Advanced Marine Structures
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Lecture - 2
Fixed type structures

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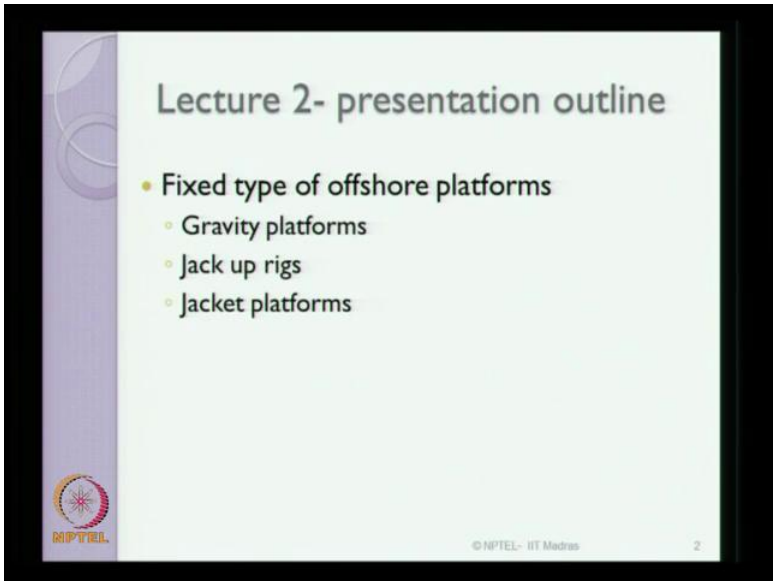

Welcome to the second lecture, on the first module of the course on advanced marine structures. In the last lecture, we discussed about the introduction and the scope of the specific course and different modules; what will be covering in this course. In this present module, we will talk about fixed type of offshore platforms, where we discuss gravity platforms, jack up rigs and jacket platforms. Ladies and gentlemen, this is very important for us to understand different types of marine structures first, so that we understand the structural form and the response behavior of these in general.

In physical terms before we understand, how to compute the ultimate load carrying capacity and the plastic analysis of these kind of structural systems. So, under this background we will talk about fixed type marine structures in this specific lecture.

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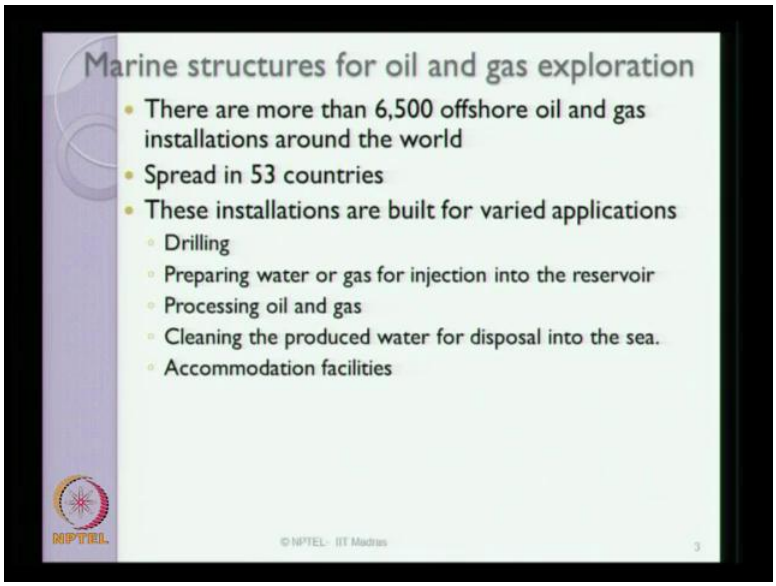

Now, marine structures are basically the structures, which are meant for oil and gas exploration. There are more than above six thousand five hundred installations, which are done around the world. They are spread in about fifty three countries; these installations are generally built for varied applications and uses. For example, some of them are built for drilling, some of them are meant for preparing water or gas for injecting into the reservoir.

For improving the recovery or the production rate of the reservoir, some of these platforms are also meant for processing the oil and gas being explored from the sea. Some of them are also constructed for cleaning the produced water before the dispose into the sea.

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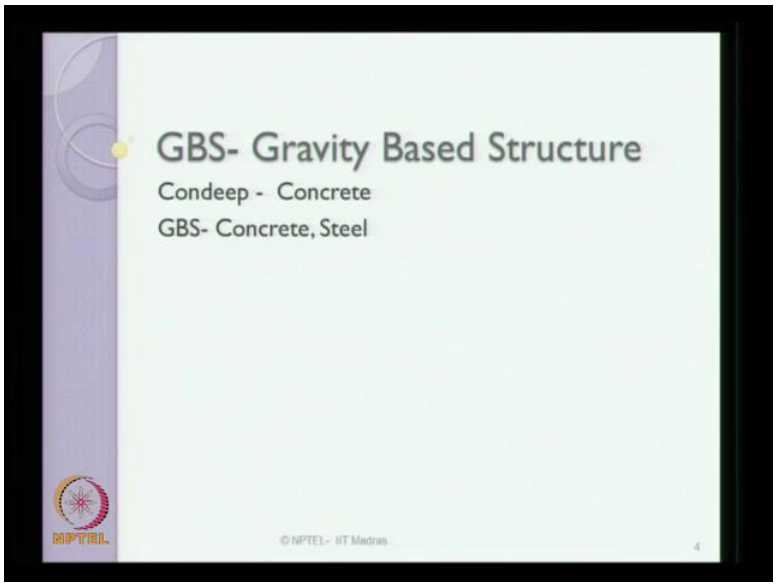

Of course, these platforms also accommodate lot of residential quarters, what we call them as accommodation facilities. So, marine structures in general are meant for many varied applications as you see in this slide. Amongst these let us talk about the first of its nature, what we call gravity based structure abbreviated as GBS. Now, the gravity based structures are essentially constructed with concrete as a construction material. For example, condeep is one such platform constructed in concrete. Gravity based structures can also be constructed in steel. But essentially most of them are popularly constructed using concrete as a construction material.

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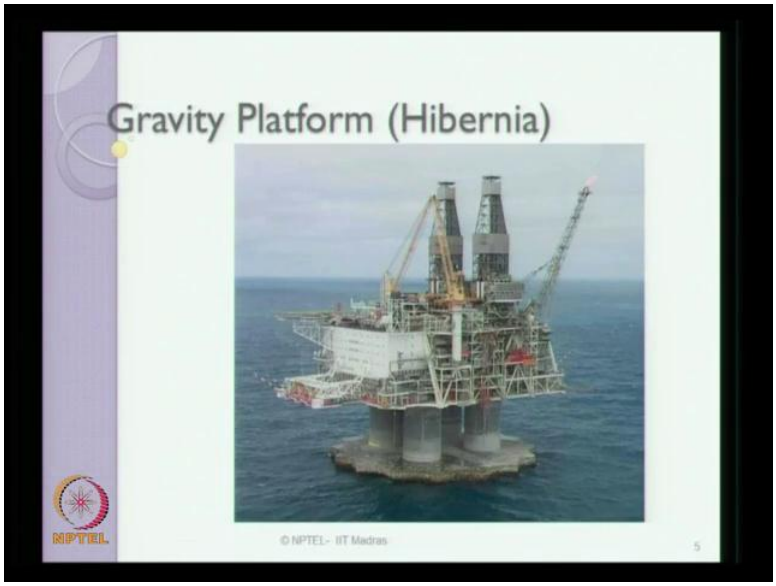

One classical example of a gravity platform as on today is Hibernia platform. The photograph of platform is shown in the slide now for the readers.

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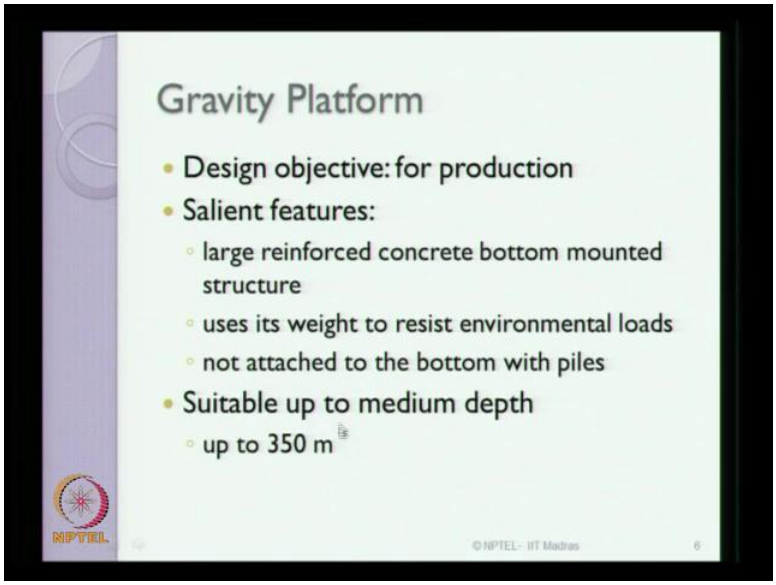

Gravity platform are essentially constructed for oil production that is the design objective. Now, let us look into the salient features of this platform. Essentially, these kinds of platforms are large reinforced concrete bottom mounted structure. Essentially, they are very massive and the construction material is reinforced form. It uses its own self weight to resist environmental loads. Remember, that these kinds of platforms rest on the sea floor in their self weight. That is why it is called bottom mounted structures.

Therefore, they are not attached to the bottom with piles. There are no requirement of piles on which these platforms will rest. These platforms will directly rest on its self weight on the sea floor. They are essentially suitable to medium depth up to let us say three hundred and fifty meters that is where people have attempted to construct gravity based structures in the literature.

