Dynamics of Ocean Structures
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Module - 1
Lecture - 2
Introduction to Different Types of Ocean Structures II

We will welcome you to the second-class module one, on the virtual classroom course on Dynamics of Ocean Structures. So, in the last lecture, we started to discuss about various types of offshore platforms. It is very important for us to know that, how these platforms are categorized, how they are classified ? Because, the dynamic analysis of these platforms actually depends upon the category or the classification.

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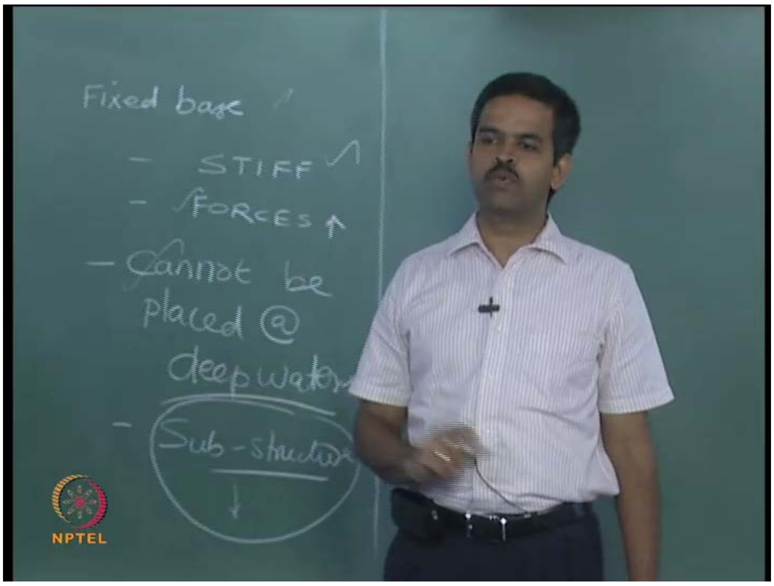

So, in the last lecture, we quickly saw that one type of platform, which is having a fixed base. Just to recollect that, we said that these platforms are very STIFF, as a result of which they attract more FORCES. So, it is very important for us to know that depending upon the classification of the platform, how structurally the platform is going to behave? What will be the inbuilt dynamic characteristic of the platform because of its geometric configuration? Because, these two factors become very important for dynamic analysis. So, we are talking about these when we speak about the classification of the platform as such. So, we will again continue to discuss different types of ocean structures in this lecture as well. We will have one more lecture on this subsequently.

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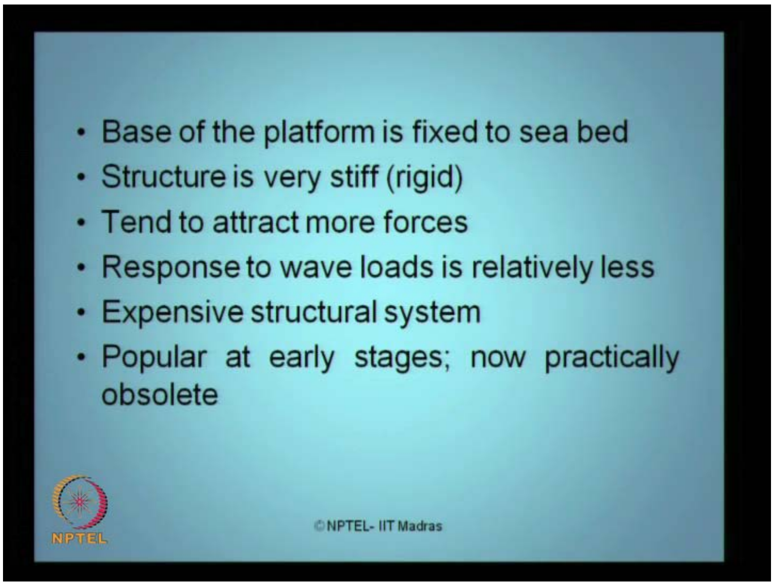

We talked about fixed type of platforms. We already said that the base of the platform is fixed to the seabed; structure is very stiff what I assume as rigid in my analysis. It tends to attract more forces; response to wave loads is relatively less, but the structure is expensive. It has its own problems related to the scouring of seabed etc. Very importantly these kinds of platforms were very popular in the early stages, but now they are practically obsolete. You do not have these platforms now. They are not attempted to be constructed because of a very simple reason. These platforms cannot be placed at deep waters; it means, that water depth is also now playing a role in selecting the geometric configuration of offshore platforms.

It is very interesting for us to know, that offshore structural systems are one amongst the unique system, which is governed by the location where it is being installed. So, if you compare this for any other kind of similar structures like bridges, like land base buildings, like tall buildings, schools, any other functional building, even monument structures, you will note that only the sub structure, may have a variation in method of the foundations etc.. In offshore platforms accordingly, even the super structure will be checked. So that is a very interesting problem, because, once I have a change in the whole structural system, sub structure and super structure as well, the mass of the platform changes and mass there becomes a very important identity for my dynamic energy.

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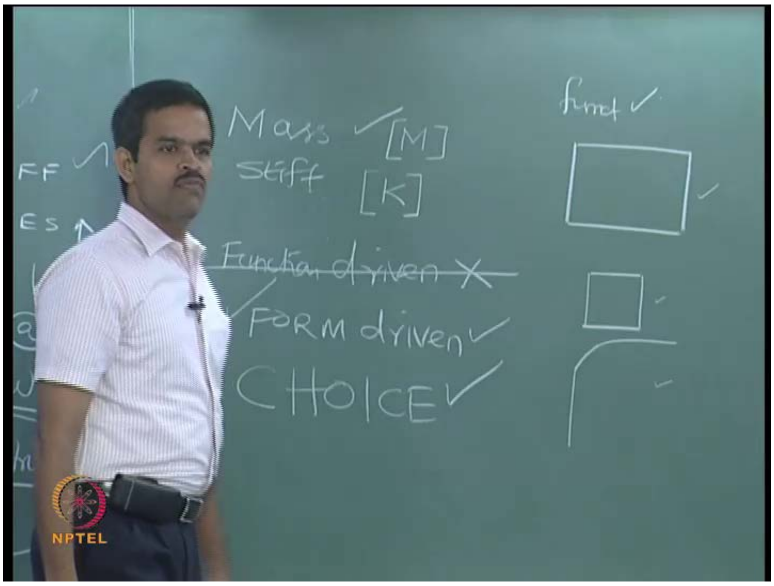

So, we have attempted to see two things. One, how mass is getting slowly focused in the platform geometry. We also saw, how stiffness is getting focused in the platform geometry. So, in dynamic analysis, we assign this with the notation mass. I am putting a matrix symbol, because, it depends upon how many degrees of freedom you are assigning the mass. We will talk about that slightly later. I also put again a matrix symbol of stiffness K. These are all international system symbols and notations; m stands for always mass, and K stands for always thickness. We will talk about the units, how to arrive at them, how to derive these for different platforms, later.

But slowly the focus is getting towards two important characteristics of dynamic analysis. Mass, is of course, the combination of substructure and super structure, and super structure will have more added values because of top set configurations, which I will show you in the next slide. Mass gets altered based on the location and water depth. Stiffness gets altered depending upon the functional characteristics of the platform. Therefore, in dynamic analysis of ocean systems, you do not have any control to play with these characteristics. Because, it is not function driven, it is FORM driven. What do you understand by form driven? and what do you understand by function driven? I can give a very simple example.

