Design of offshore structures
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Lecture - 2
Loads on offshore structures 2

So, yesterday we have we have looked at the purpose for which this offshore structures are designed and constructed. Today what we are going to see is specifically offshore structures fixed to the sea bed. That means we are not going to look at the floating systems. We will look at the fixed floating system fixed platforms for the purpose of exploration in shallow water while doing. So, we will just look at what other things is available. Both, for fixed and floating, but in detail we are going to just look at the configuration of the system. So, the structures can be classified into bottom fixed structures, means the structures are fabricated, installed and fixed to the ground by pile foundations or other forms of foundations.

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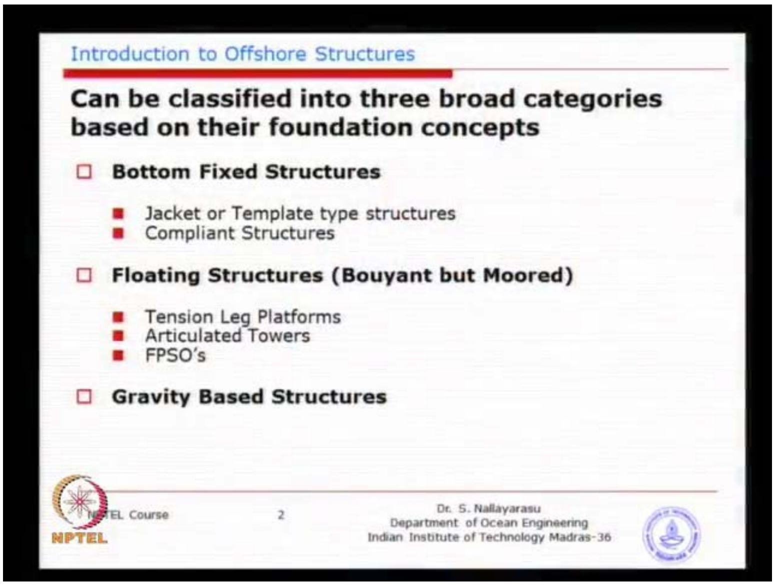

So, you have jacket or template type structures compliant structures. We will see the difference between what is a idea behind jacket structures and compliant towers. The second class will be floating structures, where the load transfer is by means of buoyancy. So, there is no foundation except for mooring lines. Then the third is gravity based structures. So, you can see there the load transfer and the resistance is coming from the weight of the structure.

The first one basically the most commonly used structures for shallow water. The last the third category the gravity based platforms also used in shallow water. As well slightly deeper water depths, but for very deep water you normally go for floating structures. Among there you have got three or 4 categories, which we will see in little bit more detail one by one. I do not think you need to write down as long as you can listen here. You can read the notes later on I am going to give you.

So, the three classes bottom fixed structures floating and then resting on sea bed three classes. So, you can see easily distinguish three categories. Basically, how the load transfer from super structure to sub structure sub structure to ground or to the sea bed or to the foundation. So, basically that is how, so we will be focussing on in this course the bottom fixed structures, especially the jacket or template type structures to the great extent.

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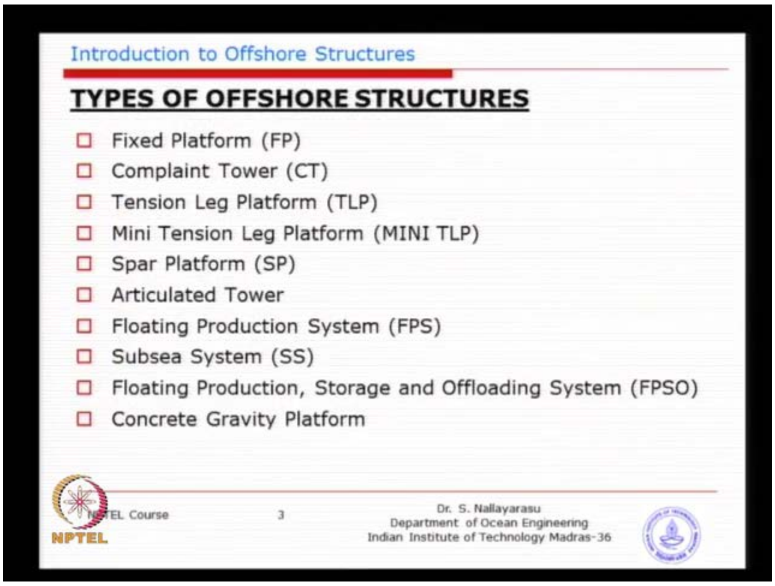

I think one by one we are going to see some pictures as well and understand the concept of how the load transfer is happening fixed platforms complaint tower. Both are based on fixed to the ground type, then the remainder is almost all of them are floating type, one by one. We will go through and the last one is the gravity platform.

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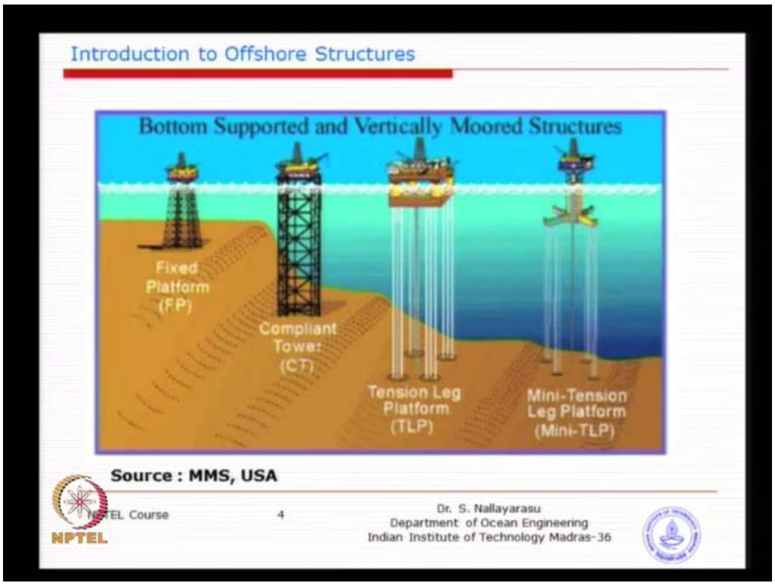

So, if you see the history of platform development you could see that gradually as the exploration extends towards deep water. You could see from a shallow water jacket to a slightly deeper water jacket. It is actually if you see the first one and the second one. Basically, the jacket is slant you see the difference the phase is slant here, whereas the jacket phase is made vertical the reason behind. If you make the similar design for example, the shallow water to deep water the base of the jacket becomes too big. Typically if you look at hundred meter water depth one in ten inclination of the legs. We will see why we are doing this later part. If you do the same thing here what will happen the base becomes too large. With today's installation capability it will be too big for transportation and installation.

So, basically that is why you made it slender then we do the remedy by means of other specific design. Basically, it becomes too slender almost a cylinder cantilever. Whereas, the first one becomes better in terms of bottom fixity and the displacements will be controlled. So, what we need to see is what difference it makes in terms of operational capability. Because, we made it slender and then how do we remedy that situation. Because, we cannot build a platform of similar kind becomes too big. Number one too big in the sense too costly number two and installation may become a little bit problem. Of course, in the recent past like within last twenty years 600 meters water depth jacket has been installed in Gulf of Mexico. So, how did they do it to overcome the installation is a different scenario.

So, the third one is you see as the water depth increasing. We have a shifted to a concept, where structures will be floating no more fixed to the ground, because basically the making of a similar structure in a very deep water becomes impossible. It may be too expensive and come up with an alternative solution. Basically, the total load transfer is happening by buoyancy. So, the basic idea is the gravity loads are taken by buoyancy provided by the hull the floating system. The station keeping is done by several means one of the idea is here mooring line is going vertical. We cannot normally call it mooring line we call it tethers basic idea is. They do not spread they go vertically down. All the time these lines will be under tension, because you have an excess buoyancy. So, when you tie them to the ground always under high tension.

So, that is called tension like platform basically there is no leg except that you got tethers vertically moved to the ground. That means there could be potentially a design of foundation required there, because you got to fix the mooring lines or the tethers to the ground. A similar concept, but exactly the hull shape and dimensions are slightly different, but other than that the idea behind is similar. You can see the terrace going down vertically, which is called mini T L P, which is just a variation of the conventional T L P with a pontoon at the bottom here. Also, pontoon at the bottom except, but only thing is instead of 4 column stabilisation here we have a single column stabilisation. Basically, little bit weaker, but here you got the legs are spread over larger dimension. So, the stability could be better.

