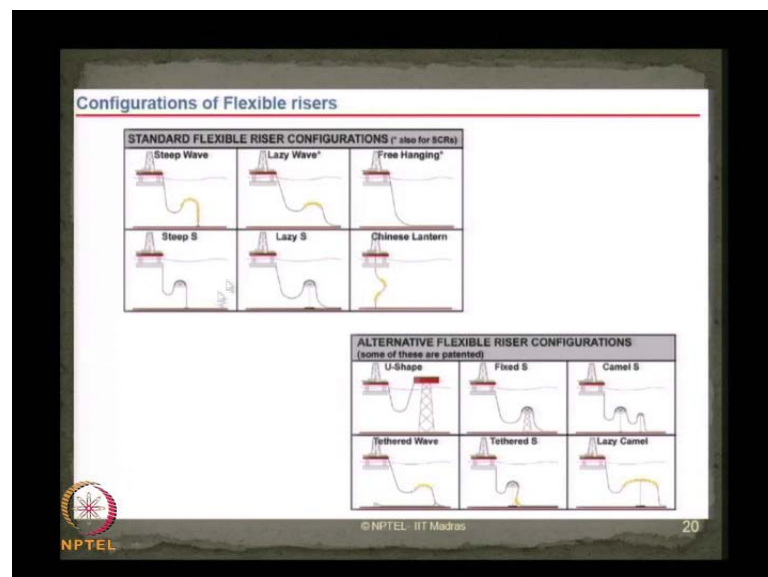
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The weight distributed steel catenary riser details are generally used in different kinds of platforms. There are some alternative to SCR's which are currently available in the market which is called flexible risers. Why we are discussing about this kind of risers is that when you talk about design and planning of installation of offshore structures, I must know one of the most important challenges of what are the different kinds of riser material available in the market, and what is the adaptability to use them in deep water systems.

Let us look at the flexible risers. A flexible riser has got a hybrid combination of different material as you see in the cross section here. It is got an extensive track record of about 85 percent of these kind of risers are generally used to sustain dynamic loads. In general, these kind of risers have been started being deployed in deep waters of laid even the depth of 2000 meters. They are also available for large installation vessel fleets in large volumes and numbers. There are only mainly three main suppliers available in the world who can prepare these kinds of flexible risers. They are very easy to install; they are highly flexible and robust for high dynamics; they have intensive corrosion resistant properties, and they have a very great advantage of reusability. Generally, the concept is they have got different pipes which are concentrically connected as you see in the cross section. These pipe-in-pipe systems are heat-treated and developed for a specific use.

For example, the inner core what you see here is a carcass material surrounded by which we are what the hoop stress layer, which is surrounding the outer layer of that. The carcass layer is surrounded by the internal fluid pressure which you create around the circumference of this riser. The hoop stress layer which is reinforcing circumferential riser or the flexible riser is then covered by a tape. To protect this riser from exterior damage then followed by this covering thus an armor layer is available in two layers which are again further coated and covered by a tape and which comes with an outer shield. So, the entire flexible riser is thoroughly protected, and this becomes completely corrosion resistant and easily reusable. At the same time, they can be used for large installation fleet vessels which are now commonly been deployed at a greater depth more than 2000 meters water depth.