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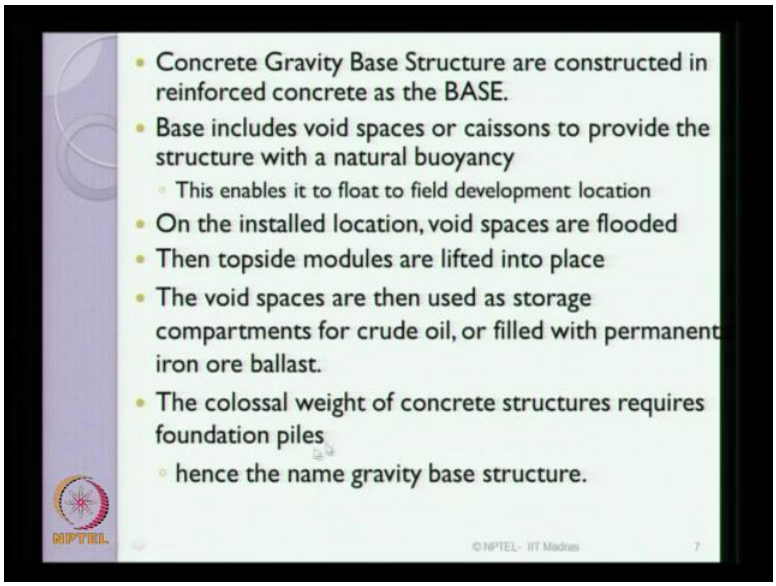

Concrete gravity base structures are constructed with the reinforced concrete as the BASE. The BASE includes void spaces; otherwise, what we call them as caissons. They are essentially used to provide the structure with natural buoyancy. This enables the structure to float to the field development location, when they are void or when they are empty. Once they reach the installation side, these void spaces are flooded with water.

Then the topside modules are lifted and placed in position. The void spaces are then used as storage compartments of crude oil or sometimes they are permanently filled with iron ore or any other ballast material. The colossal weight of concrete structures requires no foundation piles. Therefore, the name gravity base structure is given to these kinds of platforms.

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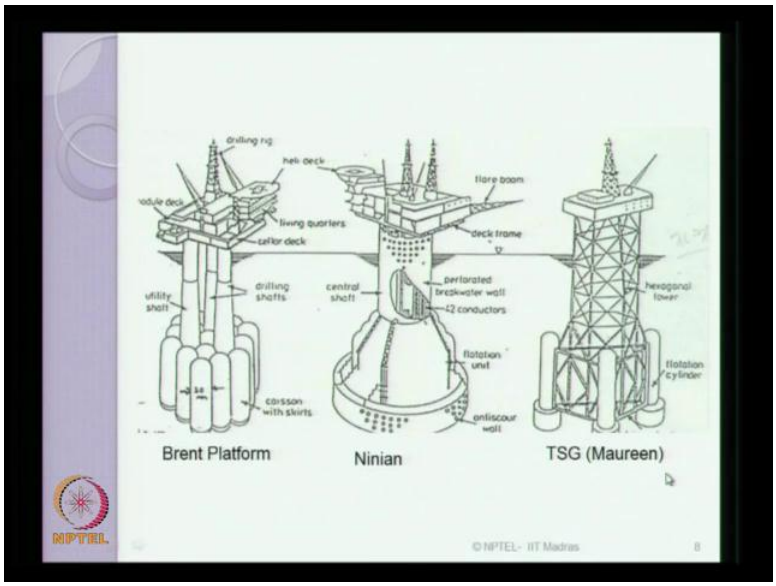

There are different varieties of structures constructed, which you can see from the literature. Brent platform, the Ninian platform, the TSG or the Maureen platform. Can see more or less the form, which is being used for constructing gravity base structures are similar. The topside details are almost similar in most of these platforms, which essentially contains the drilling ring, the module desk which are meant for drilling, production, exploration etc. These are the living quarters and of course the living quarters also how this is on the top generally and helideck for landing purposes of the people.

Now, the cellar deck is what is acquired also, which we seen in almost common in all the cases. For example in the Ninian platform we can see the helideck is projected out in one extreme corner. The similarity, amongst these kinds of platforms is been constructed is a very large massive case, which you can see in all the three cases. Because of its colossal self weight and massive structure; these kinds of platforms generally rest on the sea bed on its self weight.

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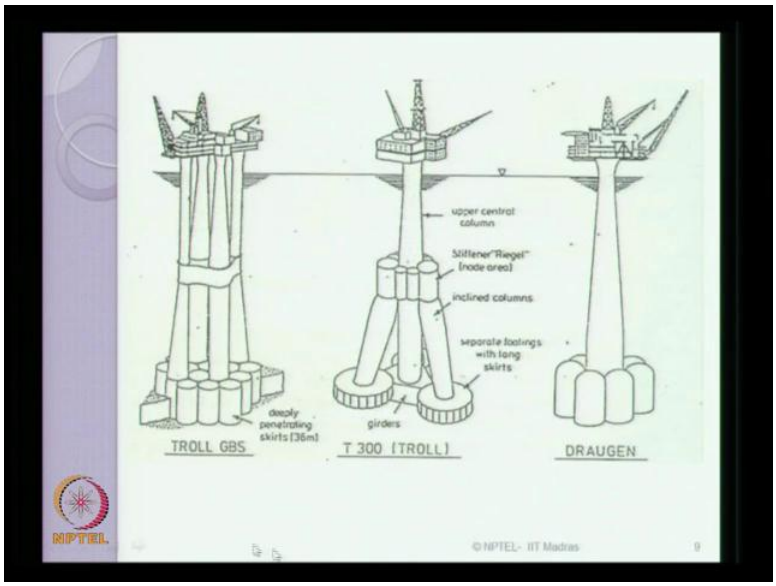

Troll GBS, troll T 300, and Draugen are other classical examples, where we can see a large gravity base at the bottom. As you can see in the slide, these are the caissons, which are void spaces in the beginning, being used to maintain the buoyancy of this platforms. Further once, the topside is installed and the platform is positioned, this can be used as storage compartments as well. In addition, in certain cases of the platforms because of its large self weight, they also require what we call skirt piles. Now, what is the purpose of a skirt pile?

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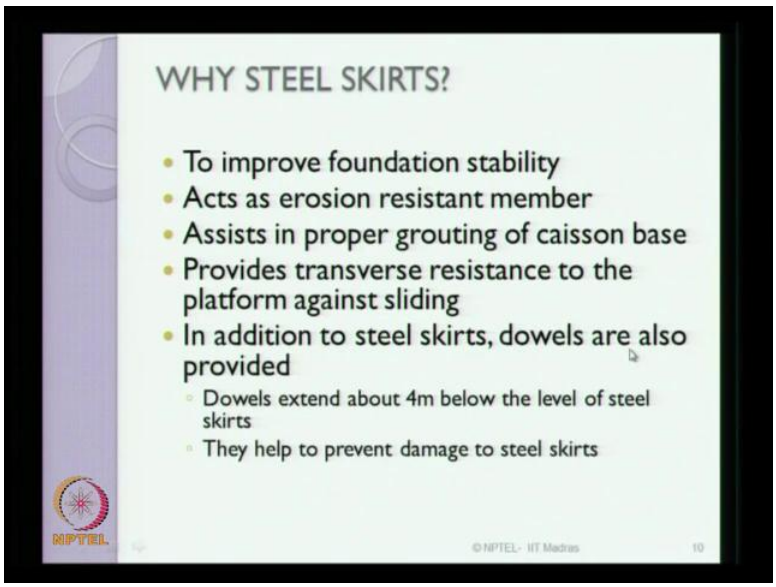

Why steel skirt piles are generally required? Steel skirts are generally required to improve the foundation stability of these kinds of platforms. They also act as erosion resistant members, it assists in proper grouting of the caisson bases. As you saw in the previous slide, it also provides phenomenal resistance to the platform against sliding, what we address as transverse resistance capacity of the platform. The transverse resistance against sliding with the lateral load is phenomenal increase by providing steel skirt piles to this gravity base platform.

In addition to the steel skirt piles sometimes it will also use dowel bars, which are also provided. The dowels extend about four meter below the level of steel skirt piles; they also help to prevent damage to the steel skirts, if they are provided.

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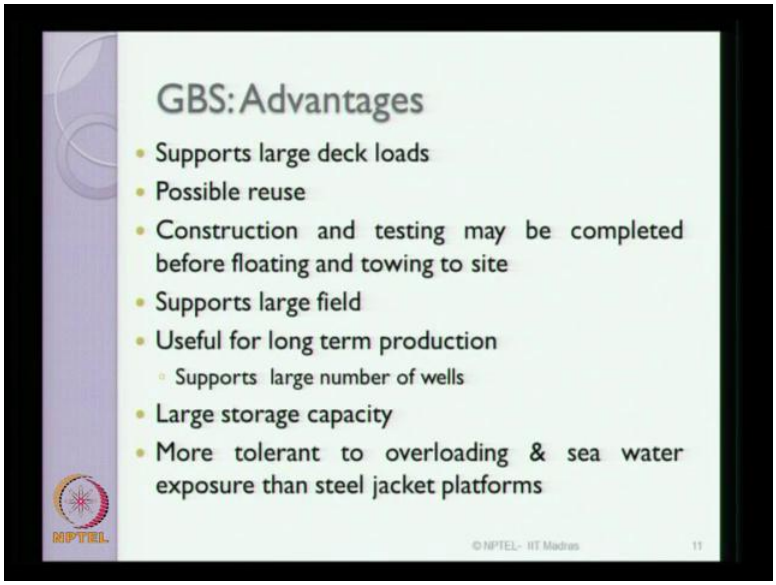

There are specific advantages of gravity base platforms, which have been seen in the literature. It supports phenomenally large amount of large deck loads. It has a very great possible reuse of the construction material, the construction and testing can be completed before the platform is floated to site or town down to site. That is one of the important advantages, because then you can insist on good quality control on the construction. Generally, these kinds of platforms are intended to support very large wheel for oil exploration.