So, you see this, the evolution of various configurations over a period of time. If you remember if you go back nineteen sixties or seventies, even building a jacket of this kind was, so difficult, because those days capability of machineries and availability of equipments were not so much, but seventies and eighties started to build up bigger. Bigger jackets reach the highest of 600, 700 meter water depth, but then after eighties many of these floating solutions have come up, which means depending on time of the availability. The technology available those days even building a jacket would have been a very big challenge.

You know nineteen seventies building a jacket in hundred meter water depth is a big worry, but today building a jacket in hundred meter water depth is a simple exercise. Many of the contractors can do it, whereas building a T L P or other types of floating systems. Even today it is a big challenge, because the systems have been continuously changing.

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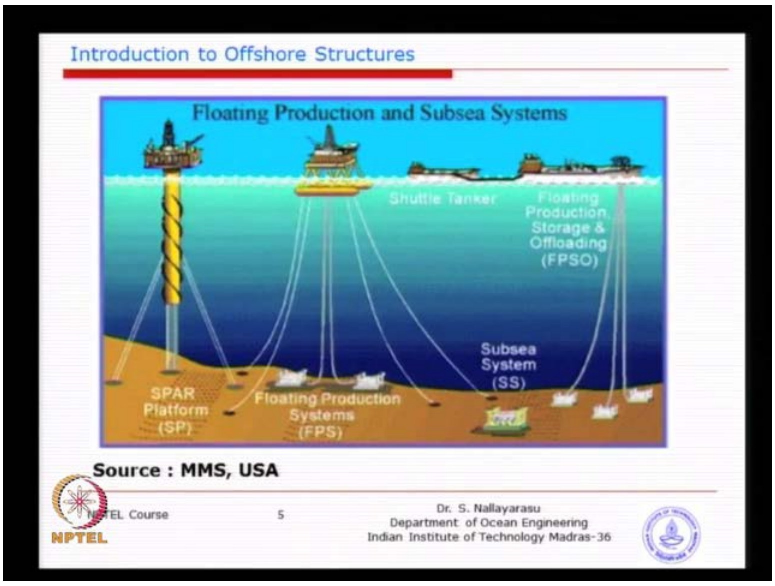

So, the other form of hulls, which also gives you an idea of change in concept. Instead of very shallow draft hulls like what you saw from the previous picture. Something like this you see here the deep draft hulls. We call it D D F deep draft floaters vertical cylinder floating upright give the specific means of design. If you could see this hull also been moved vertically, sometimes or slant lines either tout or slack, but you could see that the stability is coming from single leg. So, how do we stabilise when we go for a design very easy.

Basically, the large mass at the top makes the system very unstable. So, what you need to make sure is center of buoyancy is up always compared to centre of gravity. If you have otherwise what will happen immediately capsize. Whereas, when you go back to this the previous system you see here stability is automatically achieved. Because, the legs are spread and water line area is smaller and waterline dimensions are larger. So, waterline area is smaller the dimensions are very large. Whereas, when you come to this hull both are same. There is only a single mono hull that is the biggest problem.

So, design a spar we need to make sure that the centre of gravity and centre of buoyancy is aligned properly, always centre of buoyancy should at the top. So, that it becomes upright and similarly, you have various other hull forms like the 1 F P S O systems conventionally used by means of a simple tankers. For some time we have a special hulls something like what we see in this picture, but very rarely most of the F P A source are conversion of existing old tankers and of it.

So, how do we do it basically is the hull design for each of the location you know, which location, which type of hull is suitable first needs to be selected. For example, if we go to a cyclone prone area the F P S O hull is no good, because the load attracted by the hull will be very large. That means designing mooring systems would be potentially proved to be very difficult. Whereas, if you go for a common places some of the gulf area you could see that the loads on the hull will be very small. So, you could actually have a spread mooring. So, spread mooring versus the other type of mooring or station keeping system needs to be you know arrived at based on the environmental conditions.

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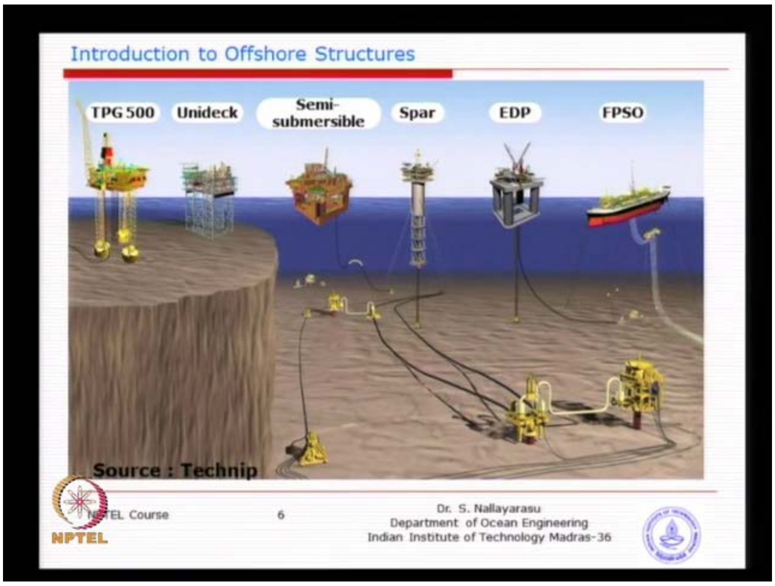

Over the period of time various types of floating hulls you could see some of them are like a semi submersible. We will see what is the meaning of semi submersible, basically the idea is the hull has the vertical columns as well as the bottom pontoons submerged below water with reasonable excess buoyancy. The spar the extended drilling platform very similar to semi shaft except that the bottom is having another deck for supporting some of the equipments, a typical floating production and storage and offloading. Basically, this is a very good concept developed around nineteen eighties, where marginal fields are...

Yesterday, we discussed about marginal field you know where pipelines are very expensive the location is very far. In such cases what you need is produce and store and the oil tankers certain tankers will come and offload, then transport to land. So, you need a temporary storage, that means you need to have a storage tank. So, this type of ships will have you now chambers you can store the produced oil. Later on transfer to the cargo ships or cargo tankers, which can trans transfer the cargo to the land.

So, the that is the idea behind and mostly the F P S is originally developed for marginal field, but nowadays it is been used for other conventional field because. Instead of storage you directly have a pipeline transferring the fluid to the land. One of the greatest advantage of F P S O is it is relocatable reusable. In case if this field is exhausted. You could actually disconnect and go to another project or another field with simple modification to the top side equipments.

You may not exactly use it hundred percent, but at least you can relocate the hull relocate the equipments without spending too much of money. Whereas, the fixed platforms the relocation actually becomes costlier than the installation. Itself you will get that type of numbers when you actually ask for removal. They will charge you more than the original cost of installation, because most of the work involves subsea cutting removal and relifting. Once you assemble such a big platform from small pieces of equipment getting them into smaller pieces for easy uplifting or transfer becomes really expensive. That is why most of the platform of after the expiry of their life, still actually lying there idle many of the locations.

As per the recent regulations you supposed to remove the platforms that aged platforms beyond their service life. You supposed to remove because they should not create problem to the environment many of the countries, like European countries. They have mandatory regulations while installation you should have provisions to remove. So, that the next time when you are trying to remove, it becomes easier than, nowadays we do not have any such provision.

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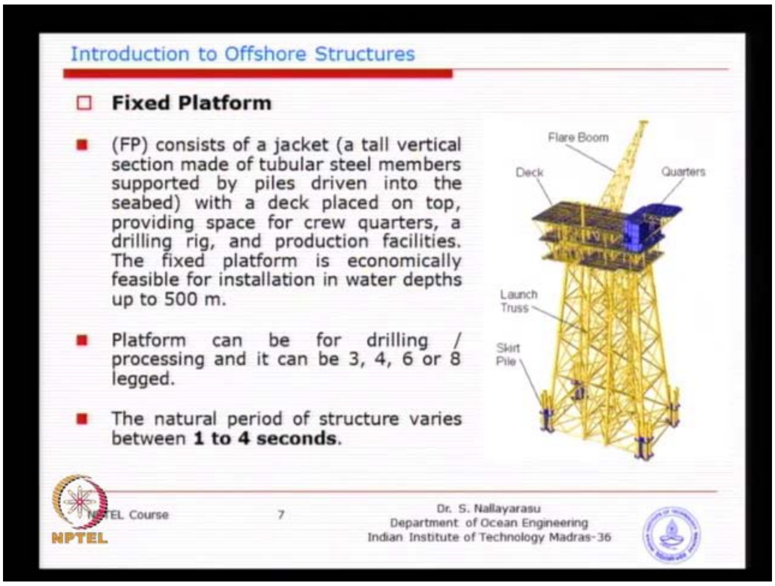

So, a fixed platform means we got several components I think as I explained yesterday we have a super structure like any other infrastructure facility. You have a super structure housing most of the facilities that produces oil and gas supports systems, like living facility power producing facility. Then the flaring facility of excess gas and you have a sub structure, which is made of primarily steel frame, which you could see a typical tower, most of the time we have a tower made of tubular numbers. We will see the reason why we do that then the tubular structure is arranged and organised. In such a way that the base is larger and the top is smaller such a very simple common sense, you could see that the base is larger your inertia of the structure will be better or increased. If you make a parallel bracing or parallel column, you will have a reduced base, which will make a reduced strength against horizontal loads at least.