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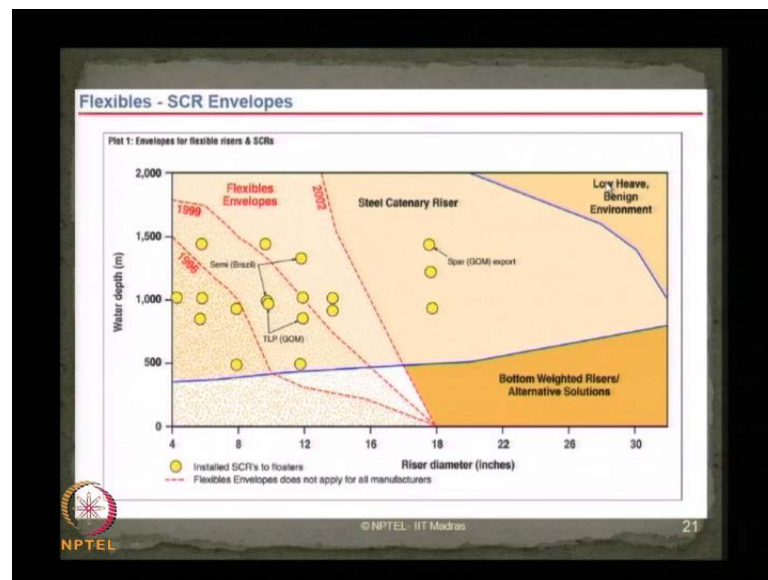


There are different kinds of configurations of flexible risers, which one must understand before selecting what kind of laying I must use for these kinds of risers. The standard flexible riser configuration is also called as SCR, which is used for steel catenary risers. Can I have steep wave configuration, can I have lazy wave configuration, the steep wave is a shape given according to the riser configuration as you see in this figures. The lazy wave does not follow a vertical line as you see in this steep wave, this is what we called free hanging configuration. There is no bent in-between the profile of the riser. If the riser has a profile bent similar to s, this is otherwise called as steep s, because this

configuration initial is comparable to that of steep wave configuration, and the bent up shape is indicates s in its geometry.

If this s bent up shape is comparable to that of a lazy wave then it is called lazy s. We also something called have a lantern shape, which is called Chinese lantern riser configuration. The alternate flexible riser configurations, these are all standard riser configurations. Can also have alternative flexible riser configurations, some of them are highly patented and being used in Gulf of Mexico in US. People have support system for the risers which are called u shape, fixed s shape, camel s shape, tethered wave shape, tethered s shape, and a lazy camel shape. These are all specific kind of geometric shape of risers which have been used for flexible risers mostly in deep water layouts.

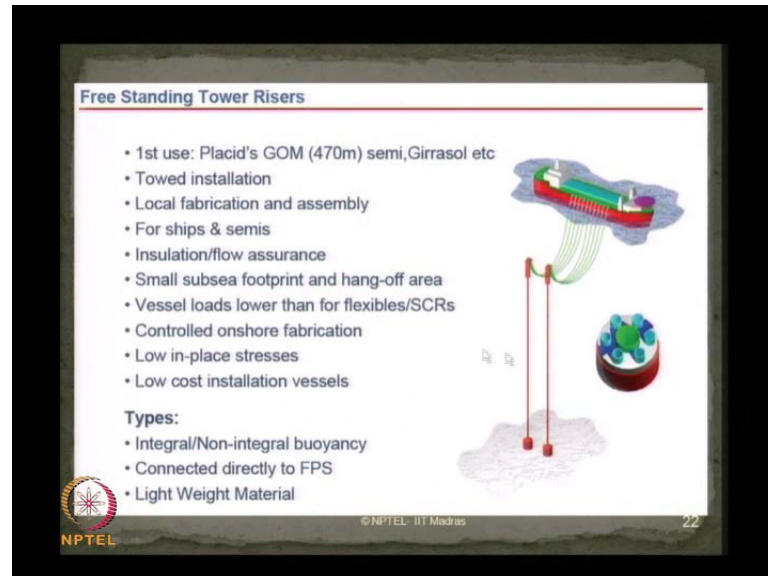
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If we look at different kinds of flexible where the steel catenary riser envelopes have been deployed. So, there is a figure we shows, the riser diameter expressed in inches against the water depth in meters where they have been installed. If we look at as the riser diameter goes larger and larger, we try to use steel catenary risers for SPAR essentially in Gulf of Mexico, where the water depth varied from about 500 meters to around 1700 meters. Whereas still 2002 are starting from 1996, the riser diameters usually restricted to only 18 inches. Now the larger diameter risers have been used essentially when they have got bottom weighted risers which are seem to be alternate solutions for deepwater risers. Of course one can use low heave, benign environment can

use larger diameter for deepwater layout where the depth of installation can even touch 2000 meters as you see in this figure.