They are useful for what we call a long term production; because these kinds of platforms generally support large number of wells as well. It has got a very large storage

capacity. They are more tolerant to overloading and sea water exposure. Because in comparison to steel jacket platforms concrete gravity base structures are less to corrosion effects in sea water.

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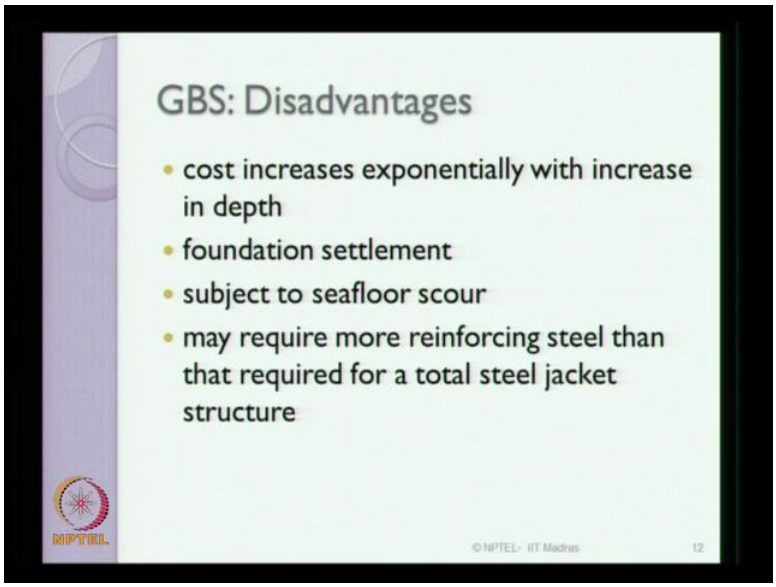

Of course, there are some demerits of these kinds of platforms. The cost of these platforms increases exponentially with the increase in water depth. Therefore, these kinds of platforms or marine structures cannot be attempted to be constructed in greater water depths. The other important structural problem associated with these platforms is the settlement of foundation. Ladies and gentlemen, as you can understand that this kind of platforms has a very large colossal self weight, so they create large impact on the sea bed where they are constructed.

They are associated with large foundation settlement effects as seen and reported in the literature. As a result of which they also cause, what we call sea floor scouring effects. Therefore, these kinds of structures generally require more reinforcing steel, than that is required to construct the steel jacket structure. The quantum of reinforcing steel which is being used to make the structure laterally load resistant is phenomenally high, which amounts to increase in cost of these kinds of platforms.

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If we quickly compare the advantage of gravity platform over jacket platforms, they provide greater safety for people on board. Because they have got high tolerance for lateral loads. Going to the sight with depth is highly possible. Therefore, this kinds of platform minimizes insulation time and cost. And of course, improves quality control in construction. Of course, these kinds of platform have low maintenance cost, because for example, if gravity base structures are constructed in concrete and they are submerged in water. Concrete generally, if submerge in water has lesser problems than the top steel structures.

These kinds of platforms, because of the larger caissons base they have at the bottom with a void space they have got adjustable crude oil capacity and they support very larger deck areas and surface load from the top side. In addition the risers, which are used for exploration and production drilling are protected, from the lateral loads. Because these risers are generally placed inside, what we call the central shaft of these kinds of platforms. They also provide possible access to the sea floor, because you can see there are large numbers of caissons, which are provided the bottom through which one can access to the sea floor. It means these amounts to better healthy monitoring of these kinds of platforms from the cellular compartments at the bottom closure to the foundation at the sea board.

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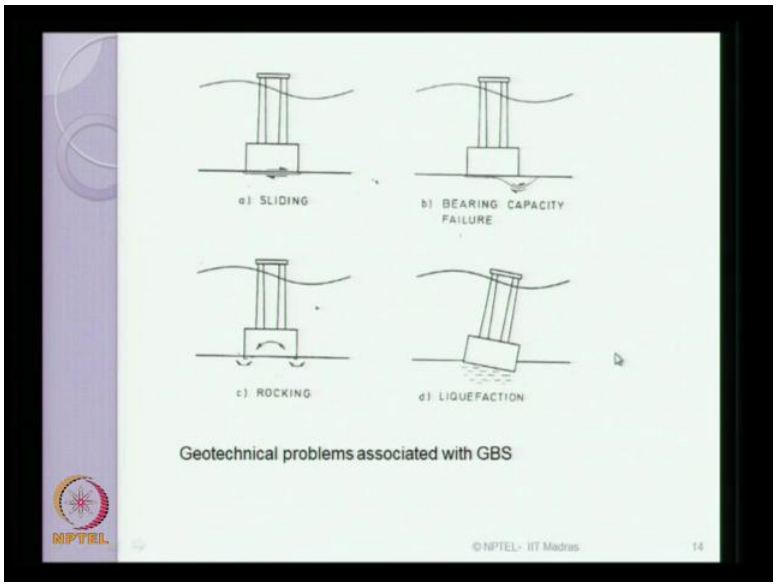

There are some specific geotechnical problems associated with gravity based structures. What you see the slide are four special critical problems that are closely associated with any massive type of structure, which are founded in sea bed. Sliding is a problem associated, which has lower resistance to lateral load upon the wave or wind load on gravity base structure.

Because of the massive colossal weight of the bottom of the structure, it can be subjected to what we call bearing capacity failure, which can initiate a localized failure in the bearing capacity of the soil, they supports this kind of structure. The other phenomenal problem, what gravity base structures have is rocking. Because of the softer moments created, at the support ends of a large colossal weight.

There can be a coupled moment generated by the structure and the lateral action of the wave and wind. On the platform, which can result in what we call rocking of the platform? Sometimes, depending upon the soil condition and the saturation level we can also address problems related to what we call soil liquefaction, which results in differential settlement of this kind of platform because of its very large colossal weight of this gravity base platform.

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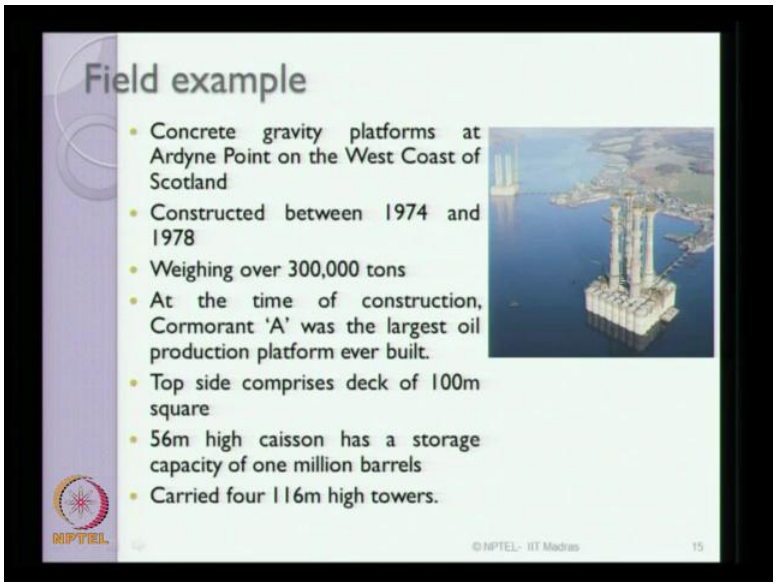

Looking at the field example one can see this interesting field example, which is a concrete gravity placed platform, which is constructed at Ardyne point on the west coast of Scotland. As you can see, these are the towers resting on the caissons, which are twenty four in numbers, which are very massive in size; these platforms are constructed between 1974 to 1978.

The total weight of this platform is closed to around three hundred thousand metric tons. At the time of construction the cormorant A which is one of the platform the other one you can see here. The cormorant A was considered to be one of the largest oil production platform ever built during early eighties. The topside of this platform comprises deck of hundred square meters in size the deck is not shown in this photograph here. It has got a 56 meter high caisson as a storage capacity of one million barrels. It carries towers of 116 meter high; these towers are of about 116 meter high, where as these caissons are about 56 meter high, which is got a very large storage capacity.

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This is the closure view of the same platform constructed in 1978 in Scotland.

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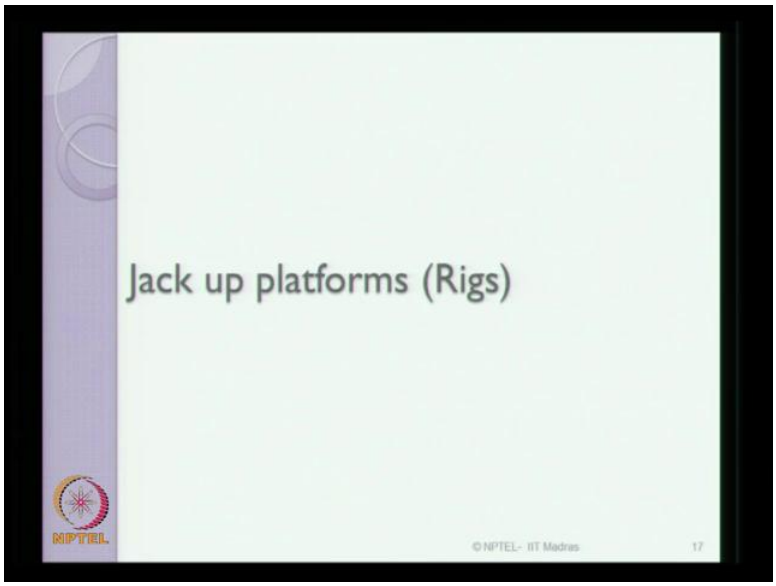

The second type of marine structure is again meant and constructed for exploration and drilling. Essentially, this is what we call a jack up platform. In summary, these kinds of platforms are addressed as drilling rigs in the literature.