So, basically most of the structures will be of this point with pile foundation. Mostly steel tubular piles fixed to the ground and fixed to the structure. So, we need to see how it is integrated we have a foundation. We have a steel structure needs to be connected to the ground by means of pile driving. Most of the platforms, built all around the globe are less than five hundred except few exceptional cases and very commonly. You see that in this part of the world both from Chinese oil field to middle east most of the platforms are less than 150 meter. You do not see any platform except in two locations, where we have done 200 meters in Chinese waters, otherwise most of the platforms less than 150.

So, you will see that most of the activities in this part of the world. We are talking about almost shallow water. There is not much deep water projects except, if you go to Gulf of Mexico or north sea or elsewhere you will find even jackets go up to 500 meters water depth and beyond. Nowadays, the new projects nobody is going for even for 500 meters jacket projects, because for 500 you got a better solution using floating systems, but nineteen seventies and eighties. Even for five hundred floating systems were not able to be designed. So, we were looking for fixed structures, but now more than 200 meters. Everyone of them is floating systems, because they become economical and easy to manipulate. You can see that structures have several configurations, later on when you refer various references or text books.

You will find that various configurations could be found like three legs 4 legs depending on the design requirement. Depending on the floor area and depending on this environmental conditions. For example, you have a 100 meter water depth, you put one single column. Typically we will be able to design what type of diameter is required. All of you might have studied your simple mechanics oiler buckling most of you have studied hopefully. So, if you look at the diameter versus length ratio. You could easily find that for 100 meters, you may need a larger diameter single pipe, but, if you put 4 columns probably, you could reduce. Because, the flexural strength will increase, because 4 columns are there, but if you have a braced tower something like this. You could also see the diameter can come down to as much as one meter or less.

So, the idea behind from single column to three column 4 column or six column or eight column is just to reduce the diameter, but why because the larger the diameter fabrication becomes too difficult. Number one number two even if you have a 25 meter diameter hundred meter long. You still will have a sensitivity against the dynamics. Later we will study in one of the course, why slender non redundant structures are not good for dynamic loading. Because, its potential is proved to be dynamic excitation.

So, that is why we have such a history of redundant structures with many lattice frames arranged together. So, that though it is going to behave like a cantilever, but at least you have a spread over a larger area or the dimension at the base is bigger. Most of the time we use 4 or eight three or six is very uncommon sometimes very rarely. We use most of the time, we have a 4 leg. Typically, like a tower you might see no like many towers on land. You go to transmission tower or you look at the water tank tower. Mostly, 4 legs three legs one of the potential problem with three legs is its asymmetric against loading 4 legs.

At least you get a symmetry in 4 directions asymmetry in diagonal directions, but three legs you get everywhere asymmetry and the directional dependant loading could potentially prove to be a disaster. So, that is why normally we do not use it. Of course, 8 legs is better again will be similar to 4 legs, but then it depends on the floor area requirement. If the area required for a process platform is larger.

Then you go for a 8 leg if the area required is smaller you go for a similar like a simple building design. You know if you have a building your floor area required is only just 20 feet by 20 feet. No reason to go for eight columns, because 20 feet any R C column or R C beam can actually span. Design is easy, but if you need a hundred feet. Then probably you need series of columns.

This is exactly the idea that we just, but it is not that simple. As what I have just explained, because there are other parameters will come and play. Even if it is say 20 meter 30 meter depending on the method of installation. You may actually change the number of legs from 4 to eight depending on, whether it is a launch method or a lift method.

So, there are various things that will come and play a role in selection of the geometry. The last one need to be a little bit understand this idea, what is called natural period. Most of you have some knowledge of dynamics in your B Tech course. At least the primary structural dynamics not so much anyway the structural dynamics is definitely a integral part of offshore systems without, which you cannot design. The idea behind is when you have a structure two cylinder the oscillation. I think you can go to maybe in the first semester you may be having a laboratory.

I think one of the lab they will be teaching you how to do a free vibration analysis or free vibration testing. You know if the such structure is too slender you will see that the oscillating period will be small or large. So, basically the idea behind the stiffness versus the oscillation, so if you look at most of the structures around a 100 meters 150 meters the oscillating period is around 1 to 3 or 3 to 4 seconds within that kind of.

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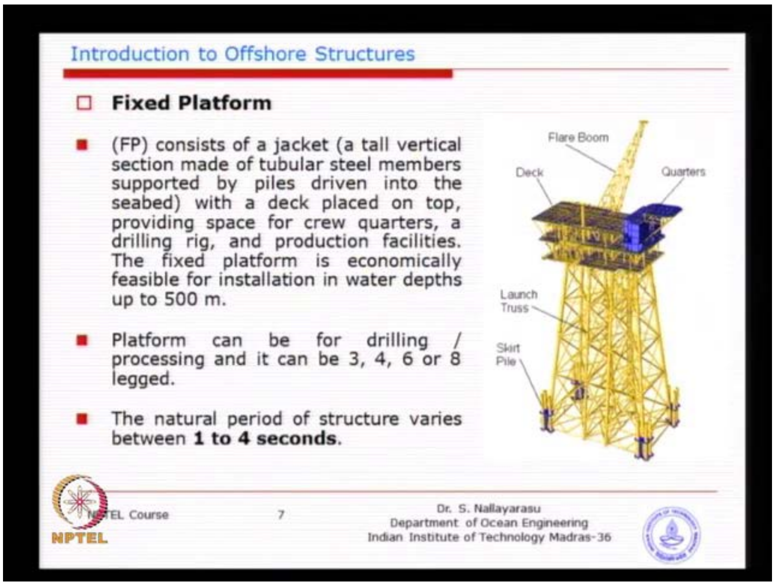

So, that is why this is very advantageous, because they are away from most of the sea waves, that you can see in many parts of the world. If you go around sea waves have a period of 4 seconds up to stage 16 seconds, but never ever come less than 4 seconds very rarely you get a small of wave three second period. So, it is a very good advantage that we are away from the their resonance going to happen. If you have the wave period and the structural vibrating period is very close.

So, once you know these two subjects then you can speak more. Let us not go into that right now, because you will be doing this dynamics course in this semester, I think or next semester. So, once you get into the dynamics of the system then you will realize the importance of this number, but historically it is proven that most of the structures have the period, because it is bottom fixed and have pile foundation to the ground. It is a frame structure, you will find that most of the vibrating period is less than 4 seconds, but if you take a similar system go to the floating system.

You will see that the periods could be as large as 20 seconds, 30 seconds, 40 seconds. So, you either have there or here you do not come into locking period of 4 to 16, this is very good. So, that is the idea behind we will see in the last slide. How people have designed over the period of last 30, 40 years either below 4 seconds or beyond 20 seconds, which is away from the, next one is the complaint tower.