I want to design, let us say, a drawing room. The shape of a drawing room may be rectangular, may be square, may be having a curvi linear profile. So, you do not find much variation in the form, but the functions of a drawing room can be different. So, what we try to do in general design is, form dominates the function. In this case, I am not interested about the function driven design. I am focusing on the form driven design, because, form will focus, at what depth I should install what kind of platform. Whether the platform should have a fixed base, whether it should be compliant and floating type, should it be a semi-submersible, should it have enough buoyancy, should it be neutrally buoyant, should it be positively buoyant?. All are essentially derived from the form. And form will control the mass and methodology of installation will control the stiffness.

So, it means in dynamic analysis of ocean systems that your major focus is not on the characteristics of the system. It is essentially from the form of the system itself. That is why generally in offshore design systems, your design and selection of the platform type matters a lot. If you look at this comparison with analysis of any other structural system, may be shell structures, which is also form driven, may be any other rectilinear plan buildings, which are onshore based system. You will first select the form, which is more or less standard. Function is not seriously altered and dynamic analysis becomes more or less categorically simple, except for the configuration problems in the sub structure. Depending upon the foundation system you may have some complexities in the dynamic analysis, when you include soil structure interaction in land-based systems; whereas in dynamic analysis of ocean system, you start the complexity in the beginning itself by choosing a form itself, which is complex..

We must understand, which form should I choose, for what kind of installation. So, these two lectures, will give you a feeling that what are the different forms constructed elsewhere in the world, how are they structurally behaving under the environmental loads, and from that we will drive the important characteristics of mass and stiffness? and further more characteristic I will follow in the coming lectures, how do it derived. Any questions here?

We must appreciate, that why ocean structural systems or offshore structures, in general, tend to became unique, not only in construction and installation, but also in analysis and design. We do not have much of a choice, we select or choose a form for a specific requirement, which is of course functional base; there is no doubt. For example, the platform selected for drilling, which is exploratory may be different from drilling, which is productive. So, there is the functional component in the selection of the platform, there is no doubt on that, but that is not dominated, because my platform geometry will get dominated depending upon where I am installing it. For what I am using it for becomes secondary. Whereas in any other design, if you see, function slightly dominants that there is a close coupling between these two. But in ocean structural systems, it is slightly deviated. Therefore, dynamic analysis of these structural systems becomes more interesting and more challenging. , is that clear; any questions?

You will see that for every form, which is been selected for different applications they should not and will not look alike, because every form will have its own problem. When people analyzed it, when they reconstruct another structure of a similar form, they do make alterations. That is why you do not find repetitive designs and forms in offshore structures, because every form is site-specific and it is not function specific; that makes the difference. Therefore, they are unique.

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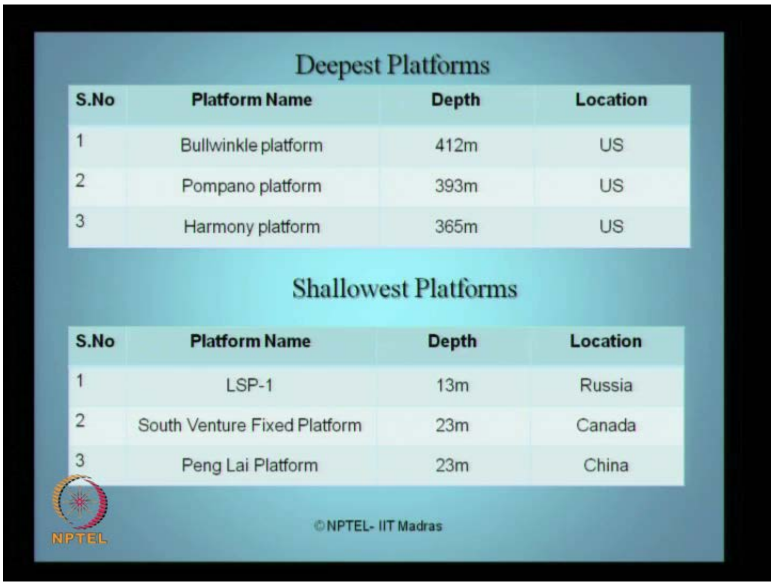

Let us quickly look at some of these photographs of the forms. These are some of the platforms constructed elsewhere; the deepest and the shallowest you will see. Obviously, all of them are in United States. The deepest one for a maximum depth. Fixed based structure has gone till 400 meters approximately. The shallowest platforms are not located in the same part.

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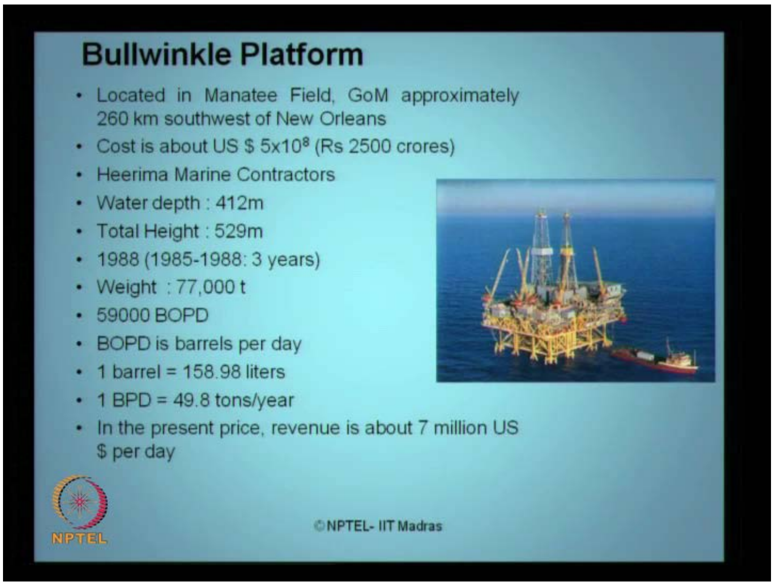

We will see all the photographs of two of the platforms. A Bullwinkle platform, where you must have seen, it is open source literature. It is located in a Manatee field Gulf of Mexico, which is approximately 260 KM of North Orleans. Cost of this is about 500 million dollars. Heerima marine contractors built it at the water depth of about 412-meters. Total height of the platform is about 530 meters. All these dimensions will be very amazing, if you compare this to any land-based system. This is as good as about 120-store building, because if you look at the building height as about 3.6-meters approximately or four meters.

Let us say to make it easy 5-meters; it is close to about 120-store building which is an amazing structure when it is land based. So, it is all not very unusual constructions. They are all unique in dimension, in its location, in its function and of course, in its cost also because they are very highly priced. Built in the year 1988, it takes about three years approximately for the completion of platform. Weight is about 77000 tons. It is a very heavy mass base system as far as fixed platforms are concerned. So, I want you to understand the evolution of how the platform mass moved from a heavy base system to a floating base system. why it was moved? And what was the reason?

77,000 tons is really a tremendous mass for any structural system of this order. It produced about 59000 BOPD. So, there is a clarification here required for all the ocean engineers or offshore engineers to understand. What is bopd? BOPD is the barrel produced per day and one barrel is approximately equal to about 160 liters. So, that is the amount of oil being produced in one day then understand the value of the reserve, which this platform generates. if you look at it in the present cost it approximately comes to about 7 million US dollars. If you look at the cost of the oil today in an international market, the revenue generated by this platform is 7 million US dollars in a day. That is why they could invest around 5000 million. US dollars to construct this platform. The revenue is very high; phenomenally high cost of construction and therefore, unique. That is the reason why these platforms are not constructed very often. They are very rare. They do extensive survey to carry out the detailed analysis before they construct such platforms. They are not always, constructed very often.