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These are different kinds and photographs of the jack up rigs taken at different sides during installation. You can see one commoness between all these kinds of jack up rigs is that, it has got the truss type legs essentially they are three in number, sometimes they are also six in numbers. So, essentially they are tripod based structure, which has got a deck supported by these three legs. Now why it is called as a jack up can see there is a difference between the photograph of this as well as the remaining one. This has been taken intentionally, when the deck is being raised or when the legs have been pulled inside to the seabed during commissioning oil installation.

When the jack up rig is being toned to the side for exploratory drilling, the deck we will located at the bottom side as you see here and the legs all will be projected up from the deck. On installation these legs will be pushed into the sea bed and the deck will be lifted up that is why this is called a jack up rig. Now, most interesting part of this kind of platform is that, when the legs are projected in an upward position or when the deck is in the lower position, this can be easily toned from one location to another location. So, they are stable when the legs are projected up from the deck. They are also stable when the legs are projected into the sea floor during commissioning or drilling operation.

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This is a closure view of one of the jack up rig, which is very famously deployed in North Sea, which is Marx Jain. This will give you a very clear picture about, how these legs are protruding the deck and how they are projecting into the sea floor as you see here.

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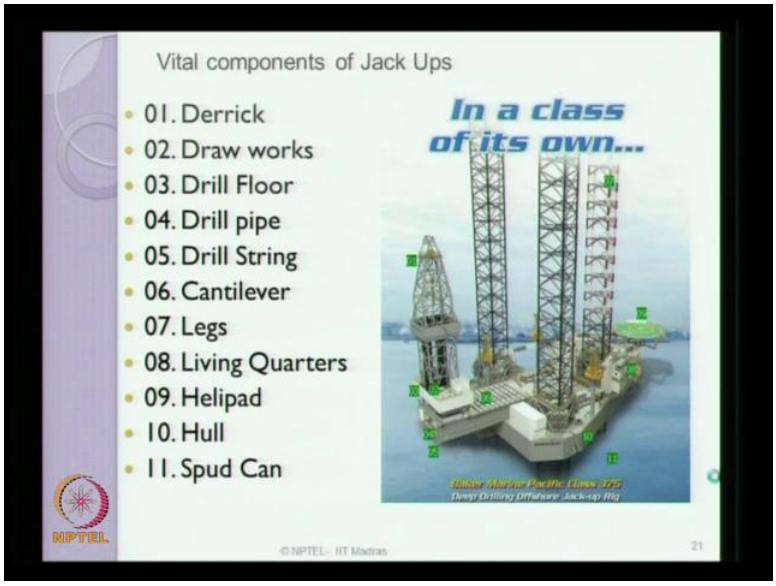

There are vital components of the jack ups, which we must understand for our better knowledge on this kind of marine structure. There are different components marked as one two and so on. I will explain them quickly in the slide here; one is what we call as

the derrick; two, which is located here, is what we call as the draw down works. Three is the drill floor where this is being located. Four is the drill pipe, which is not explicitly seen in this photograph. Five is a drill string, which is being used as a part of the drilling component.

Six, of course is a cantilever projection, which comes out of the deck area. And seven, are the legs what we call that jack up legs or truss base structures. Eight, is the living quarters, where people are accommodated to work on during the drilling operation. Now, of course nine is a helideck or helipad, and ten is of course, the main deck or the hull on which the hull will be raised and on which both operational drilling will take place. The eleventh special component of the leg, which we call as a spud can which is being essentially used for foundation of these legs, when they are projected into the sea floor for enough stability which will discuss in detail in the next slide.

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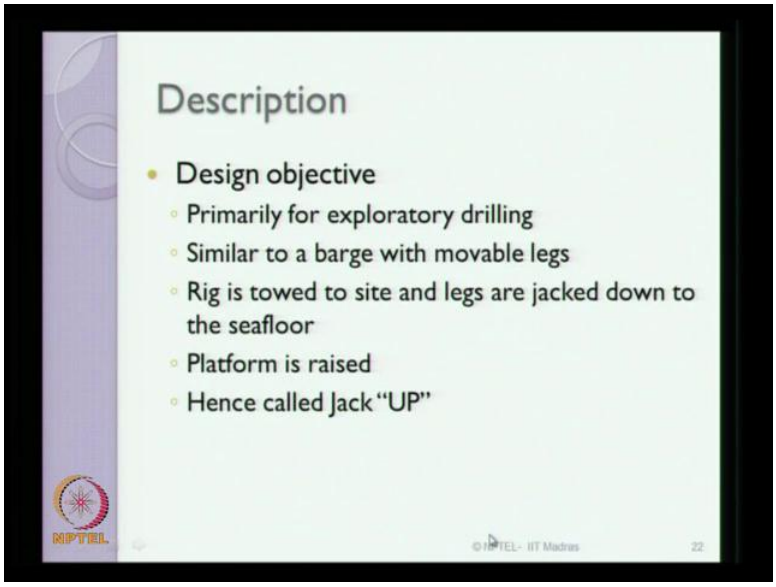

If you look at the design objectives of jack up rigs; essentially they are meant for exploratory drilling. Ladies and gentlemen, there are two kinds of drilling, which are generally attempted in marine structures. One is what we call drilling for exploration just to see what is a capability of a specific well in terms of its production capacity. The other is what we call production drilling. Once, exploratory drilling is complete and the yield of the well is established. Then a permanent type platform is constructed then production drilling actually starts.

So, jack up rigs are meant for preliminary drilling exercise, what we call as exploratory drilling. They are actually similar to barges with movable legs. The rig is towed to the side when the legs are jacked up after that towed to the side the legs are the jacked down to the seafloor and the platform is raised. That is why this kind of platform is given a special name called jack up rigs. They are suitable for shallow water depths only. Maximum operational depth could be up to 140 meters.

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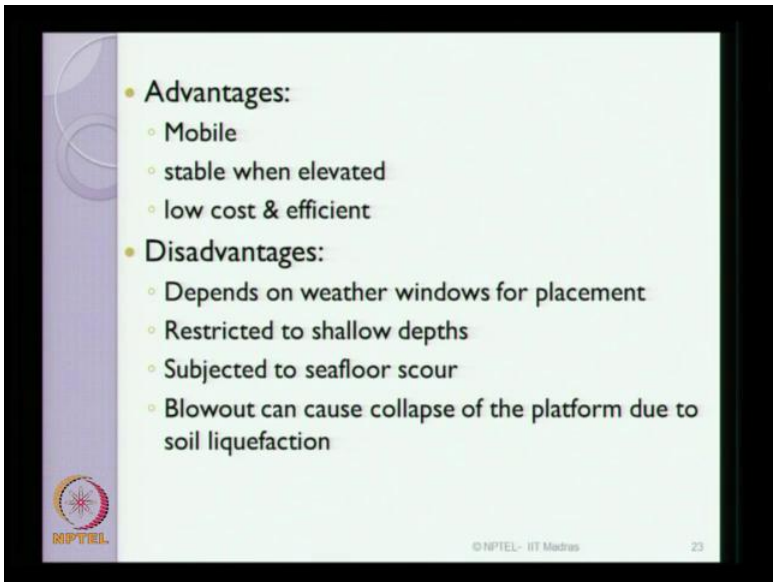

Of course, there are some specific advantages of jack up rigs, when used for exploratory drilling. They are highly mobile, they are stable, when the legs are elevated. They have a very low cost operation and they are very highly efficient, when they meant for exploratory drilling. There are some demerits of this kind of platforms, they depend on whether windows for a placing them. They cannot operate in all kind of sea states and weather conditions. They restricted only to shallow depths these platforms are highly subjected to seafloor scouring effects. Now, blowout can cause collapse of the platform, due to what we call soil liquefaction.

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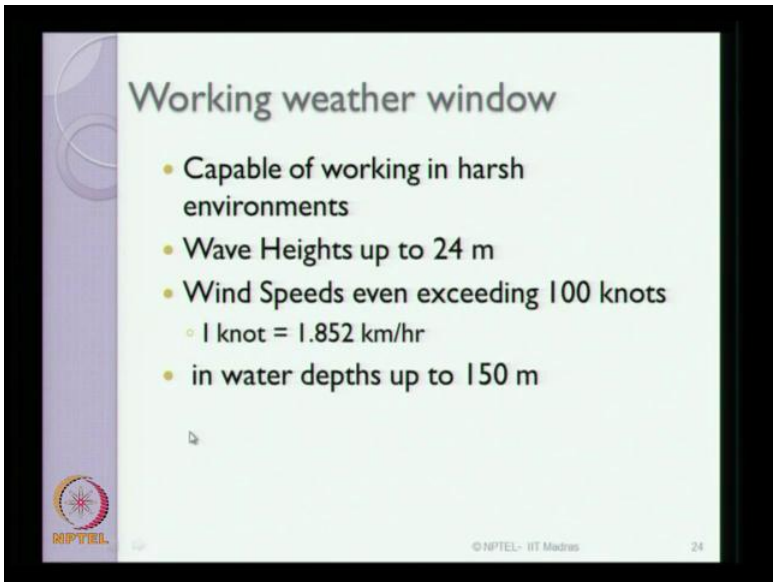

If you look at the working weather window of this kind of platform they are capable of of course working in harsh environment, the wave height is up to 24 meters can be allowed in this kind of operation. The wind speeds even exceeding 100 knots can also be sustained by this kind of platform. Ladies and gentlemen one knot is about 1.85 kilometer in hour. They are successful in operating up to water depths of one fifty meters.