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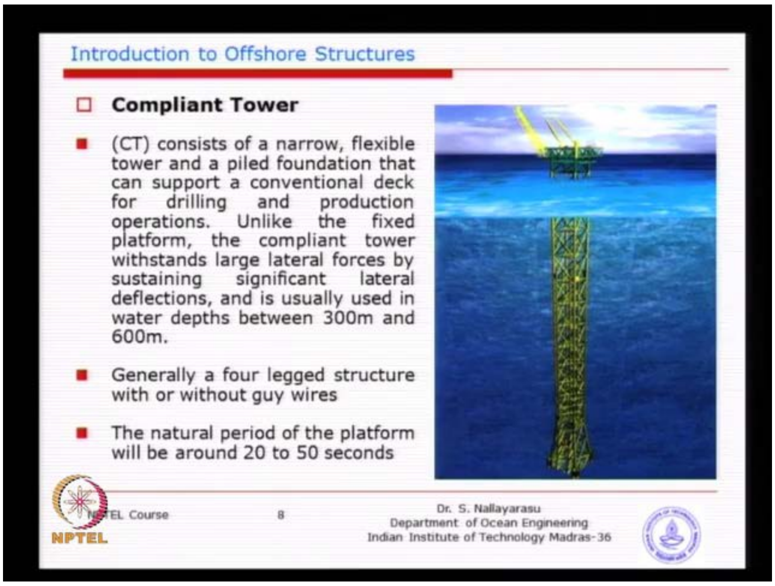

I think you understood the idea behind a fixed platform then we go to the fixed platform with a slender structural arrangement. That means the structure is purposefully made slender because the water depth here is too large. That if you make it large by base at the bottom becomes potentially expensive difficult to install. Then sometimes we have a you know the guy wires fixed to the ground, but that concept has not been utilised so far in the real field, except in very few locations because of the vulnerability of the cable to break. If the cable breaks what happens? The system becomes unstable. That is why very few locations, so called guide tower has been used. Otherwise, it is designed as a complaint tower.

So, what is the meaning of complaint basically when the wave forces act on the structure. It is not going to resist as a rigid structure it is going to get displaced. So, there is a relative motion between the wave and the structure allowing the large bending. What we do is we have a little bit of relief from the loading coming from the waves number one, but then how do we sustain that motion here. We change the equipments at the top to shoot such a large displacement from the sea waves. So, that means there is a certain price to be paid, because not all equipments will work. Typical example will be a drilling system. You expected a rigid platform for drilling now, if this platform has a large displacement horizontally. Typically about a meter or so, means those drilling systems or the equipments needs to be modified. In such a way that they would be able to operate, otherwise they will fail terribly.

So, this complaint tower is basically a simple idea that suited well for those time, when the water depth were larger, when the floating systems were not possible. We went for this type of system, but nowadays nobody is going for complaint tower, because we got very good floating systems available for the design, when the water depth is more. That is why if you go into the literature you would not find many of this systems, used in the past. Only very few if you count maybe five or six of them. So, the natural period is very large, because of the slenderness, it just goes beyond the wave. So, that is how you assign the structural strength. In such a way that you do not go into a locking period of say a 10 seconds 15 seconds. It becomes a potential problem, resonance will be creating a lot of trouble.

So, here the manipulation of the structural system is done in such a way that the period is going beyond, those twenty seconds. Sometimes, we use the tune massed dampers. In such a way that it go you beyond there. So, manipulation of the structural arrangement could be made, because it is very slender. The mass system at the top would make the larger the mass, at the top you will see the period shifting higher and higher.

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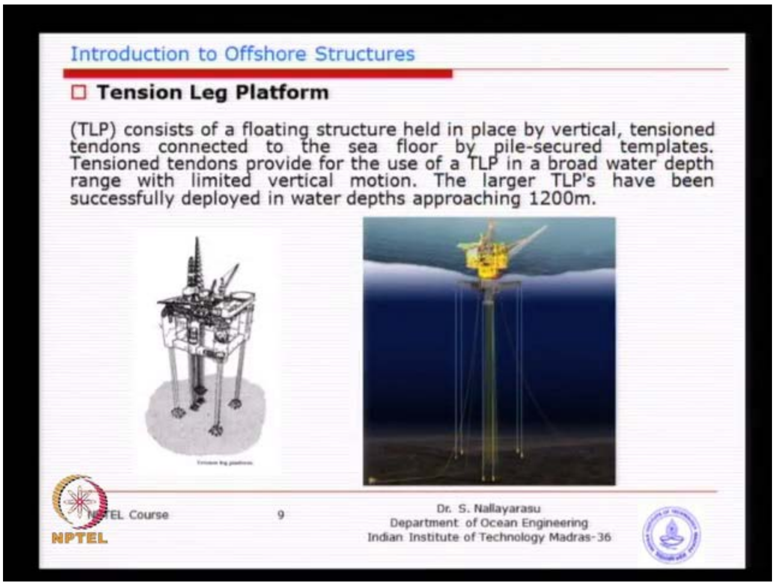

So, we have seen this earlier tension leg platform the concept is very simple. It is very similar to simple floating pontoon the load or the payload is at the top. It is floating, because you have excess buoyancy. So, you may see that if you look at that there is a horizontal pontoon is connected to 4 legs. Each of the columns is connected to the ground by means of tethers. Many occasions in the literature you will find tethers are mooring wires typical mooring wires, but in recent cases we actually have structural members tubes. Large diameter tubes attached to the hull as well as to the ground, which gives you little bit of horizontal stiffness also. At the same time you have a positive buoyancy, which creates always tension at the hull there the line after the line.

So, this is a variation of the second one is basically a mini T L P, which is very similar function. So, the load balancing for both of them is weight is smaller buoyancy is larger and larger the buoyancy more will be the tension in the tether lines. So, basically that is the idea behind and horizontal stability is achieved by means of the tether movement. Basically, there will be always there a delta movement horizontally, because you do not have a inclined mooring lines all of them are held vertical. This is very good for drilling, because the most of the problem for drilling is the vertical movement. As you can see heave movement is going to be a bigger problem. So, for example, drilling in T L P based platforms could be potentially very easy. Because, the heave movement will be very much restrained. That is why you will see that new last twenty years of development for deep water drilling, mostly based on T L P concepts.

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This is another one developed by as early as nineteen sixties and seventies, but never used this concept is very interesting. Basically, hinge at the bottom with a gravity base or piled base, but the vertical column as such is fully buoyant. So, you have a weight at the top as soon as the horizontal loads. Due to this wave forces attacked by the external forces to the column the column gets displaced, but because the buoyancy is available from this column. The buoyancy will bring back the column to the vertical position to or neutral position.

So, back and forth it will be achieved by the inherent buoyancy of the system, but one of the problem of construction is making such a universal joint at the bottom. It is only in the paper, so far nobody have implemented, this because it is so difficult to construct such a system with a large diameter. You could see universal wall joint in many of the mechanical applications, but they are all very small. You will see that fabricating and installing such a system will be very difficult. So, this articulated tower concept is very interesting, but practically not feasible, because of the construction difficulty and normally not used.

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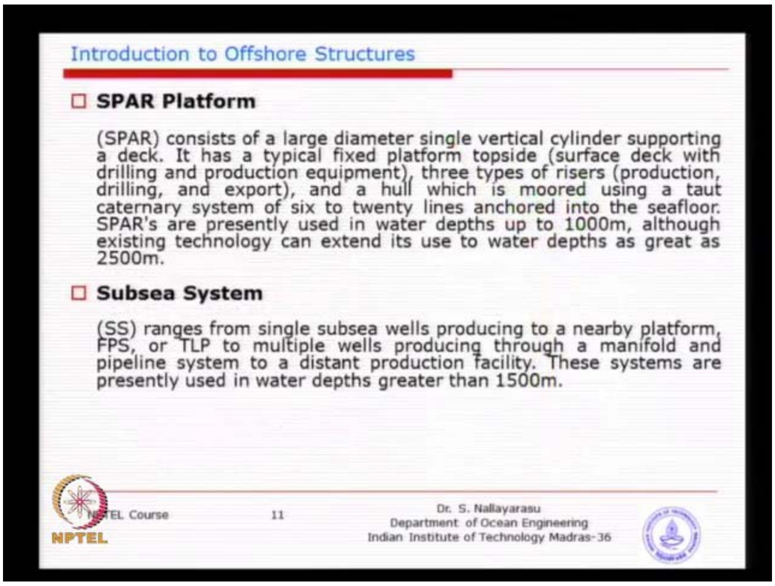

We have seen the spar platform I think there will be one picture. So, this spar concept is very common nowadays especially in deep water developments.