They are very rare that is why you have seen the last slide we have got only about 5300 odd platforms all over the world. It is not important how many of them do we have in India, but in general we are talking about the prescriptive in the international scenario. So, these examples will give you an idea that what is the material being used in this kind of construction and what is the material expected to be used in this construction steel.

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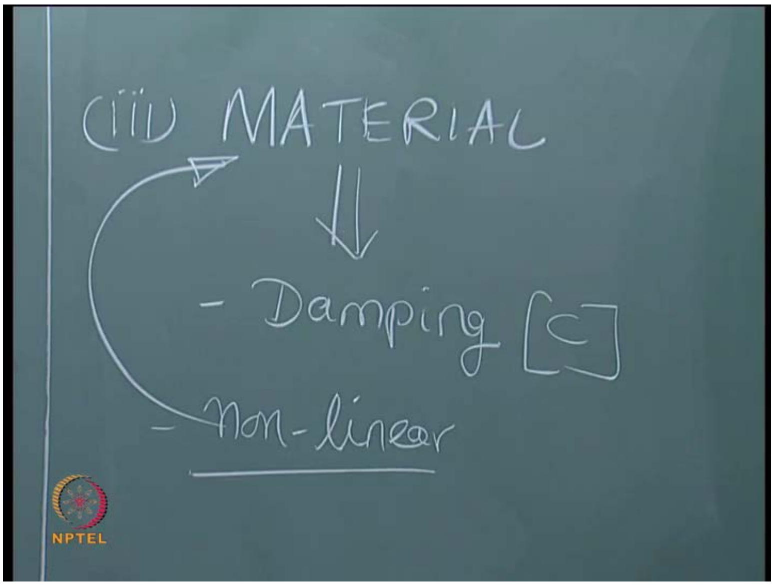

So, other characteristic actually comes from here, is a third one. You may wonder why I am talking about material in dynamics.? Material may be interested for construction technology and construction management and to practice cost management etc. I am talking about material, because I am going to derive a very important concept from material, which I am going to say damping. It is of course, an important characteristic in dynamic analysis, which is indicated by C. There are varieties of damping; material based damping is also important for us. I will talk about non-linear dynamic analysis, in the later module. When I say nonlinearity, it is essentially a material-dependent characteristic.

I must understand that the material can become non-linear under the given forces. Can I stretch it to a non-linear regime? I must know this. Essentially the material what you see here is steel but does not essentially always. There are other materials also coming up, which I will show you. Because the moment you say steel, it is the only material possible for this construction then. I cannot compensate on mass because steel density is fixed. But if you want to compensate on mass to make it floatable or a float, then, I must have a material, which actually floats or whose mass is relatively lesser.

So, when I talk about form driven design or choice, I have to work on mass the moment I say material is only steel then. I have no option that is how the evolution of platforms started actually initially. It was some steel even now steel platforms are constructed, but there are other material also playing on. So, material selection is also important in dynamic analysis indirectly for me, when you talk about damping characteristics of the material and nonlinearity, if I wish to do a non-linear dynamic analysis. Any questions here?

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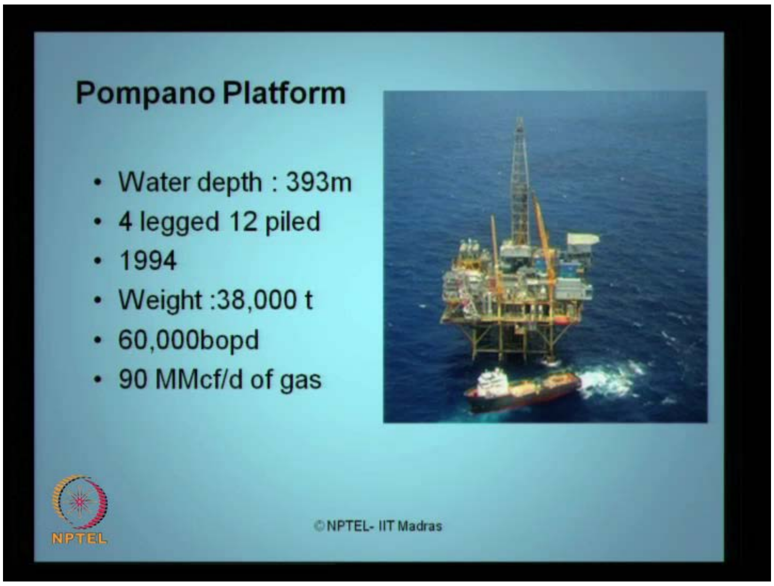

So, there is another platform which we have pompano platform it is another example, classical example, of a fixed base structure water depth of about 400 meters 4 legged 12 piled system constructed 1994 38000 tons weight 60000 bopd and of course, volume of gas.

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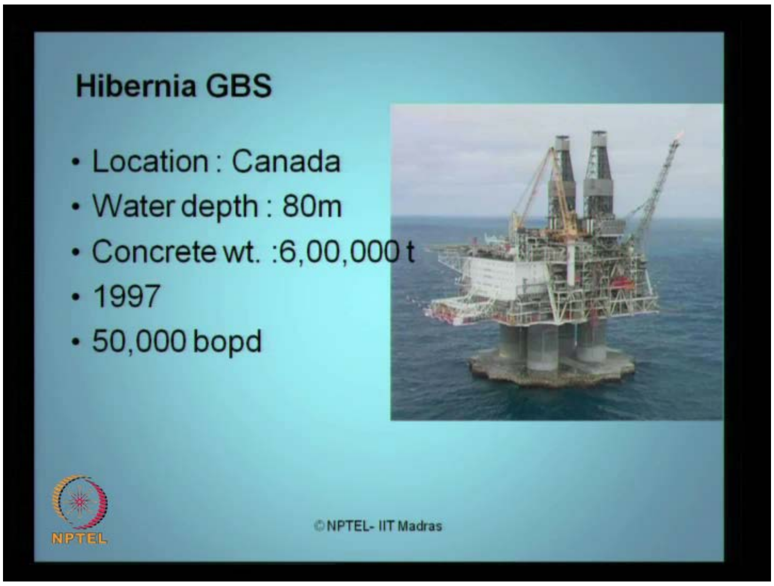

Hibernia it's the gravity based structural system. Which is GBS platform, you can see now, the foundation system has slightly altered with respect to the previous platform Hibernia platform here.

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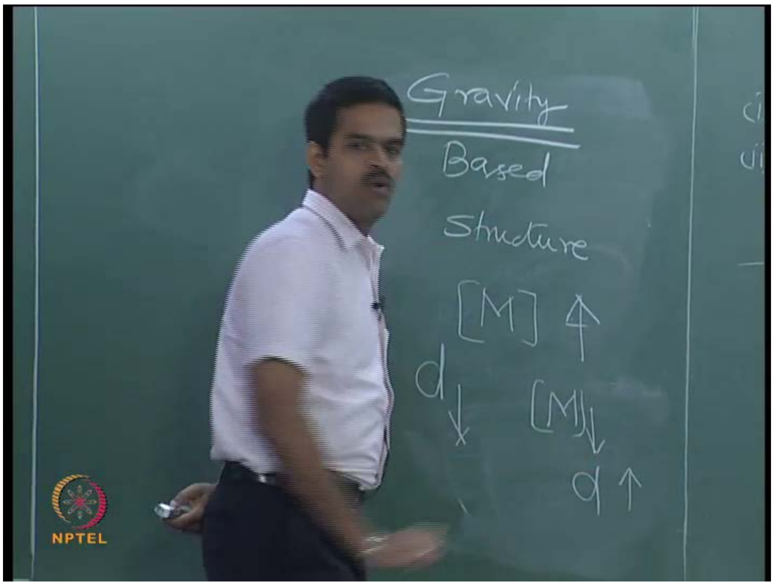

This is a classical example of gravity based structure. It is the another fixed based platform which I call. So, the name itself suggest that the structure is having a very high volume of mass very high value. So, it does not want to rest on the sea bed at its self edge that is we call this as gravity based structure which is also a fixed base it may not require a pile foundation located in Canada 80 meters.