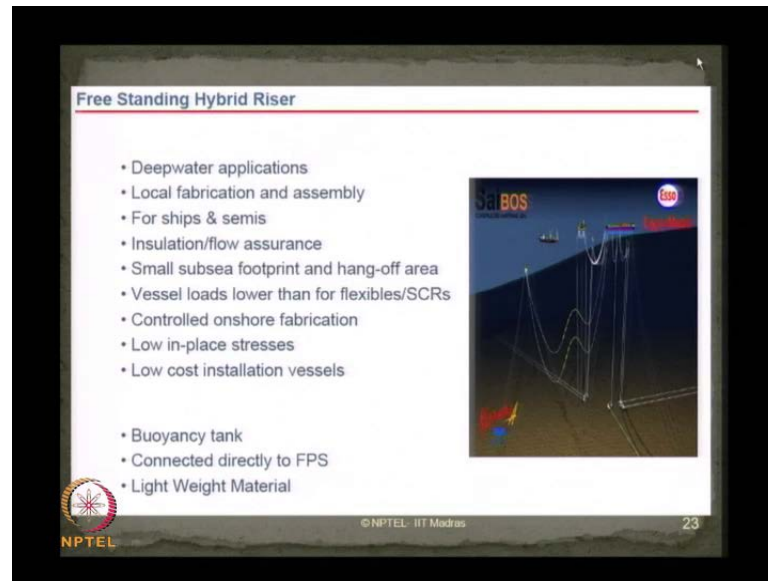
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Now, alternatively to SCR, we have something called free standing tower risers, where the risers are generally supported as you see in the figure here. The first use of these kinds of free standing tower riser has been done in Placid's Gulf of Mexico. The depth of 470 meters from the semi-submersibles in Girrasol. The towed installation is what you see here is an animated figure. It is got a local fabrication and assembly; it is can be recommended for ships and semi-submersibles. The insulation and flow assurance are the more comfortable, and more supportive for deepwater installations. The small subsea footprint and hang-off area are seem to be a great advantage of these kinds of risers, because these risers leave only a very small kind of footprint on the seafloor.

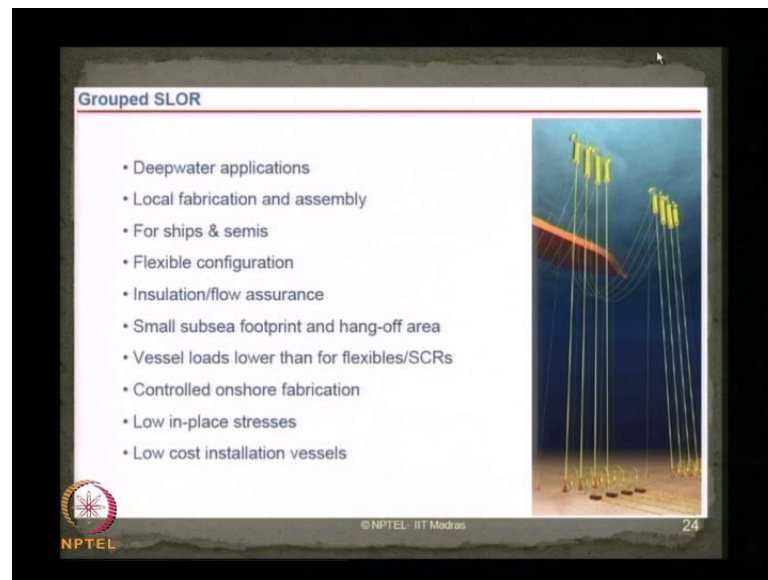
The vessels they can load lower than the flexible and SCR, they have controlled onshore fabrication; they have low-in place stresses, because they have got tower type supporting system of the risers. They have of course, low cost installation vessels to be used for deploying these kinds of risers. Generally, the different types used for free standing tower risers are the following; they have got integral, non-integral buoyancy type. They are connected directly to FPSOs and FPS. They use generally lightweight material therefore, the riser configuration and the laying of riser with this can support system or the tower support system becomes easy and simple.