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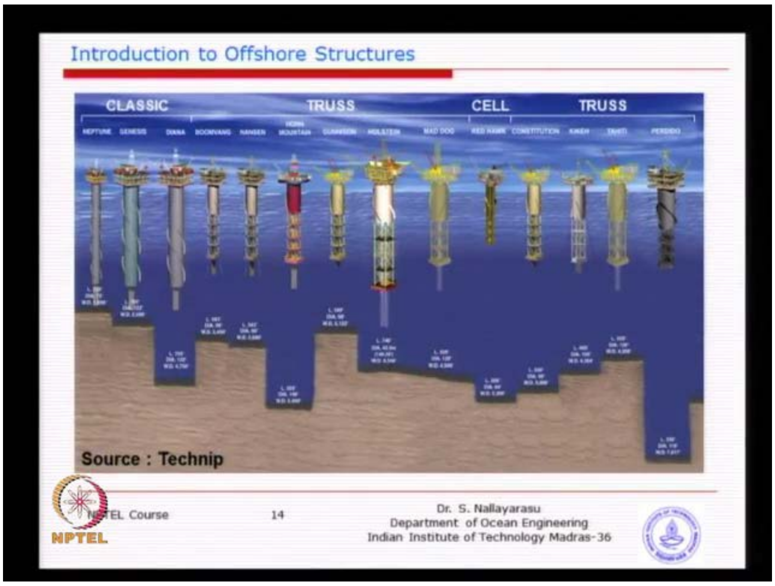

What you can see here over the period of time various types of spar, but the concept is similar is vertical cylinder with buoyancy sufficient, enough to hold the weight at the top and to float vertically upright, this is a very important idea. So, how do we do this we have a top weight. We have a buoyancy chamber, which produces or gives a sufficient buoyancy. Also, we have a weight at the bottom, which we call it ballast. So, that the centre of gravity is below and centre of buoyancy is above. So, idea must be very simple, so that it floats upright, but imagine if you take the same cylinder with no weight. You just put it in water, what will happen? It will float horizontally. So, we are just trying to manipulate this buoyancy and the weight. So, that it comes into this position.

Once it comes into this position then sufficient number of moorings to station keep is the simple system. So, the spar you can see a variety of variations truss spar cell spar. Instead of single diameter single cylinder you have multiple cylinders of same diameter or different diameters truss spar. Basically, the buoyancy is at the top, but the remainder part is made up of jacket. Sometimes, we call it jacket spar you have a jacket at the bottom, which is hanging from the floating hull and the top size.

The reason why we need this bottom part is basically to support the risers and conductors. Otherwise they will be too wobbly, so you do not want to stop too early, because the wave action. In this area could potentially prove to be problem for the risers. So, that is why you need to support them so various configurations, but the concept is very simple here buoyancy. Also, must be higher than the weight and centre of gravity and centre of buoyancy is manipulated, to give a vertical upright position and single column. So, that is the most important aspect. So, the stability is purely by means of manipulation of buoyancy centre and centre of gravity, whereas the multiple columns even if the centre of gravity is higher. You will be able to achieve the stability like a ship or like other semi subs or 4 column structures. So, this spar in the recent times is getting popular, because of its simplicity.

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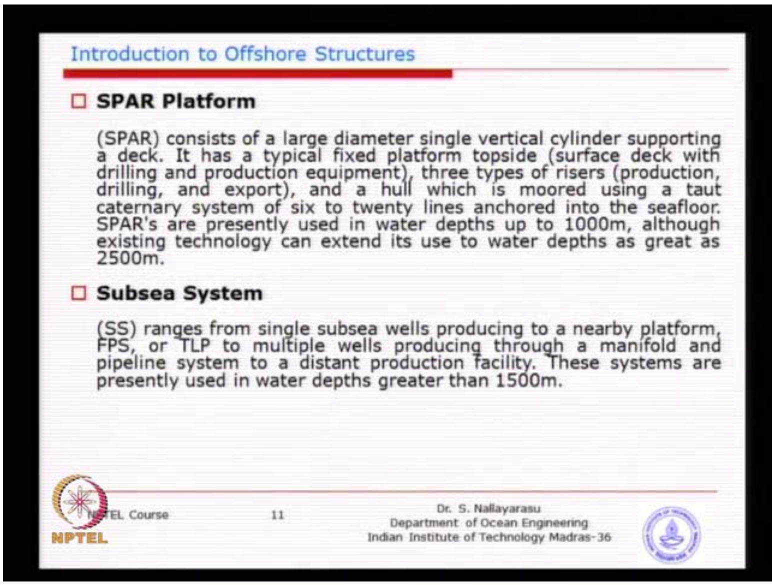

Ease of installation and cost efficiency is very high compared to other hulls. Many, times in the last twenty years almost hundreds of spar platforms have been installed in the deeper waters in seen some cases. We also have alternatives whenever the water depth is too large. Proved to be expensive to go for a floating system we come with a sub sea systems.

Subsea system is very simple, basically you drill the well, but then you do not have any structure. Basically, the well is connected from the deep water location to a shallow water location the similar concept, which we have designed for reliance back in 2000, 2000 two times the water depth is 1200. So, when the design contract was given to us. We came with an idea that the deep water at that time even 2000 time was expensive to go for floating systems. Basically, the well was drilled and capped at the sea bed the lines were connected to a shallow water around 150 meter. So, all the wells were connected in a shallow water platform.

So, this subsea system what is the difficulty is capping the well at the sea bed at such a water depth you need a special equipment. Now, that is where you get little bit troubled, because those equipments cannot be supplied by everybody. Only very few companies have the subsea system. So, that is when it is limited to few companies doing this projects, but this is proved to be very economical, because you do not need any fixture structure or floating structure in deep water. We will see that well configuration in one of the days. Then we have this floating systems conventional production system or floating production and storage and offloading.

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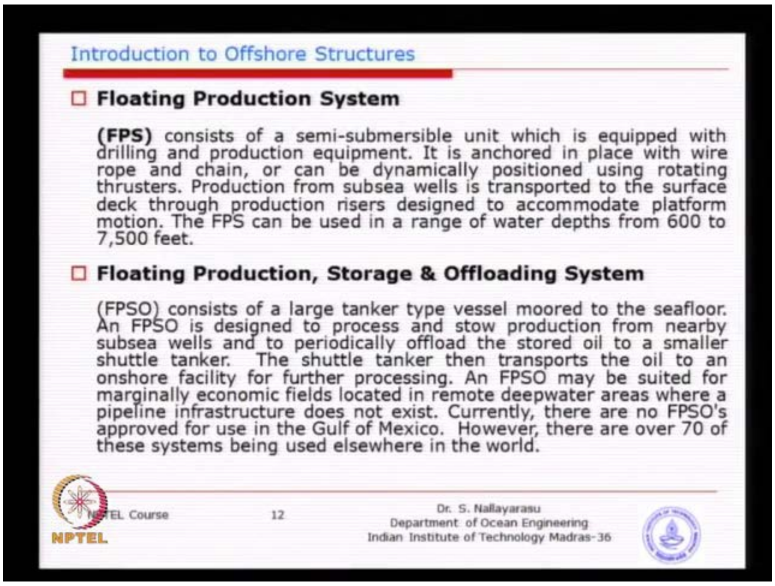

Either way when you have this you do not have the storage facility directly going through a riser and pipelines. Whereas, this F P S O means you have production as well storage. Then offloading intermittently to a tanker, this is very common even now for marginal fields. Whereas, for full fledged long duration fields you still have F P S O, but we call it F P S. Because, there is no storage and offloading, direct transfer by risers and pipelines something like this, you have a F P S O sometimes you have a loading buoy.

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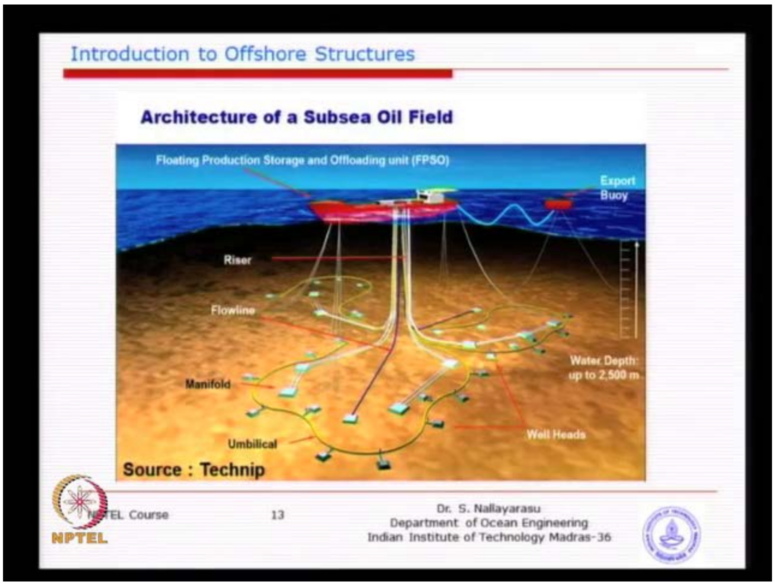

So, whenever the tanker is full with crude after producing for a period of time you bring an oil tanker transfer through. Then the tanker will take the oil away, so there is no direct lines connected. So, you see here the subsea the one that we were talking about many of the wells are connected to one of the floating systems. So, you could see that if you if you if you look at each of the solution.