So, you can understand that, when I go for a huge mass system. The depth where in I put is reduced. When I go for a light mass system I can go for a depth at a higher volume. It means, there is a proportion which is connecting water depth, where you are going to install to the mass of the structural system, which you are selecting. So, this indication what we learned from this three examples, very simply that when I go for deeper and deeper I can go for mass of a lower value when I go for higher mass I cannot afford to build it at a greater depth therefore, essential reasons are two one of course, the cost.

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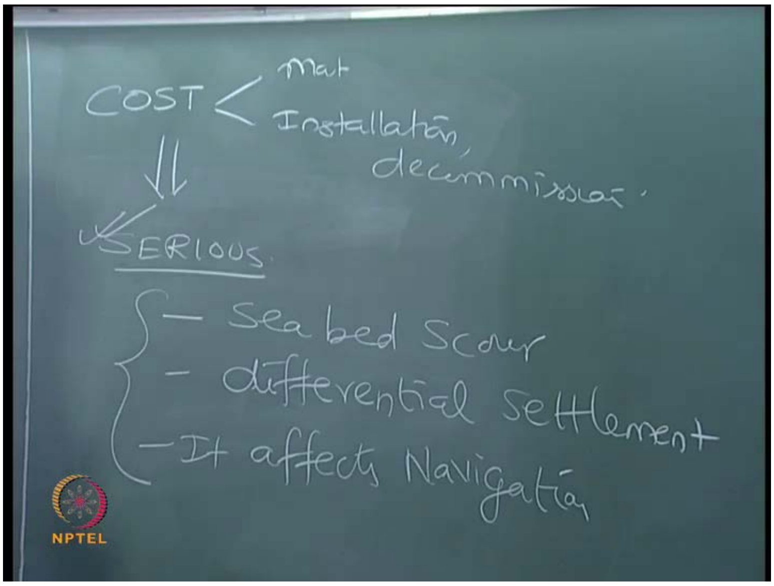

The moment is say, cost. It is not the cost of construction or the material, it is the cost of installation decommissioning all as I said in offshore platforms. We do not bother about the cost much, because when we find an oil reserve then cost may not be very important, but, why I am talking about the cost here indirectly is that, it causes other serious problems for example, sea beds cover sea bed erosion it causes differential settlement. It affects navigation. So, these are all serious problems as far as massive structures are concerned one such example, is gravity based structure which you see here Somen

Hibernia GBS platform you can see the weight constructed in 1997 50000 BOPD and so on so forth.

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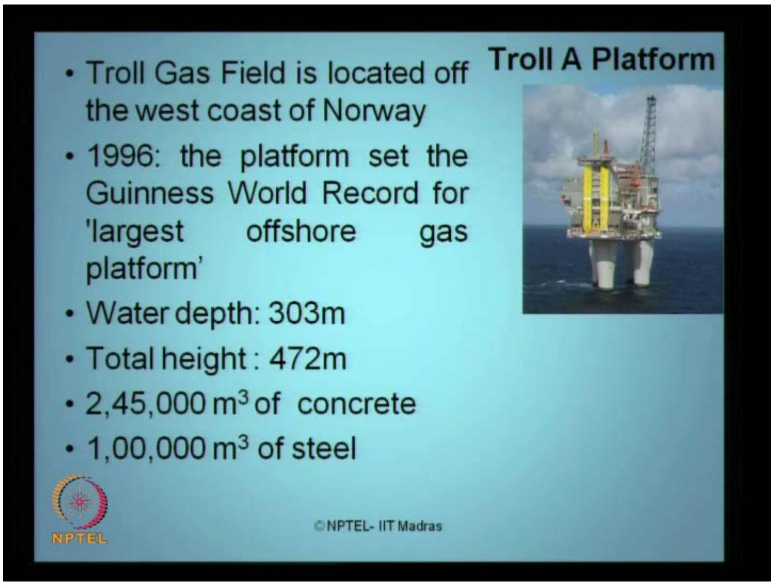

Troll, a platform constructed in Norway, we can guess what type of structure is this. It is again the top side is essentially the steel whereas the pile foundation etcetera, substructure is efficiently concrete interestingly ladies and gentleman 1996 this platform has set a Guinness world record this was considered to be the largest offshore platform then in 1996. So, offshore platforms are not only unique, they are also in the Guinness book of world records, because of its capacity size installation many reasons.

Not of course, because of the cost you can't record it in terms of cost any reason. Why we are not able to actually award a Guinness record based on the cost index what is the reason for example, I have a pen which is unbelievably, let us say, one crore or 100 million US dollars. Can it be considered as a Guinness book of world record pen, because it is so expensive? Why cost index not considered as one of the parameter to evaluate the Guinness book of world records? For example, why size of course, is there as becomes smaller and smaller, it can get a name in Guinness book of and it is larger and larger?

It can get the name in there, but cost is never being indicated, because cost cannot be normalized in different parts all over the world, It cannot be normalized, it fluctuates every hour, every minute. It fluctuates actually. That is depending upon the economical situation of any country. So, Guinness book of world records in universal parameter which has got to be normalized about all the countries. But, cannot be right it is cost factor is not important here it is considered as largest offshore platform. So, total height about 472 meters, volume of concrete we know, the density of concrete, what is density of concrete by the way? Density of concert plain reinforce cement concrete. I think it should be one at a time no, otherwise people will take benefit of doubt 2500 or 25000 k g per k g per cubic. Let us put it here in this.

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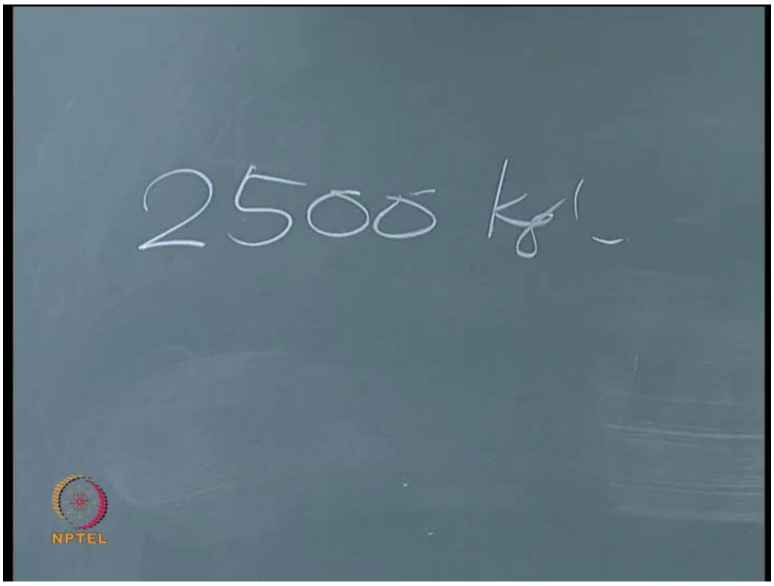

So, largest platform Guinness book of world record gravity based system very high volume of concrete and of course, very high volume of steel being used in this.