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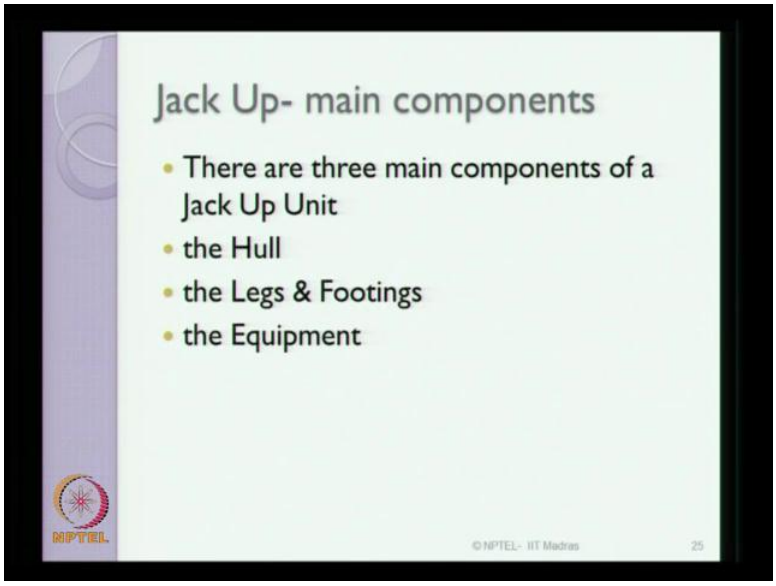

We have already seen, some of the components of jack up rigs. Let us quickly see the main components of a jack up rig. Essentially jack up platforms consists of three main components. The hull on which the whole mechanical devices are equipped the legs and the footing on which the hull rests of course, the equipments which are used for drilling and production.

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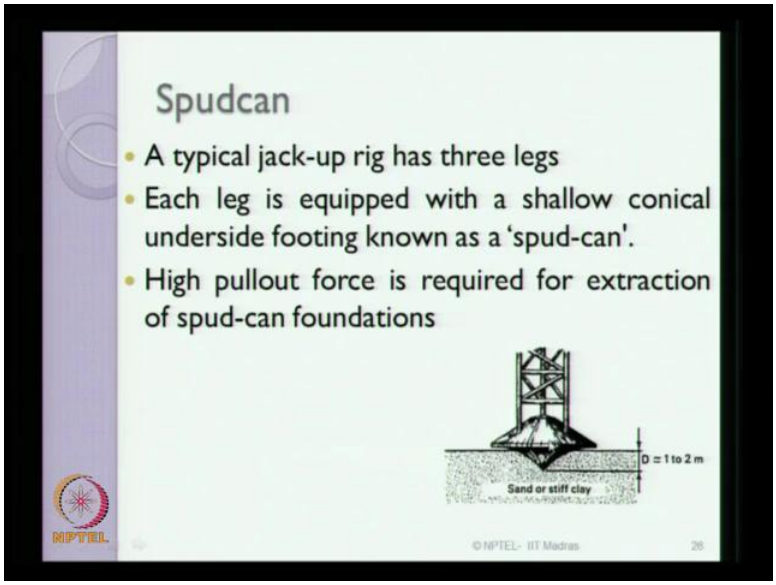

As I said very interesting to know how these legs are founded in the seabed, when they are doing the drilling operation. Spud-can, specific component, which is being used for housing or for placing the legs in position in the seafloor. The picture shows you the sand or the spud can which is mounted on sand or stiff clay. The spud-can is a typical foundation detail, which being used for a jack up rig. Jack up rig typically has three legs and each one of them has a spud can at its bottom. Each leg is equipped with what we call a shallow conical underside footing, which we call the spud-can is a conical footing located underside of a leg of a specific jack up rig.

This gets penetrated up to a depth of about two meters. And because of the hollowness inside because of the section pressure the clay particle or the stiff clay through which this is penetrated gets filled up in this void and this get blocked. Once the spud-can is firmly fixed in sand or stiff clay then it is very difficult to plug this foundation out from the soil. You may require very high pullout forces for extracting the spud can foundation from the

sea bed, which is essentially meant for sand or stiff clay. And remember this kind of spud-can foundation is not recommended for hard soil or a rocky bottom.

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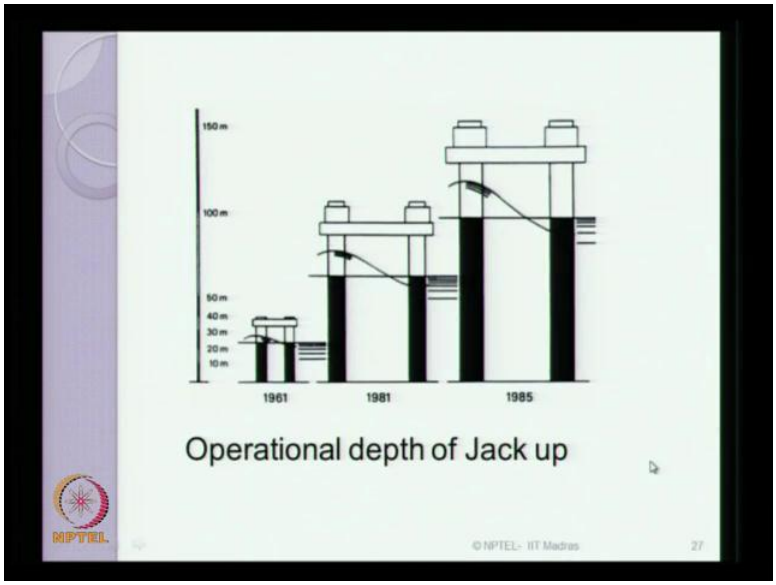

You look at the operational depth of jack up rigs in the literature in early sixty's people have been people have been operating these rigs only to depth of about forty meters. They move this operational advantage to hundred and fifty meters in early ninety's. So, use of jack up rig has motivated people for its successful deployment from a depth of about forty meter to four times of this in a span of about twenty five years.

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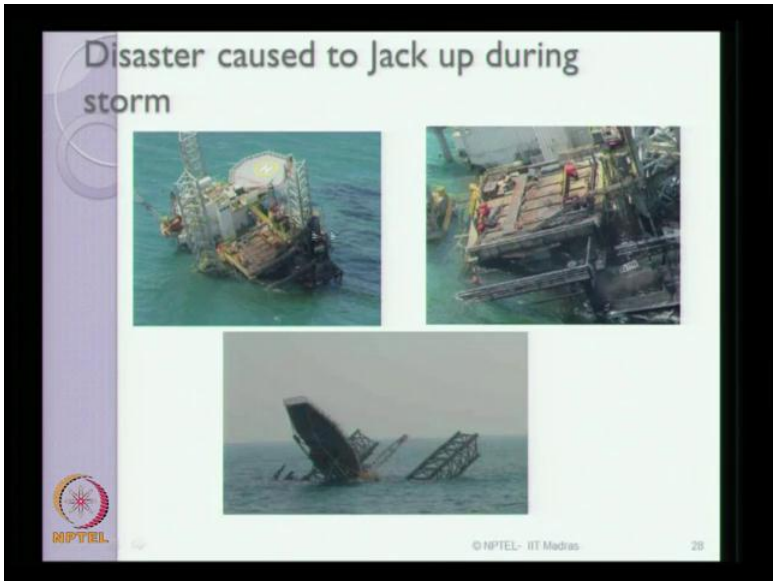

Of course, there are also not avoided from accidents, these are some of the photographs, which show when the disaster caused a jack up rig during a storm condition. These are the three legs, the helipad, the living quarters, and the derricks on the flat or the cranes, which have been actually seen. Can see this complete sink has been an accident caused on a jack up rig during a storm, which we address as a disaster.

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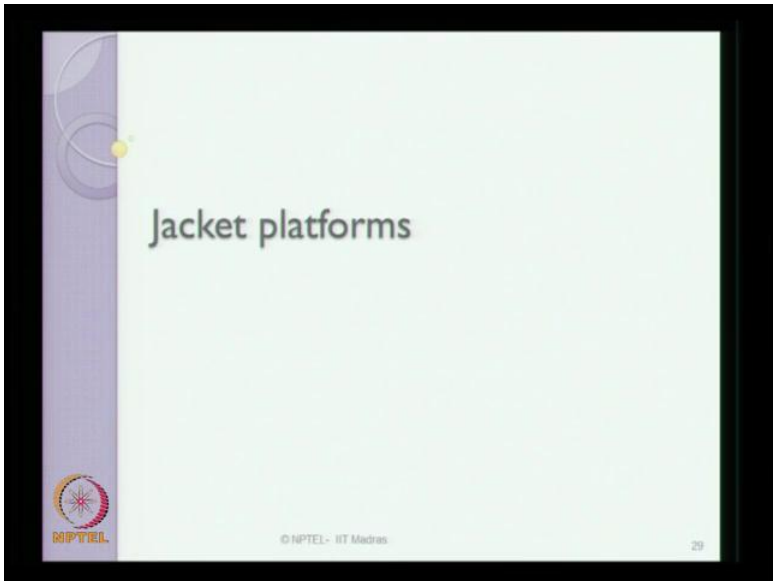

The third kind of marine structure, which we addressed in this lecture, will be a jacket platform.

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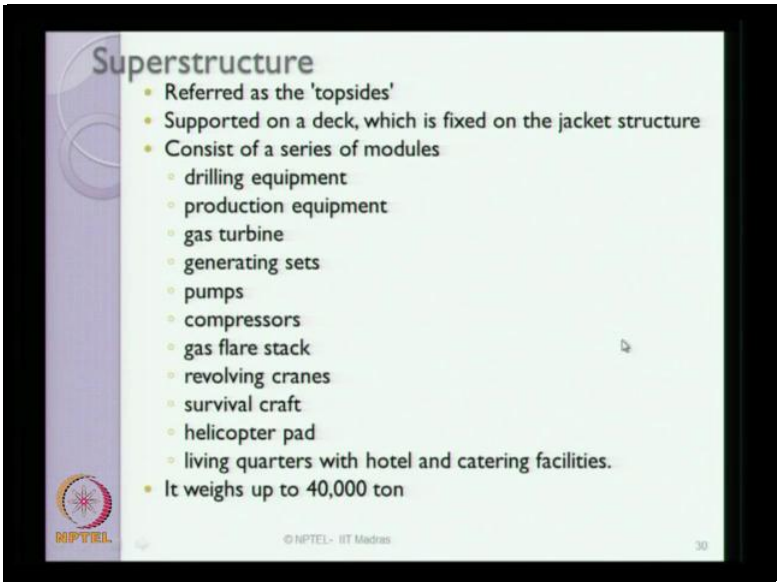

The jacket platforms are essentially consist of a super structure, which is referred as top sides in the literature. The top side actually supports a deck, which is fixed on the jacket structure. It consists of series of modules, which are present on the topside. There are different modules looking for different segmental operation of a jacket structure, drilling equipments, production equipments, gas turbines, generating units, pumps, compressors, flare strakes, revolving cranes, survival craft, helicopter pads, living quarters and catering facilities. These are different kinds of modules, which are housed on topside of a jacket platform, which put together is what we call is a super structure of a jacket platform. The generally the topside of this structure weighs about 40,000 metric tons.