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We can also have free standing hybrid risers as you see in this photograph here. They are generally used for deepwater applications. They also have a local fabrication assembly, which uses this kind of hybrid risers for deep waters. They are very well suitable for drill ships and semi-submersibles. They have insulation and flow assurance characteristics which are highly beneficial for deepwater installations. They also leave very small subsea footprint and hang-off area as see in the figure. The figure what you see here is the riser and these are all the tower supporting system, and they leave very small footprint on the seafloor compared to other kind of conventional risers. They also have controlled onshore fabrication, and low in-place stresses which has been measured by analytical studies by different researchers. It has been also seen, they have got low cost installation vessels being required for commissioning these kinds of risers in deep waters. They are useful for supporting systems like buoyancy tanks. They are connected to FPS directly, and they use generally lightweight material therefore, the installation becomes simple and easy, because they have tower supporting systems, which are used for installing these kinds of risers.

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Grouped SLOR

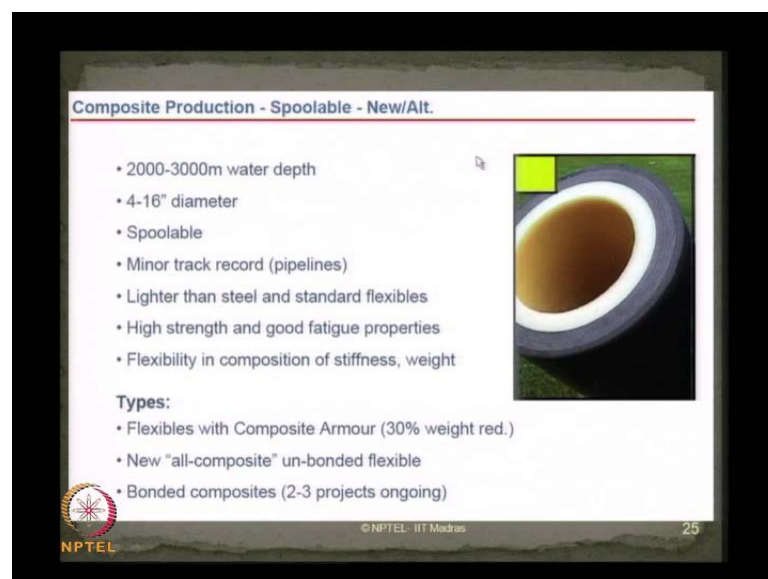
- Deepwater applications
- Local fabrication and assembly
- For ships & semis
- Flexible configuration
- Insulation/flow assurance
- Small subsea footprint and hang-off area
- Vessel loads lower than for flexibles/SCRs
- Controlled onshore fabrication
- Low in-place stresses
- Low cost installation vessels

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The slide features a 3D rendering of a grouped SLOR system, showing multiple risers connected to a central platform structure on the seabed. The risers are depicted as vertical lines extending upwards, with a central platform structure at the top. The background is a dark blue, representing the deep water environment.

You also have something called grouped SLOR risers, where you can see the risers in the tower supporting system are grouped in one and from there they have been used for different kinds of wells as you see here further. These kinds of grouped systems are generally recommended for deepwater applications, they have a local fabrication assembly, which are well suitable for drill ships and semi-submersibles. They also have low in-place stresses and the low cost installation vessels, makes these kinds of riser installation more economical.

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Composite Production - Spoolable - New/Ait.