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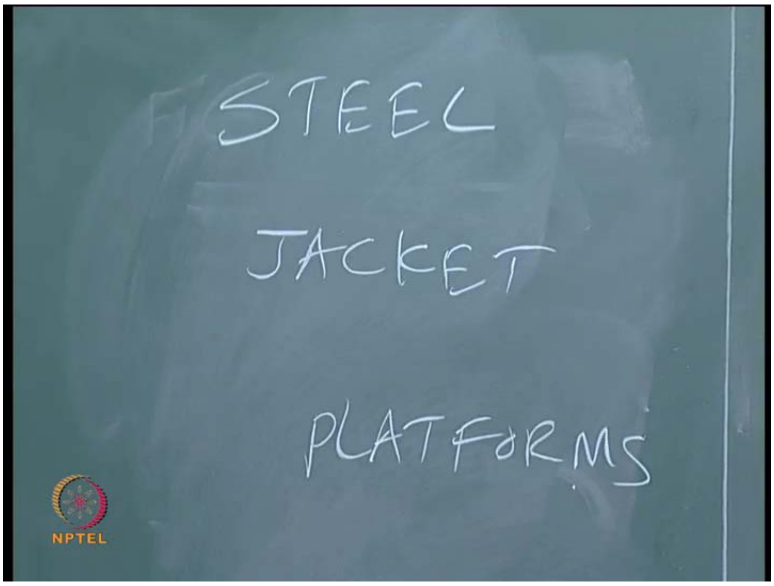

So, you see the construction here, the second type of platform. Which is commonly used, which is also a fixed base, a steel jacket. Structured steel jacket platforms, the name itself suggest the material.

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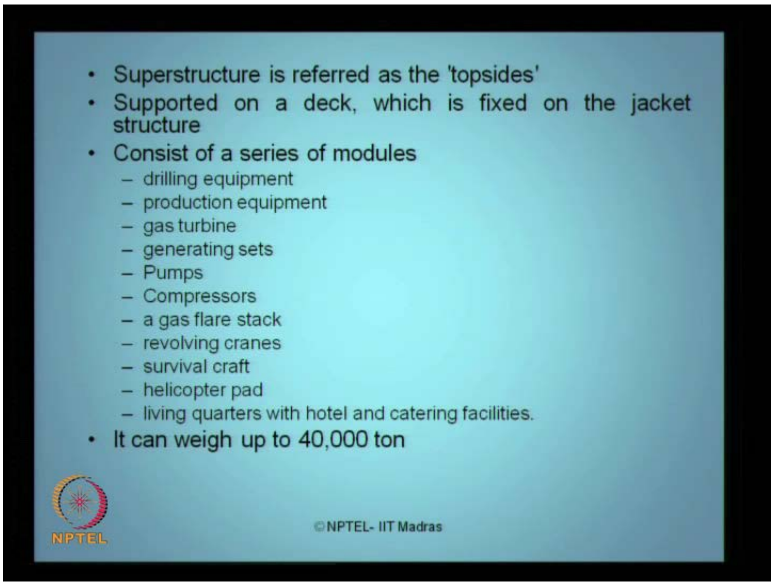

The top side is referred. The super structure is generally referred as a topside. It supports lot of equipments, which are being given here as drilling equipment, production gas turbine generating sets, pumps compressors, gas flare stack revolving cranes, survival crafts helipad and living quarters. One may wonder that, why they are interested in talking about these details in dynamic analysis?

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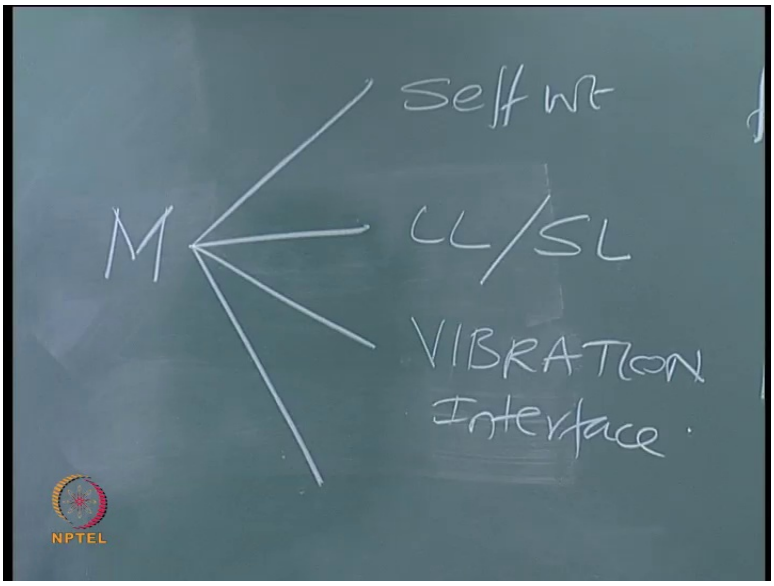

Now the mass will have elements contributed from different sources. One is from the self-weight of the material, which depends upon the geometric dimensions of the member. And of course, the density of the material the second can be the live load or super imposed load, which is being cost where some of the operational equipments, which are seen on the top side here. The third could be the vibration interface, when these equipments are under operation with respect to the dynamic analysis of the original structure.

So, we must know the characteristic of, at what speed, at what velocity or at what acceleration, the pump will operate? What will be the operational temperature pressure in speed of the compressor? What would be the weight where is it geometrically located with respect to the c g of the platform? All will cause influence on dynamic response behavior of the platform as such. So, it becomes important. Parallelly we can compare, if you want to design a water tank, the dynamic analysis of water tank with and without water, are different, when the tank is empty the characteristics are different or the response behavior is different when the tank is getting filled.

It is different when the tank is full, it is different while discharging and loading again. The behavior can be different what we call as sloshing affect slamming affect which will be actually one of the inflows cost with a liquid on a content. So, similarly here we are looking for the interface. So, we should know what are those components which are available. So, if you are looking for any problem where you are going to design a new form of the platform, as I said depending upon the water depth, your research may be focusing on a new type of an offshore platform which will be suitable for depth of 2000 meters. You will select the form, for the form you will select some functional requirements from the equipments.

So, which equipment you will allot there, where and why, we must have an idea about this though. Remember very carefully that we are not going to do dynamic analysis of all of these things independently and then. Do a coupling analysis with the platform that is not in the scope of this course at all, but we must have an idea that the top side of a platform is not a blunt area, it is having lot of electro mechanical process equipments complexly located on the top side the interface makes a difference. So, our focus is only on that point.

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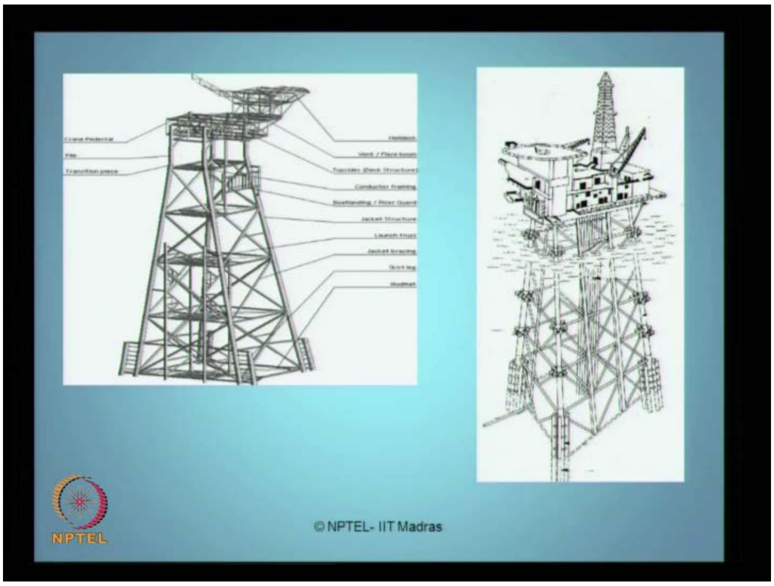

So, this is basically a schematic view of a jacket like structure, which you must have seen, if you are a naval architect or ocean engineering student. for the benefit of other viewers also. Let us see there is an important schematic view of a jacket like structure the pointer is not working. So, I can point out here directly this is my mouse these has some of the important components which you must name. I will give this details in the next lecture not because I do not have it I have it here. I want you to look at once. I want you to self read it what are the important complex pressure in the top side in a simple jacket structure.