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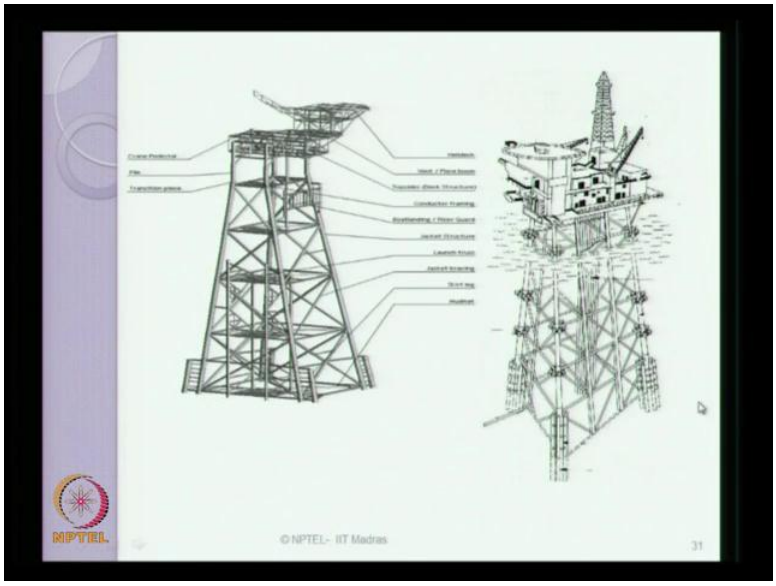

It is a typical view of an animated figure of a jacket platform, which consists of the derrick mask, the crane, the flare boom ,the helipad, the living quarters. And of course, what we call as a jacket legs. Essentially these kind of structures are transparent to wave action, what do you mean by transparence is the wave is enabled or allowed to pass through the form of the structure. Since, they are transparent; the lateral loads exerted on these members are phenomenally reduced in comparison to the caissons of gravity base structures.

So, they are steel jacket platforms essentially they consist of at the bottom, which is house and supported by a skirt pile on the sides. And there is something called being used, I will discuss this application separately in the next slide. The legs what you see

here is what is called as a jacket structure; of course, as a boat landing facility available near to the mean sea level or the drought level of this platform.

The topside consists of various modules as you just now saw in the previous slide and of course, the topside also houses, the crane, the flare boom, and the helideck, as you can see in the schematic view here. This is one of the outline diagram the free sketch of a jacket typical jacket platform, which being constructed for medium or shallow water depths.

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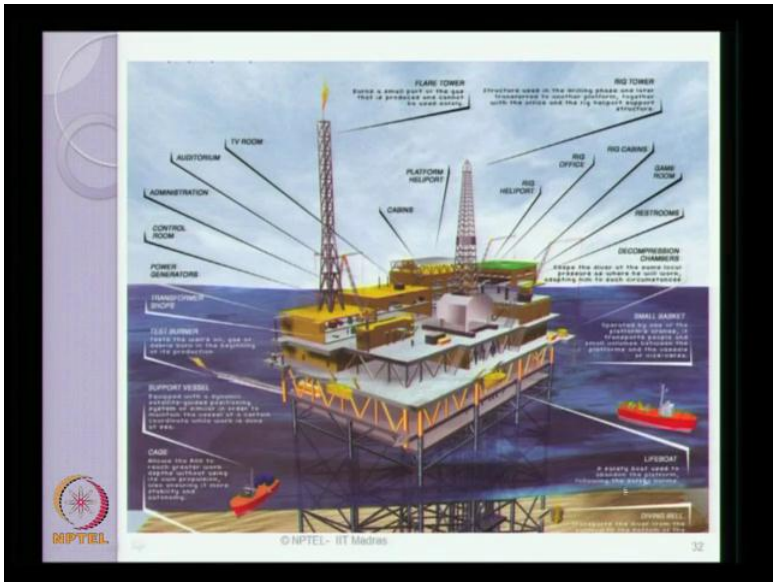

This picture shows more detail about the topside as you understand here. The topside consists of flag tower as you can see here. Nothing but a truss base system it also consists of a drilling rig, which we call as a rig tower it consists of a platform, helipad. It also houses different kinds of operational cabins, has got rig helipad. It has got a rig office and rig cabin, which controls the whole drilling rig operation from the sector. It has got rest rooms and living quarters, it has got recreational areas as well on the topside is got decompression chambers, which houses lot of mechanical compression equipments, which are used during drilling operation. There are modules and tires, where the life boats are affixed to this platform in case of emergency, the people can escape from the platform using the life boats.

There are different cages and support missiles and test runners or burners, which has been used to check the flare boom details of a production well as well. Different modules

also contain the power generation units, the control room and the administrative block and of course, an auditorium and TV room. So, it is as good as a self developed town ship; so, it is a very large in size, which houses all basic amenities, recreational facilities, production facilities, technical facilities and of course, the details that are required for production of oil from sea bed.

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If you look at the subside details of this; these are all the jacket legs what we see here, is also has a remote operated vehicle to see the positioning of the platform. It has got umbilical cables, which are supporting, which are used for the drilling risers, the jacket is what we see here. As the legs and the jackets also has supports derive from the export pipelines and the production pipelines or the product wells, which has been used for exploring oil or producing oil from the seabed.

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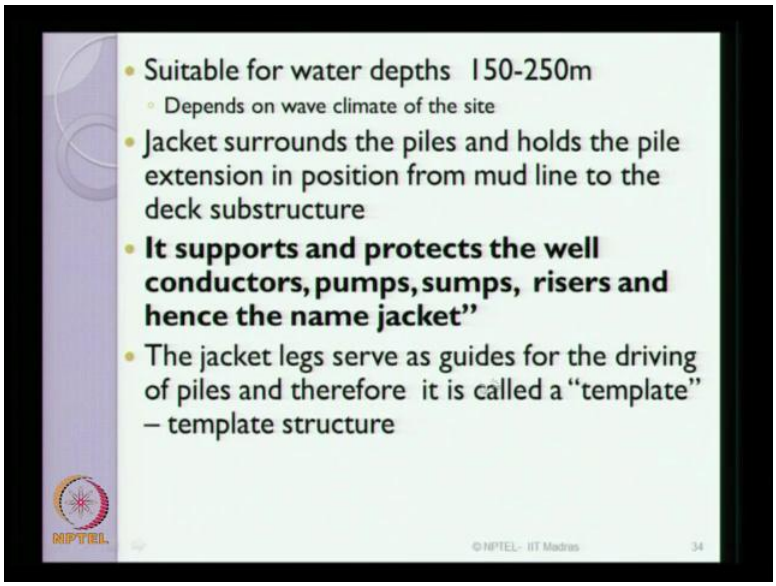

These kinds of platforms are generally suitable for water depths up to 250 meters. Of course the selection of this kind of marine structure depends on the wave climate at a specific site. Jacket surrounds the pile and holds the pile extension from the mud line to the deck substructure. It supports and protects the well conductors, pumps, sumps, risers that is why the legs or otherwise called as jackets. The jacket leg serves as guides for driving of piles therefore, some literature also address these kinds of platforms as template structures.

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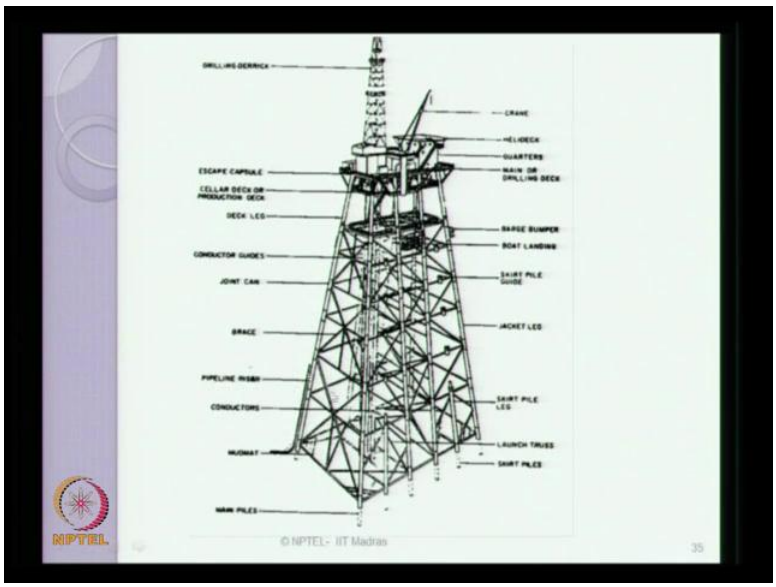

This is an interesting picture, showing you the different components of a jacket type marine structure, say drilling derrick what you see here, is a crane, is a helideck, is a living quarters. These are the main drilling deck module, present here. It is an escape capsule, which has got life boats housed in this. This is a cellar deck which is essentially used for production. These are the deck legs as you can see here; inclined champ word legs, constructed of steel. These are the barge bumpers, which are used to protect or to prevent shocks on the legs, or impacts of vessels. These are the boat landing modules, which are being used. These are the skirt pile guides, which are recommended. These are the joint cans as you see here, and different locations.