You can actually combine anyone with anyone of the combination, depending on situation cost involved. The environmental conditions at the site the reason, why we did not go for this for east coast, it is because this is cyclone prone area F P S O station keeping could proved to be potentially difficult of course, can design, but then larger cost. Instead if we connect all this lines to a shallow water by pipelines and make a fixed structure, it could potentially be cheaper.

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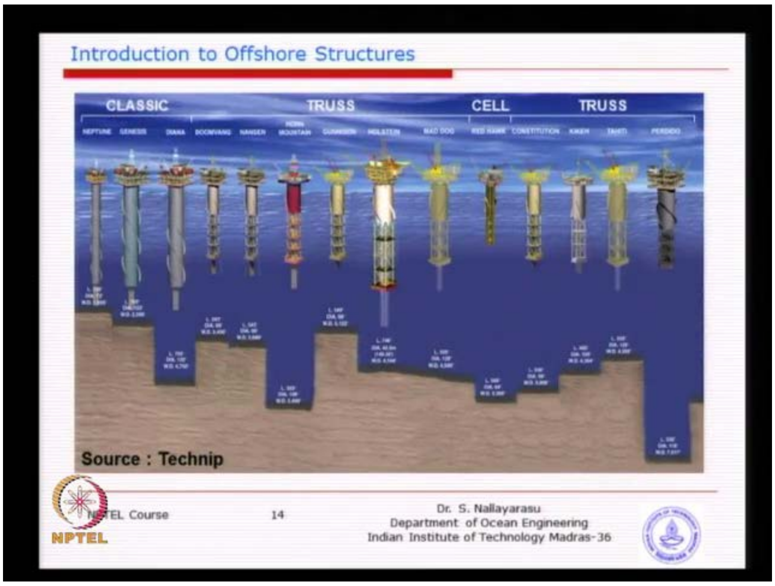

I think we have seen this spar based concepts. So, all of you I think what you need to understand is how the thinking has evolved over the time. Because, constantly trying to improve ideas. So, that keep two things in mind not only cost it is safe number one. Number two easy to install is the second, third is the economical consideration. Because, you could have cheaper solution, but cannot install it will become a potential problem.

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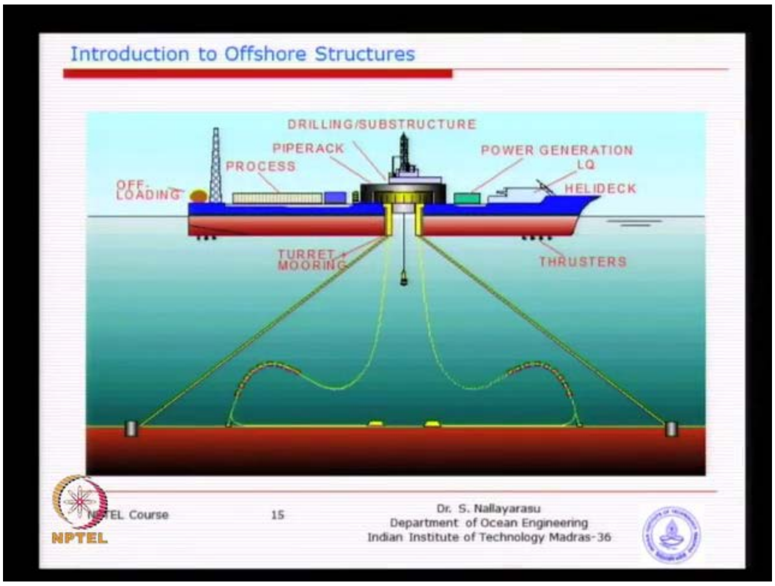

Then the F P S O of different kind you can see here have a mooring, which makes the ship to rotate about its centre of the axis. You see here there is a yellow colour bearing line. We basically we call it a turret, which revolves the ship the ship is going to revolve around this bearings at the centre. So, that means this is almost like a complaint system, it is a very weather van. We call it weather van, because whenever there is a wave or wind load on the system the system is going to the hull, is going to revolve around.

That means the load is not going to be attracted by the mooring lines. The mooring lines are only going to carry the buoyancy system, whatever the buoyancy available is going to just keep it. Some amount of movement, but otherwise it is only station keeping the inner parade, but the hull itself is not going being held in position by the mooring lines itself. Because, it is weather waning.

So, the only problem with this system is if there is a connectivity between the sea bed to the ship. For example, you have a riser typically transferring oil from produced this F P S O. If it has to go through this and then go to the land now this connection between this line to the ship, because the ship is rotating, imagine it is not a fixed part. So, you have one line coming, but it means to have a swivel.

So, that line also needs to rotate all the time. Otherwise, what would happen? It will just break. So, that is one of the difficulty where designing a rotatable and leak proof connection, between a pipeline coming from sea bed to the ship. It is a big challenge and of course, it is not something new. It is been in use for several decades people have designed multiple couplers. Where, it will be able to rotate at the same time no leakages come through.

So, link we have several companies applying such kind of mechanical components. So, that is one difficulty, the second difficulty is designing a bearing system by which the whole ship can rotate. It is not such a small bearing like what we see in motors. So, it is going to be a diameter of that bearing could potentially be 20 25 meters. So, you could see a large bearing by which it could revolve around.

So, this has become very common in the F P S O. Because, you do not have a mooring line problem, because mooring lines are not taking any load here, but this you see at the centre of the ship. You have made a big opening normally. This is not very good weakening the ship by sufficient to fail. So, this normally adopted for new build F P S O, if it is a old F P old tankers converted, you see here we normally do not break at the centre.

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This is actually a old tanker converted into a F P S O. There we put the similar turret at the tail end. So, that you do not need to actually do a lot of modification to the hull, because otherwise it becomes a big project. So, the difference between this and this is the location of the turret the meaning of the turret is holding the ship at particular location. At the same time relieving the load by allowing the rotation of the ship, above its axis of the turret, you got the idea simple idea. So, this is internal turret this is called external turret, because the turret is located at the one end or most of the time it will be in the stern end. Sometime you can see slightly inside also instead of exactly outside. You could also see at the, slightly few different cartoon pictures of various ideas F P S O.

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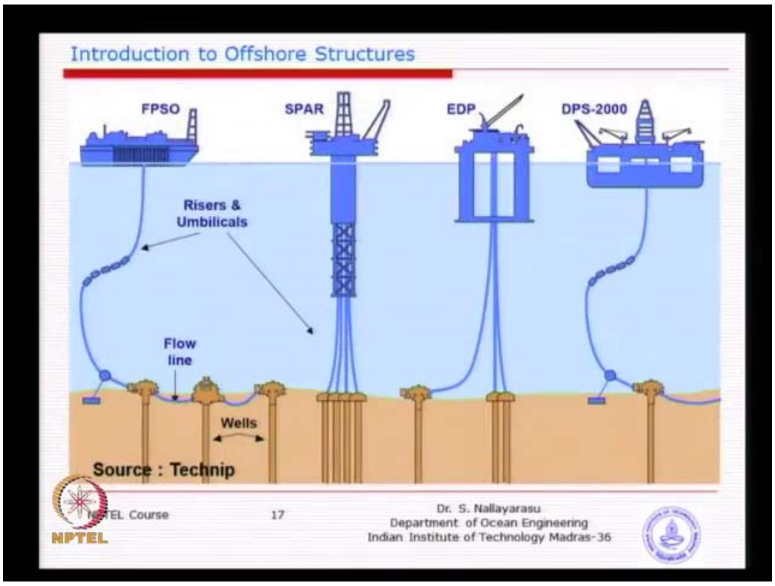

Sometimes, you have a riser of this kind spar drilling platform extended drilling platform similar to semi submersible. Then this is also a drilling system from one of the companies D P S 2000.