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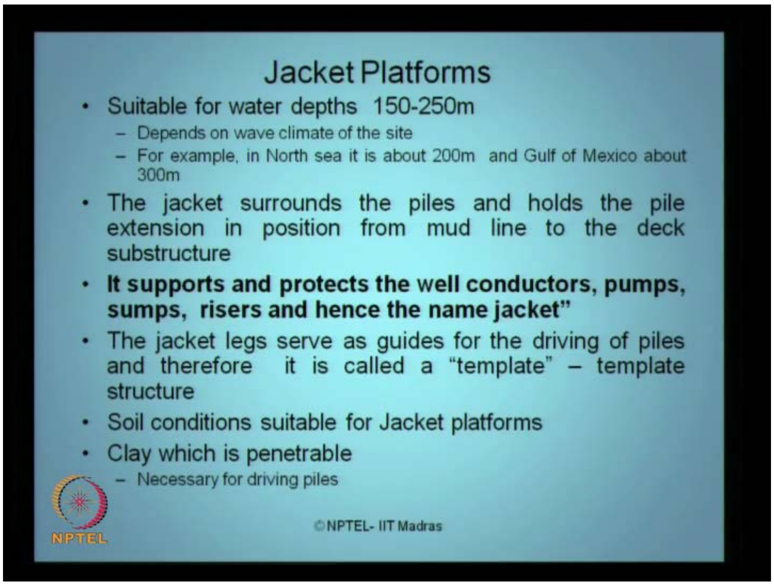

So, they are suitable for water depths up to 250 people have attempted to build. This at 350 meter as well depends on the wave climate, the jacket surrounds the pile and holds the pile extension in position in the soil and the soil should be essentially clay, it supports and protects the well conductor's pumps etcetera. That is why the name jacket is being given jacket is always an enclosure, I wear a jacket, they enclose my body etcetera. So, jacket is nothing, but, an enclosure it is also called as a template structure because the jacket legs use or used as the guides for driving the drilling legs in the template structure.

So, it is also called as a template structure soil conditions suitable for this kind of platform is clay, because you need that piles to be penetrated. It is not suitable for rocky environment. So, that is about the basic knowledge of where should I select a jacket platform and why. So, essentially the material predominantly used is steel.

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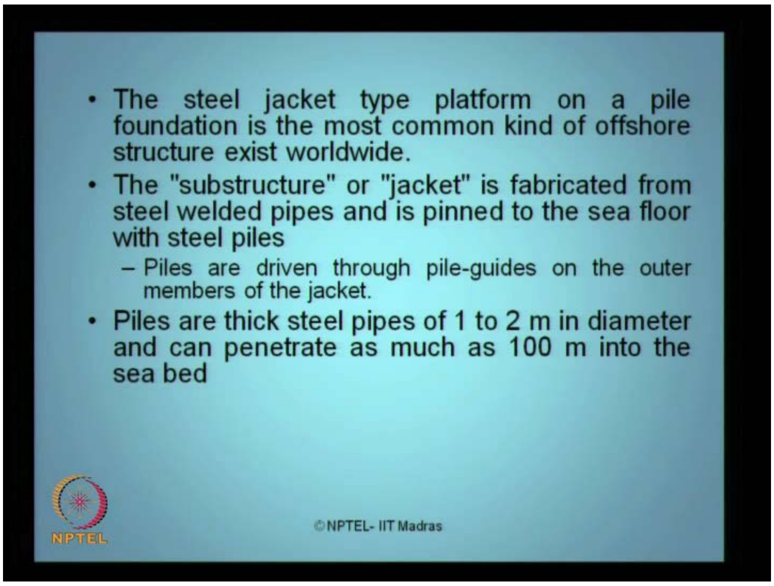

The substructure or the jacket is actually pile supported system. Which is bottom supported piles can be as large as 2 meter in diameter and they can penetrate as deep as 100 meters depending upon your soil condition.

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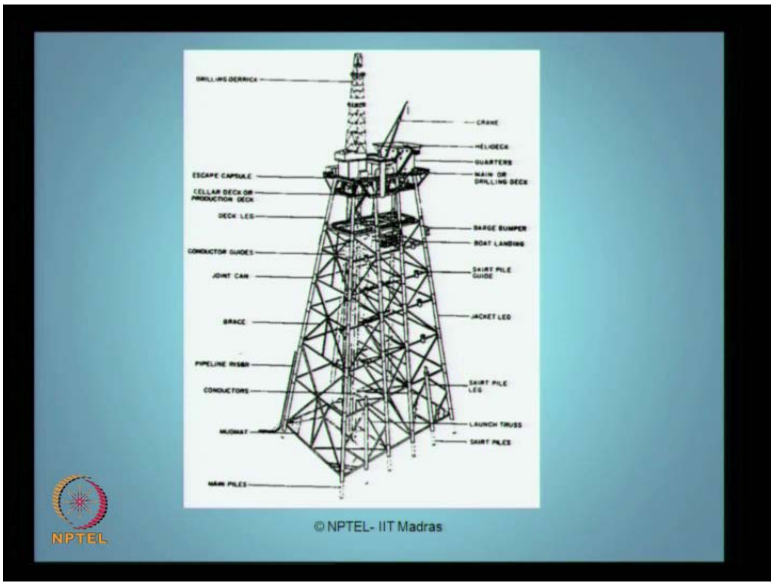

This is again another figure which shows me the parts either you can draw a line diagram of this and note down the parts or I want you to look at some of the platforms in reality in photographs and website and then, identify the parts.

There are engineering, which has been practiced on wonder, but same ideas have become un-documentedand this is common in many engineering trends. So, this has given the strength to identify a certain type of forms. So, you may also be driven to select a new form on your research problem there, you must have an idea what are the complexities involved in the top side. So, you must go through. We will now talk about gravity platforms, which is another type of platform called gravity based structural system GBS platforms.