These are the braces x bracing etc, which are used to improve the stability of the jacket legs under lateral loading. These are the pipeline risers, which are actually used for production raising the bottom most set is what we call as a mud mat on which the jacket structure rests. These are the main piles and these are the skirt piles as you see which can improve the lateral stability of these kinds of platforms. Interestingly the launch truss is a vital component of a jacket structure, which we discuss in detail.

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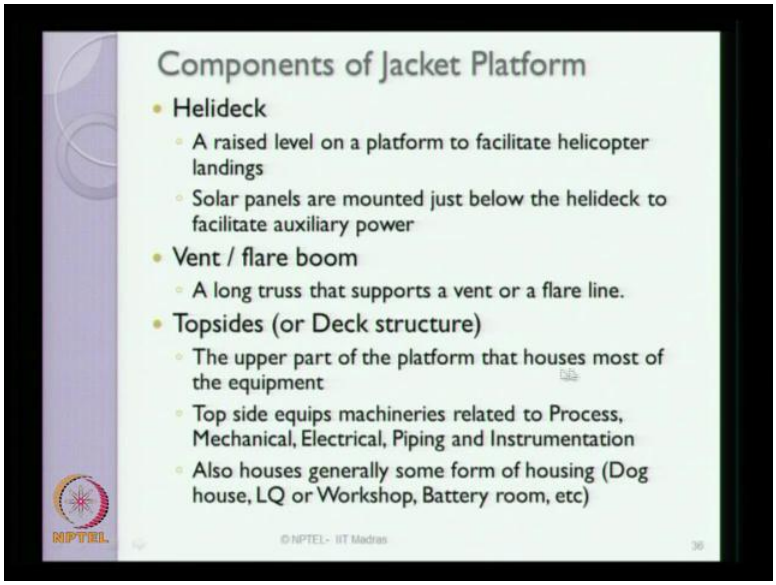

If you look at the components of the jacket platform one by one, helideck is a raised level platform, which facilitates the helipad landing. It houses solar panels, which are mounted just below the helideck to create auxiliary power for production as well as for survival. It contains vent and flare booms is nothing but, a long truss that supports vent

or a flare line. The topside is essentially consists of upper part of the platform, which houses most of the equipments the topside equipments consists of machinery related to process, mechanical, electrical, piping, and instrumentation. It also houses generally, some form of housing which are meant for people who are working on boat.

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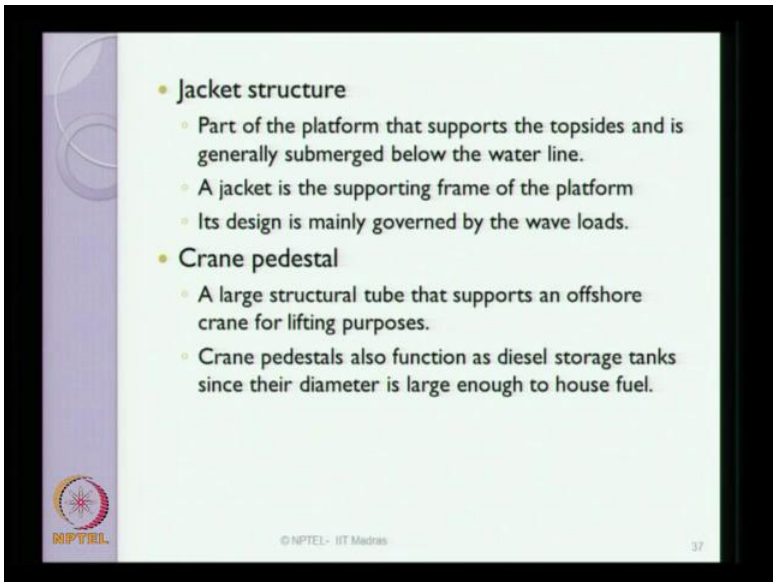

The jacket structure essentially consists of part of the platform, which supports the topside and generally it is submerged below the water. A jacket is a supporting frame of the platform, which is mainly designed to resist the wave loads acting on the platform. Crane pedestal is a large structural tube that supports the offshore crane for lifting purposes. Crane pedestals function also as diesel storage tanks. Since the diameter is large enough to house fuel.

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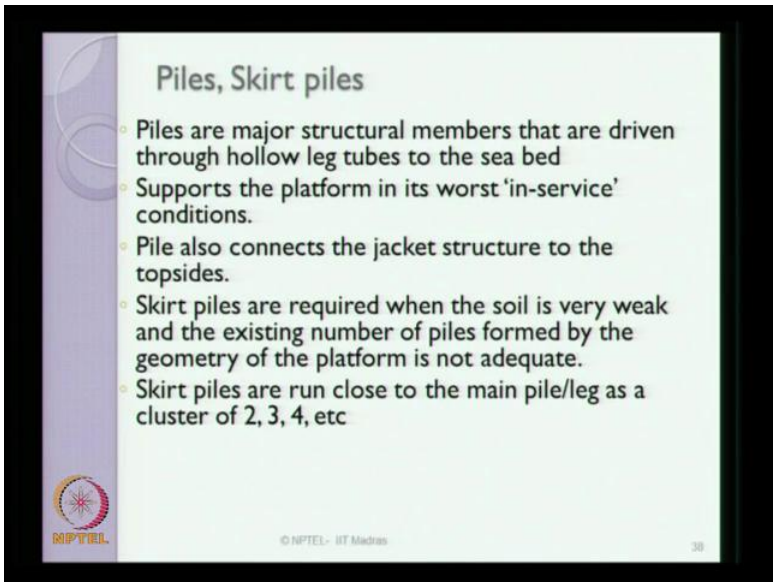

If you look at the piles and the skirt piles is a vital components, on which the jacket structures rest. Piles are major structural members that are driven through hollow leg tubes to the seabed. It supports the platform in service condition; piles also connect the jacket structures with the topsides. Skirt piles are especially required to improve the lateral stability of the platform. When the soil is very weak, skirt piles are generally done in groups of two, three and four etc.

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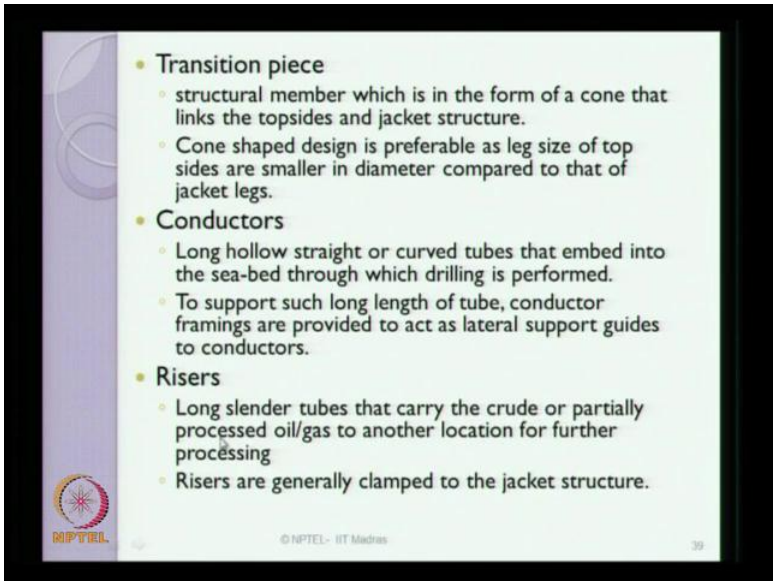

The transition piece is one of the important segments, a structural member, which is in the form of a cone, which connects the topside to the jacket structure. The jacket structure is nothing but the leg; topside is nothing but the details of the machineries, what you saw on in the last slide. The topside and the jacket are interconnected by a piece, which is conical in shape, which rocks the deck to that of the legs.

This piece is what we call the transition piece, it is a cone shaped design piece, which is preferable as a leg size of the topsides or smaller in diameter compared that of the jacket legs. Conductors are long hollow straight or curved tubes that embed in to the seabed through which the drilling is performed, to support such long lengths of the tubes.

Conductor framings are also provided, which also act as lateral support guides to the conductors, which receive support and strength from the jacket legs. Risers, nothing but long slender tubes that carry the crude oil or partially processed crude oil to another location for further processing. Risers are generally clamped to the jacket structure, and they receive support from the jacket legs only.

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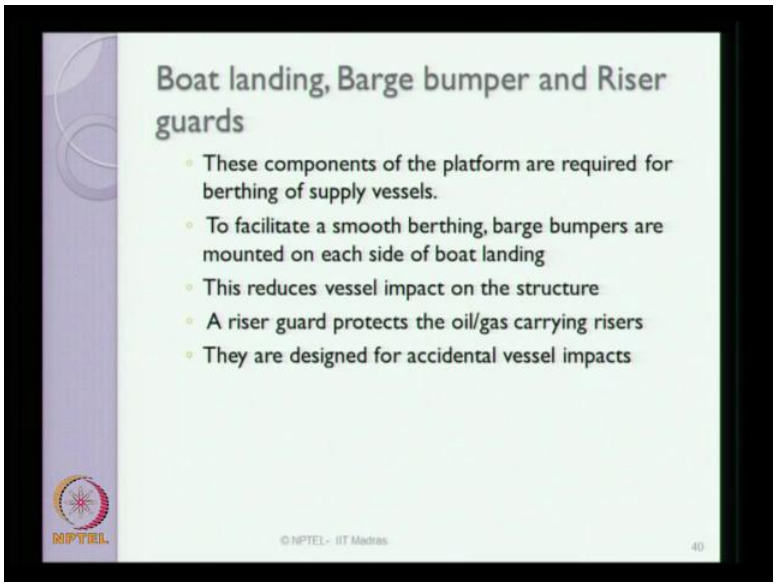

If you look at the boat landing, barge bumpers and riser guards; these are also ancillary components of the platform, which are required for berthing of the supply vessels. To facilitate a smooth berthing, barge bumpers are installed on each side of the boat landing. This reduces the vessel impact on the jacket structure; the riser guard also protects the oil

and gas carrying risers. They also designed for accidental vessel impacts caused by these vessels on the risers.