- 2000-3000m water depth
- 4-16" diameter
- Spoolable
- Minor track record (pipelines)
- Lighter than steel and standard flexibles
- High strength and good fatigue properties
- Flexibility in composition of stiffness, weight

Types:

- Flexibles with Composite Armour (30% weight red.)
- New "all-composite" un-bonded flexible
- Bonded composites (2-3 projects ongoing)

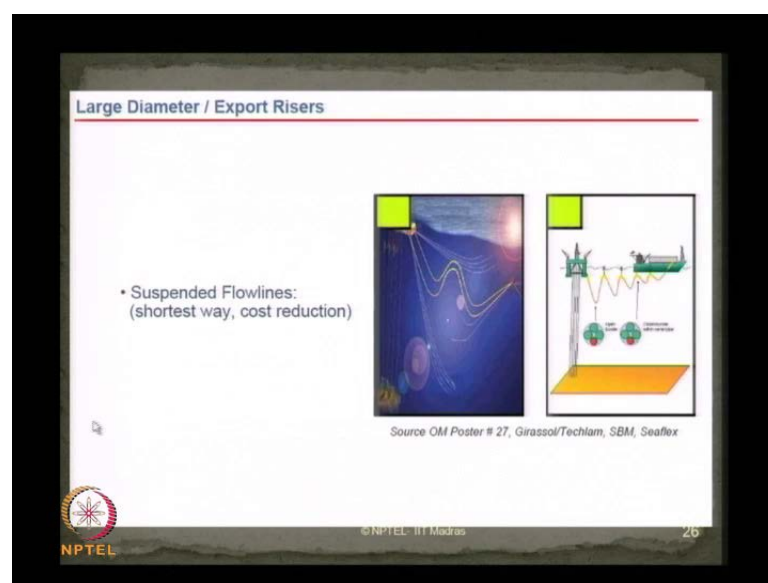
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The slide includes a photograph of a large, spoolable composite pipe section. The pipe is shown in a cross-section, revealing a dark outer layer and a lighter inner core. The pipe is coiled, demonstrating its flexibility and spoolability. The background of the photo is a green field.

In the recent times, people have attempted to use composite production spoolable as a new alternative type of riser. This is a composite material which is being used as a riser material which is the recently being done for depth of about 3000 meters water depth. They can vary have a diameter from 4 to 16 inches, and they are essentially spoolable. So, transporting these kind of risers for installation location on a drill ship or in a (()) is simple, because these kind of risers are highly flexible in a form sense, they can be spooled off and they can be transported.

The minor track record of these kinds of pipelines is one important merit for using these kinds of production risers. They are lighter than steel, and they are standard flexible; they have high strength and very good fatigue properties, and the flexibility in composition of stiffness and weight suits these kind of risers for deep water application up to about 3000 meters. There are different types of these kinds of risers available; they are flexible risers with composite armor that is 30 percent weight reduction happens because of the armor composition in the flexible configuration. New all composite risers are also available using un-bonded flexible risers, you also have bonded composites where two-three current project in Gulf of Mexico are being using this kind of composite risers where the weight of the riser is further reduced and make it flexible. So that these risers are viewed larger diameter can be easily spooled off to be transported from one location to another for installation.

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We look at large diameter export risers, because we need to transform or transport the oil or the Gaseous connections from the vessel to an offshore facility or from the satellite vessels to the main production facility. We need export risers essentially these kinds of risers are suspended flow lines as you see in the figure here. There are usually suspended flow lines, for example, I have a TLP which is having a production riser, I want to transport the crude oil accumulated in this production platform to my bar or my drillship or my storage facility, where I use this kind of export risers where essentially these kinds of risers are suspended flow lines as you see in this photograph here. So, in this lecture we discussed about different kinds of riser configuration, different kinds of types of material being used for offshore riser configuration, and they will be helpful for planning the layout of this kind of risers in deepwater drilling facility.

Thank you.