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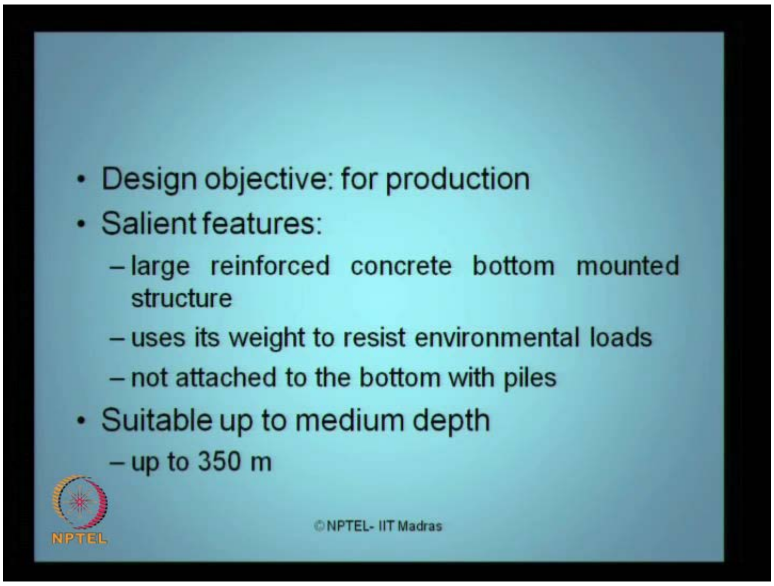

The design objective is essentially for production and the salient features are the following. It has got a large reinforced concrete bottom. we all agree that why concrete has got to be reinforced. Concrete is excellently good in compressive strength, but it is very weak in tension. Now an interesting question, which is very commonly posed to every structural engineer is this. Let us see how you are able to react to this question when we talk about concrete as a design material.

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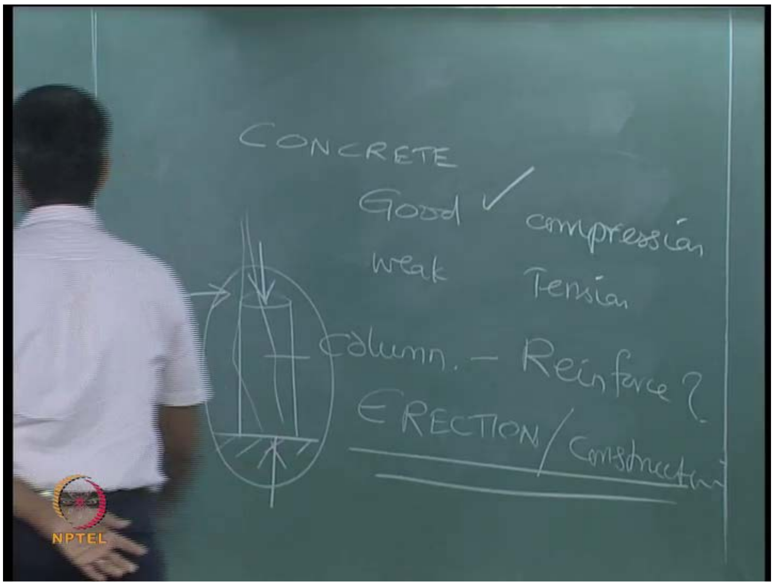

Concrete is very good in compression, but very weak in tension. . I have a column, which may be circular or rectangular and is subjected to purely compression only; it is a column purely under compression. But, I reinforce it. Why?Concrete is excellent in compression; thenwhy do I reinforce it?Depending upon the point of application of load, nature of load, combination of loads and major difficulty is erection or construction problems, there can be errors that the column may not become, vertical. It may be inclined more importantly with all the possible recent methodology of constructions still.

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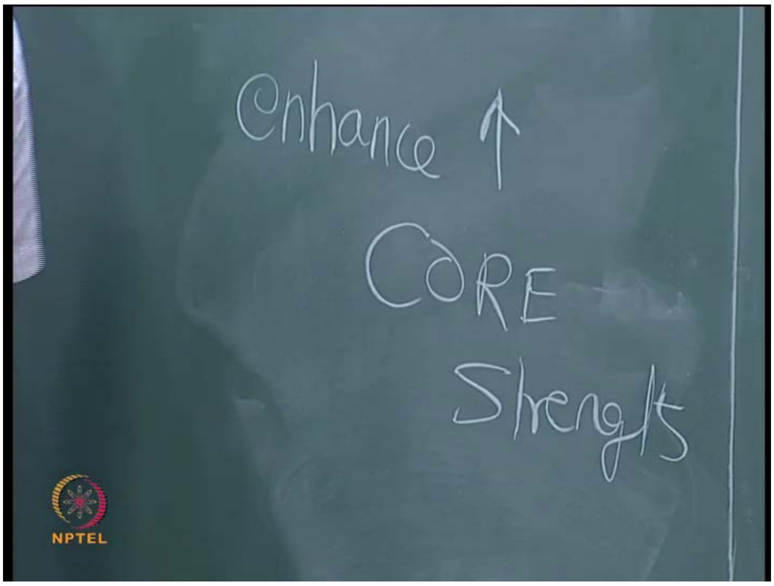

Concrete is reinforced only to enhance the core strength; what we call as confinement effect; the confinement affect it is very important. So, concrete is reinforced because of the following, but any way gravity based structure essentially where concrete structures they use their own weights self weight to resist the environmental loads. And of course, they are not attached to any piles because they can rest on the sea floor directly, because of the weight. They are identified to be suitable for a medium depth up to about 350 meters that is what the literature says where people have constructed these kind of platforms.

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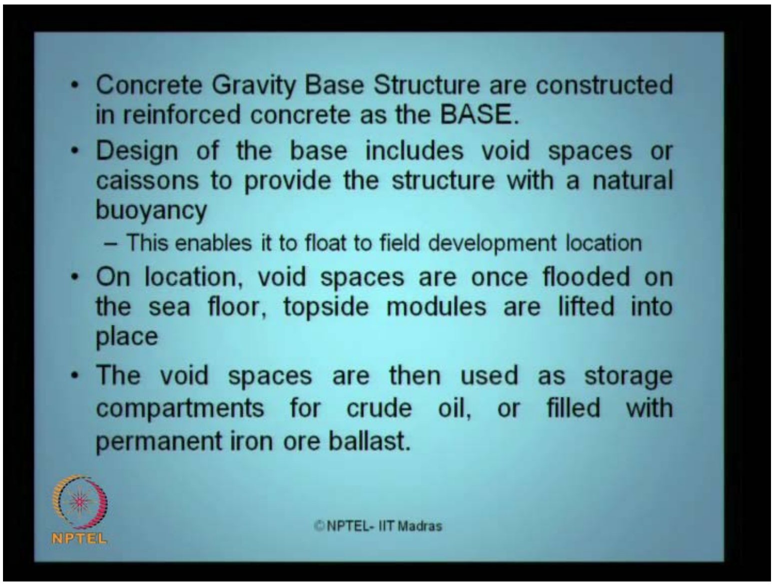

So, GBS platform has a base, which is essentially of concrete. Interestingly it is designed with a lot of void spaces, which I called as caissons. I will show you a photograph next to this now to explain why this is important in a concrete structure, which is having a lot of void space for functioning. It is Important because I want to store oil in that void space or I can store some ballast material, which can be used during installation and commissioning or decommissioning. But how are they connected to this void space? Analysis of any structural system, which has got a void space is different from that of a system, which does not have a void space.

So, in case of any structural system like a GBS platform, which has got the void space in terms of caissons, it is important to do free floating analysis and dynamic analysis in place. Both are dynamic analysis: one is called as free floating analysis, which is also important. Because I have got enough void spaces, it will be governed by the buoyancy forces when the same platform is resting on its position. Then I have to do dynamic analysis, because now the forces attracted by this platform will be different. So, it is important for me to understand the free floating analysis. It is not free vibration analysis. I am saying free floating analysis and dynamic analysis in position, because the load acting on the structural system in these two cases will be different.

And very interestingly you will now agree that all structures built except these examples what I am showing may not have to be checked for all these kinds of analysis. They are not required, but they become unique more in dynamic analysis since that we talk about offshore structural systems. You must do both type of analysis to qualify them whether to see the feasibility, whether they can be installed in a specific water depth under specific site conditions etc.So, that is what the slide says. The void spaces, as I said, are filled up with storage compartments of crude oil or they can be used for filling of the material for ballasting; may be water or stones etc..