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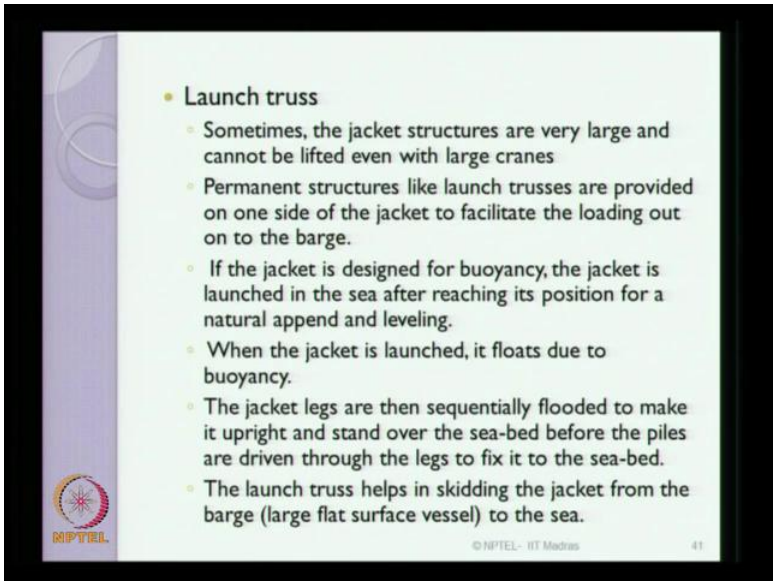

Launch truss, is one of the vital components, sometimes when the jacket structures are very large in size and cannot be lifted even with large cranes they are done. The permanent structures like launch trusses will be provided on one side with jacket to facilitate the loading out on the jacket to barge.

The jacket is designed for buoyancy, then the jacket is launched in the sea at reaching its position for a natural and append and leveling operation. When the jacket is launched it uploads on its own. Because of the buoyancy design the jacket legs are then sequentially flooded, to make it upright and stand over the seabed before the piles are driven through the legs fix it to the seabed. The launch truss actually helps in skidding the jacket from the barge to the sea on site of in location or installation.

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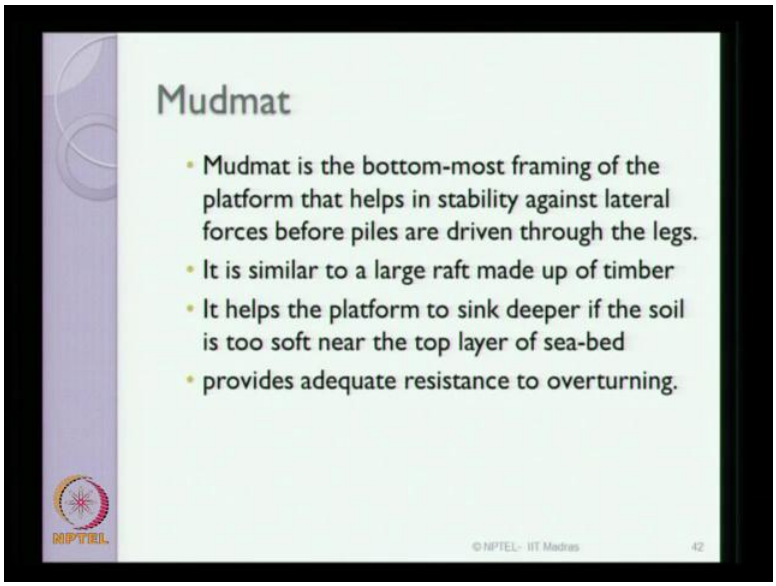

Mud mat is one of the vital component of this kind of structure, which is a bottom most frame of the platform, which helps in improving stability against lateral forces. Before the piles are driven through the legs. It is similar to a large raft made out of timber; it helps the platform to sink deeper. If the soil is too soft, it provides adequate resistance against over turning in case of any installation problems.

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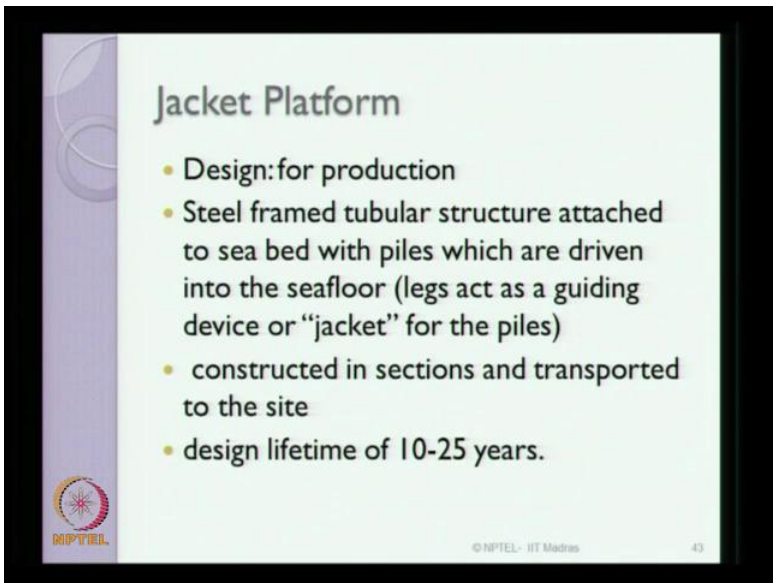

Jacket platforms are essentially production type platforms. It consists of steel framed tubeless structure, which is attached to the sea bed with piles. It is constructed in sections

and transported to the sites. The design lifetime of these kinds of platforms is about 10 to 25 years depending upon the yield of the well.

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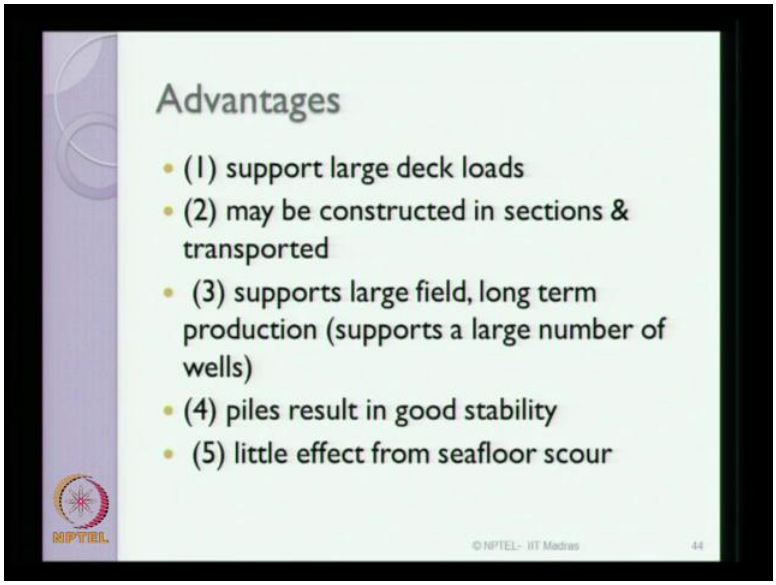

The salient advantages of these kinds of marine structures are : it supports large deck loads, it may be constructed in sections and transported, and supports large field and it is essentially meant for long term production. Because it can support large number of production wells as well. Piles result in good stability against lateral loading; they have very little effect on seafloor scouring unlike gravity base structures.

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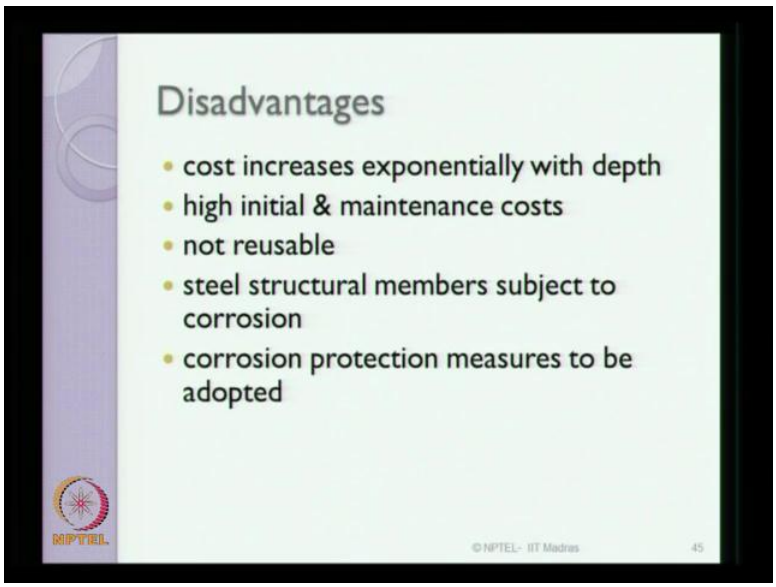

There are some disadvantages of these kinds of marine structures, the cost of these structures increase exponentially with increase in water depth. They have very high initial and maintenance costs, they are not mostly reusable. The steel structural members are subjected to extensive corrosion in the sea environment. Therefore, corrosion protection measures become very important and they are also expensive.

So, in this present lecture, we discussed about three types of marine structures, gravity base structure, jack up rigs, and fixed type jacket structure, which are essentially meant for exploratory or production type of drilling operations. We have also seen important components, which are consisting or comprising these kind of structures, is better that we understand these kind of structures in detail, before we start discussing the ultimate load carrying capacity of these members under combined action of wind, wave, current, and seismic load.

Thank you.