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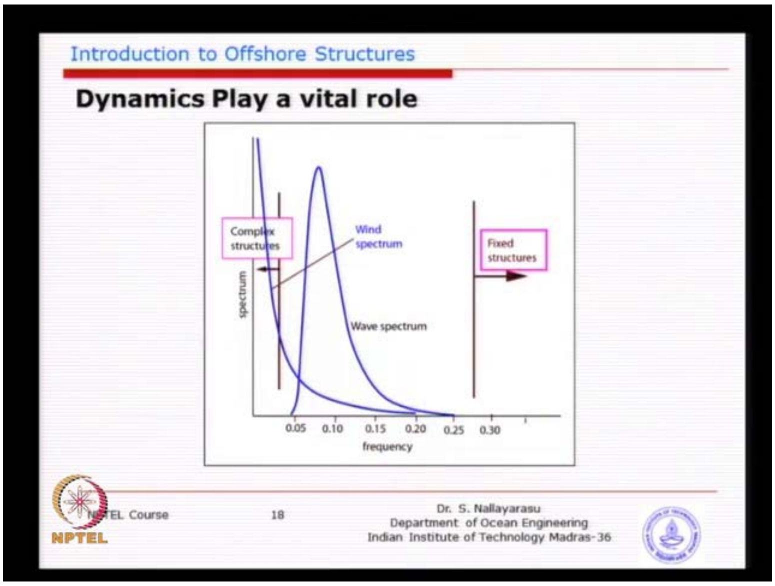

So, this is the picture we wanted to show before we complete the lecture today. Basically, you see here the frequency of the wind spectrum. The frequency distribution of wave and you see most of the picture structures. Actually, I should have drawn in period instead of frequency, it would have been easier. So, if you convert about 0.2 0.53

will be falling short of 4 seconds. So, if you are having low frequency components like you see there the wind is even very low compared to the wave spectrum. Later on you will see in your hydrodynamics course. This is true for most of the sea stage you go all around the world.

So, having a fixture structure in this fashion avoiding the peak energy area of most of the spectra will be better, because the excitation and the associated resonance will not happen. That is the idea behind this corresponds to about 4 seconds this corresponds to about 14 , 16 seconds here about 20. So, this is about 5 seconds, this is about 16 seconds. So, you can see there it is a interesting idea that the people have derived a device the system in that fashion.

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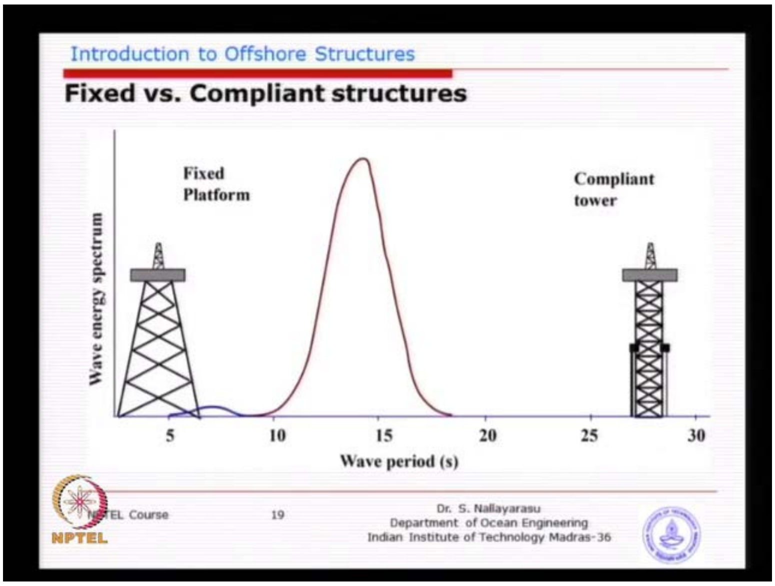

Something similar given in period fixed versus compliant. So, the most of the energy content of the wave will be about in fact between 10 seconds to 16 seconds potentially very large energy magnitude. Whereas, the fixed platforms we keep it in this side the complaint tower or floating system is going to the other side.

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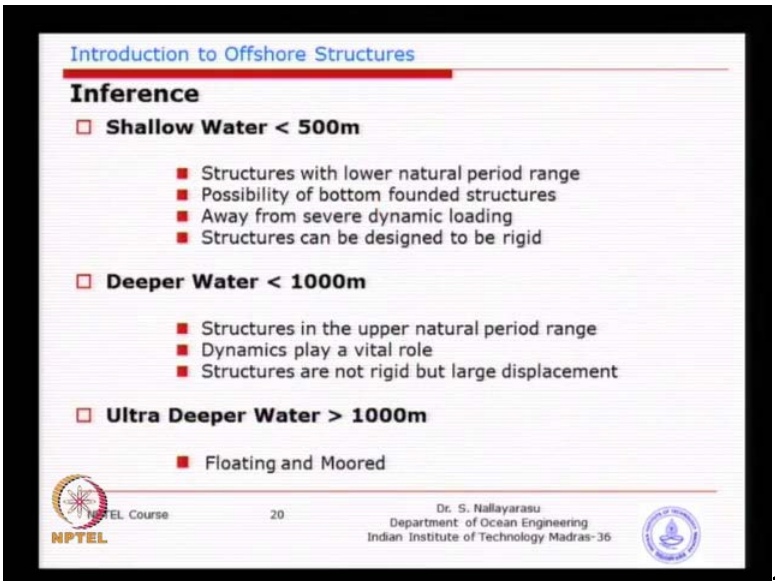

What we will try do is we have few more slides. Then we will try to complete today itself. So, basically the idea of shallow water deep water these numbers are not very strict 500 meter could be a deep water several decades back. Today 500 meters is not as bad as what we were we were thinking about 20, 30 years back, it is becoming very much shallow water.

So, it is a gradually changing trend today we think 1000 meter could be difficult to do a project, but proved to be easy. Afterwards, ultra deep water most of the time we go for a floating and moored systems deeper water. Still talk about floating systems or semi floating systems or some very large fixture structures like 675. If you go into net search for largest deepest jacket. You will find one of them installed is 675 most of the shallow water conventionally, jackets but then some of the recent projects prove, that even in 300 meter water depth people are using F P S O. As the reason that I am trying to explain is very good, because economical, relocatable and you know very cheap.

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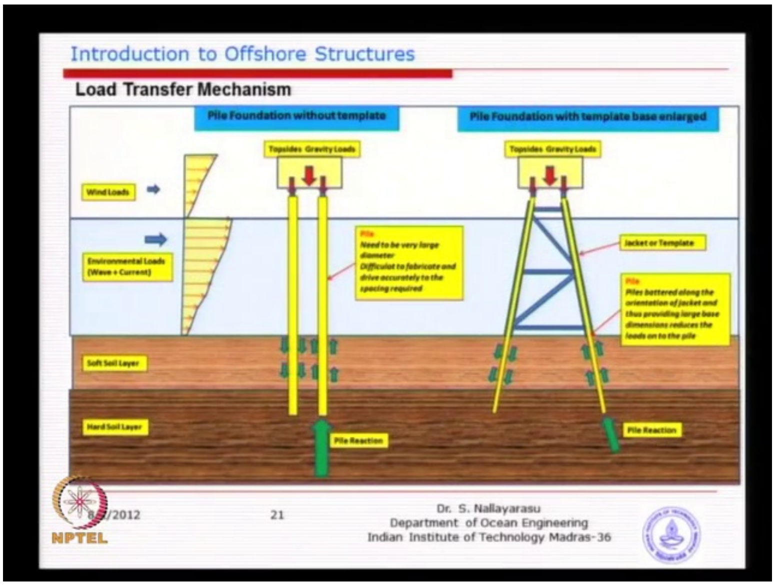

We will just focus on what exactly the idea. We were discussing few minutes back about the load transfer for fixture structures. So, that tomorrow we can move on to a new chapter. So, you see the first one conventionally a individual pile. You might see this type of construction. When you go to a coastal areas or even land you drive several piles and fix up a super structure on top. Something like this you have a cylinder system one or two or three. It depends on the load carry capacity.

Basically, you see this is the starting point of a piled structure you have A S tubular or other forms of piles is driven into the ground. And bring an installed super structure, but one of the problem here you see here the super structure is brought from somewhere. Because, it is free fabricated is it not? Because this platform is installed in the middle of the ocean, now to fabricate this in that location becomes a bigger worry. So, normally what is done is you pre fabricate mostly con not concrete mostly steel structure. So, that you can transport easily without much trouble and put it on top. So, if you see there in this picture the spacing of these supports have to be prearranged.

Now, installation of this pile at a pre destined distances between each of them have to be very accurate. If you install by half a meter incorrectly, because this is already fabricated isn't it? When you bring it and install on top, it may not match the support points may not match. So, what will need to be run you either need to change the location of the pile, which proves to be very difficult number one. You have to change the super structure.