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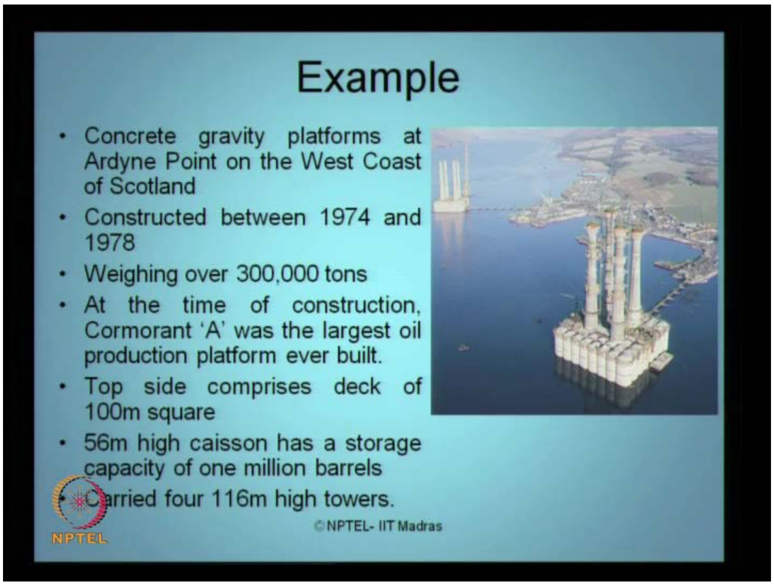

Or an iron ore ballasting say for example a GBS platform. Concrete gravity platform at the Western coast of Scotland, which is constructed in late seventies.

Weighing over about 300000 tons. At the time of construction, it was the largest oil production platform in the Scotland region. These are all the void space of caissons, which you see here these are all the void spaces. It is a tower on which it rests. It rests on

4 towers.The size of the platform is about 100 square meters and the height of the tower is about 56 meters. Caisson alone is approximately about ten to eleven storey building. The towers are much taller than 116 meters. So, you can imagine the total prototype size of this platform. They are not constructed once; they are in series. You can see at least two of them in the photograph here. One is in the towing stage and the other is getting inside for the towing stage.

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The other photograph will show you when they have used tug boards to install them.It becomes important for me to understand the free flotation analysis also for any of this big form based structure, which is a very interesting and exclusive demand in dynamic analysis for ocean studies. The third kind of platform what we see here is going to be a jack up platform or what we call jack up rig that is a third type.

We have seen platforms of two types; one has a fixed base and the other is gravity based structure. Both of them are massive structures; larger in size, but limited to water depth up to 350 meters. When I go for deeper waters, the platform model and the geometry or the form has got to get modified.

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You see the jack up platform here. You see that the structural configuration of the platform is completely modified. You have only a simple hull. A simple hull essentially resting on three or pairs of legs, which are steel jacket systems. That is why this is called as a jack up rig, because when the rig is not in operation the hull which you see here will be kept at the lower most position like this. You will float it; once you reach that location, the deck is raised or the leg is put inside. That is why we call this is as jack up rig; the deck goes up and the legs get inside.

Very interesting different kinds of platforms; Jack up rigs essentially are used for explorative drilling and also for production drilling for marginal fields but not for large fields; they have a limitation. If you look at the accidental investigations of these kinds of platforms, in general, most of these platforms are failed not during operation; most of them failed when they have been towed. So, free flotation analysis for these kinds of studies becomes very important, because literature show that these platforms failed when they have been towed from one position to another.

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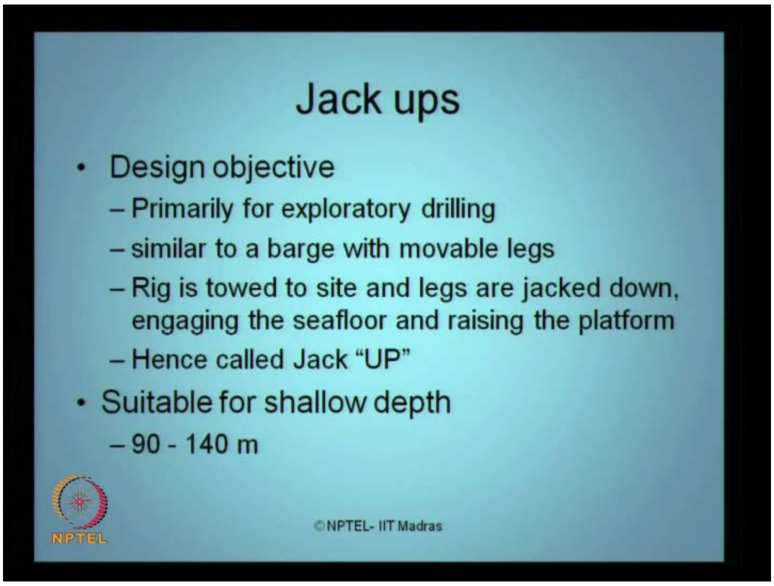

That is the close view of a massive, which is very famous jack up bridge. A shot in Singapore. The primary objectives for explorative drilling, as I said, are similar to the barge movement like a vessel. The rigs are towed downwhen the deck is raised up that is why it is called jack up rig. It is essentiallyrecommended for shallow waters up to 150 meters. Now you may get confused in the literature how do we define shallow, intermediate, deep, ultra deep waters.

How do you define them, what would be the category, what would be their terminology or what would be their parameters that will help me to define the water depth. There are many ways of assigning water depths depending upon hydrodynamic characteristics, depending upon choices of platform. Therefore, the depth where I install this structure has got to be a shallow water and so on. But these definitions also keep on changing in the literature. It is not that standard that had 172 meter you call it as shallow water; at 172.1, it becomes intermediate depth it is not like that, it is conveniently revised.

So, there should be an essential understanding for us to know what would be the classification. We will discuss this in the next lecture and few more platforms, we will talk about this in the next lecture. We will have one more lecture on types of offshore structural systems. Slowly at the end of these three lectures, we must arrive at the basic standards of what are the different structural actions of different kinds of platforms we will narrowed on to that point. So, these three lectures, will create the following objectives. One those who have not seen any such platform either in photograph at least has an opportunity to see it here that is number one. Number two, people thought that offshore structures are as similar and same as that of any land base structure. They are amazing structural systems; they are complex in nature. They are unique on its type and they have created world records as well. So, we must understand and realize that we are going to design or analyze a very unique structural system. Thirdly and most importantly, the whole exercise of oil explosion and drilling is getting into deeper waters because oil is not available in shallow waters.

Therefore, every existing form of structure cannot be applied and used at deeper waters. It means there is a constant research happening in offshore industry to understand what kind of platform I must design for deeper waters. The moment you have this question in your mind, if you do not understand the dynamic characteristic of this platform behavior, then you could not design one of its kind. And believe me no platforms, which I had shown you are available now. None of a single platform will have the detailed dynamic analysis reported in the literature because they get patented completely.

So, you will not come to understand how actually they have been tested and what are their intrinsic behavior under environmental loads, it is not disclosed. So, you have no data base to understand how they have behaved or how they are behaving under the wave loads. So, essentially you must create an analytical model of this, try to understand the behavior, simulate it and understand it. Therefore, mathematical modeling of these structures becomes important for us in understanding point of view. Form-driven structures become important for me in research point of view, and of course understanding them line by line is important for examination point of view.