So, how do we avoid this basically a simple idea that you provide a template for pile driving. I think most of you might have seen the templates for driving nails driving other forms of structures, just make a opening on the sea bed with a template. You drive the piles at that predetermined location, so that this can be easily installed to a prefixed dimension.

So, that is the idea behind, you see the next picture instead of making a template only at the seabed, because again the piles could prove to be opening at the top, because of the wave load. So, you have a template, which is just in dark blue colour made of a steel frame only for driving the piles. So, the idea behind the method of called the jacket design is nothing but a simple template only for driving the pile. Once you do this system the pile need not be very large. Because, it is fully braced system the pile is going through a frame. So, while doing this what has happened is the pile has gone through without any problem at a predetermined spacing, which was designed to be required by the super structure. Number two the pile has become smaller, because is fully braced connection. So, the slenderness ratio of this and this could potentially be different.

So, that is why we sometimes call it template type of structure. Sometimes, call it jacket type of structure. So, you see here the load transfer here primarily bending mostly little bit of actual transfer happens. Whereas, here primarily axial, because you are going to decouple the horizontal loads as axial loads on the columns. Because, it is a fully braced frame and more stronger. Basically, how do we prefabricate this, so called template, we have to bring it before we bring the super structure. So, that means that is exactly we are going to learn in this course, how do we prefabricate, how do we transport, how do we install. Then drive the piles and then install the super structures. So, the various activities are involved.

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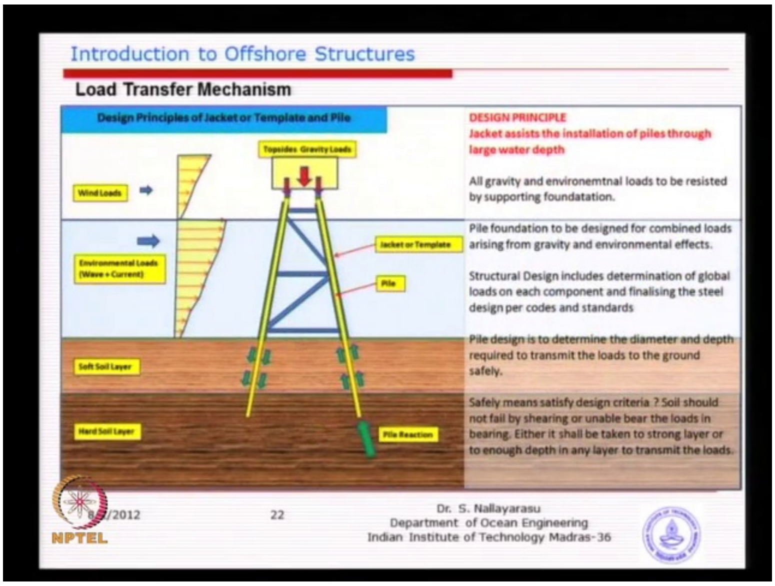

Now, you see here while doing, so you could see that this load transfer mechanism instead of vertical columns widened column base to reduce the load. If you imagine if you make it vertical the load on this will be smaller or larger. It will be larger because the base is smaller. We can easily do a simple hand calculation the horizontal load multiplied by the height or the centre of load will give you the movement or overturning movement divided by the spacing. The bed or the sea bed will give you the reaction very simple calculation. So, the larger the width at the base you will find that smaller the load transfer to the soil and the foundation. So, basically that is the idea behind.

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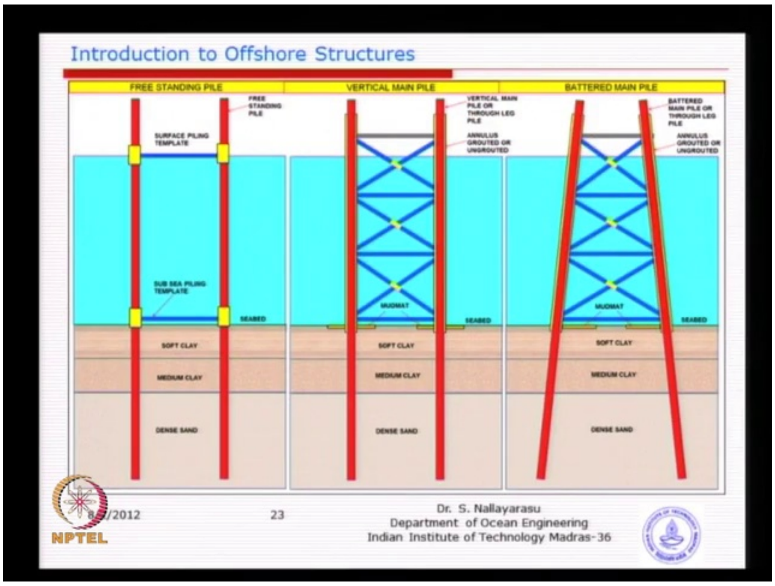

On several cases you see this three pictures how people have been thinking that you have a template at the bottom template at the top, which controls the spacing, then instead of that, because holding this two things together will become difficult. How do we do it? Somebody have to hold the top and bottom without dislocation during pile driving. So, in order to achieve that you make a steel truss world few members, it becomes a simple template, which happily anybody can drive the pile. You see the last one, which is just a manipulation of this to reduce the pile load. Because, I wanted the base to be bigger, I think it is a simple idea to transfer from one concept to other and the last one you can see there.

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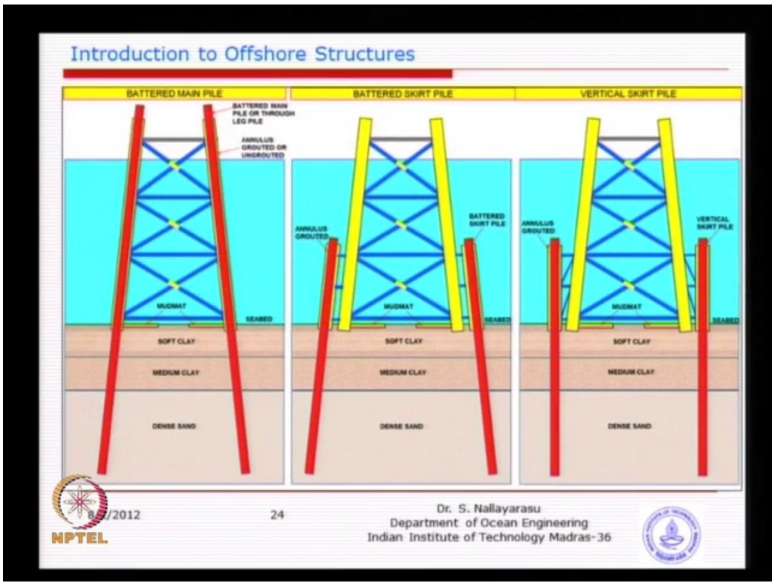

When you see this picture, you install this pile through the leg the pile and the column is duplicated. Whereas, you go here the column is separated from pile. So, that what you can see here the wastage of material inside the full length of the column is avoided, only difference is the pile has to be installed through a underwater system. So, this is called skirt pile, this is called main pile. That is the difference there the pile through leg is called the main pile. Whereas, the pile is driven through additional skirt or additional sleeve is called skirt leg pile. It is just a difference you got both of them vertical inclined. The last one we made the pile to be vertical, which facilitate the installation quite a great extent.

So, you can see from the last two pictures how thinking was put together constantly to improve and reduce the cost and reduce the risk in offshore installation. So, basically this jacket design is not something new. It is been there for several years and decades. In fact it has become a very simple projects, nowadays for jacket design. So, we will look at the next chapter tomorrow I think, any questions?

So, I think today yesterday and today we have seen what is the necessity of offshore structure? I think most of you have understood. Basically, various systems available and the one that we are going to focus for this project, for this particular subject is fixture structures. Under fixed structure a typically a template, which is used as a pile driving facility actually the jacket is not something that is built for other purpose. It is only for driving the pile at the predetermined spacing. Number two is increased base, number three reduce the slenderness, because you got a braced system. Basically, we will see the developments how we can achieve this pictures.

When you see here how do we achieve this three stages fabrication of jacket fabrication of super structure pile driving. Then jacket should be transported from land because everything is fabricated on land. So, you will see maybe tomorrow we will go through one sequence of transportation from land and to the final location. Maybe one or two classes is required, then after that we will go to the design.