Foundation for Offshore Structures
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Module-1
Lecture-1
Basics of Soil Mechanics I

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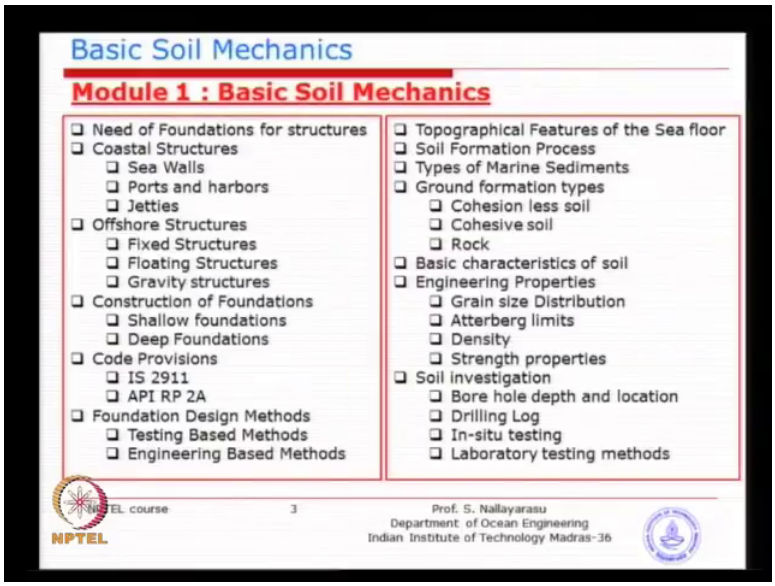

Today we are going to just briefly look at the basics as we discussed yesterday the 5 modules in this subject, we will spend some time on the 1st module. So the 1st module we are going to have brief introduction of various types of foundations for offshore structures as well to some extent coastal structures, as you can see I have just briefly trying to introduce, so you can see the difference between coastal and offshore, so that you can appreciate what difficulty we will face during the design of you know deep foundations.

And then we will go on to a bit on construction sequence which will give you an idea how we can actually differentiate between shallow and deep foundation. Then we will look at some of the codes and then the method of design that is the most critical one to complete. So I will try to do this within next few hours, probably within 2 weeks. And followed by, we will introduce you know brief idea about how these soil formations take place over the period of time and the types of soil formations so that you can appreciate as the material for engineering, how you can quantify the characteristics for strength.

So that is the idea behind you know basically you know the different types formations and then we will take forward with engineering properties, how do we arrive at them, either we do field testing or testing at the laboratory and how do we bring the samples to the lab. So basically the soil investigation part is quite important in the whole process of project development because that is fair, you know most of the information is coming from and if the information is incorrect, it could lead to a wrong direction in the design.

So the soil investigation is a primary part, in fact that is the 1st activity you will carry out when you are thinking of development of any project, basically to go forward, which type of structure you would like to place on this place. For example yesterday we were talking about gravity structure versus the friction platform. Depending on the type of soil, soil layers, how far soft soil or whether the strong soil is on the surface, this will completely change what type of structure you can actually plan for the site. So that is why the 1st activity that you will be planning is to find out what type of pile, soil investigation is integral part of the design process.

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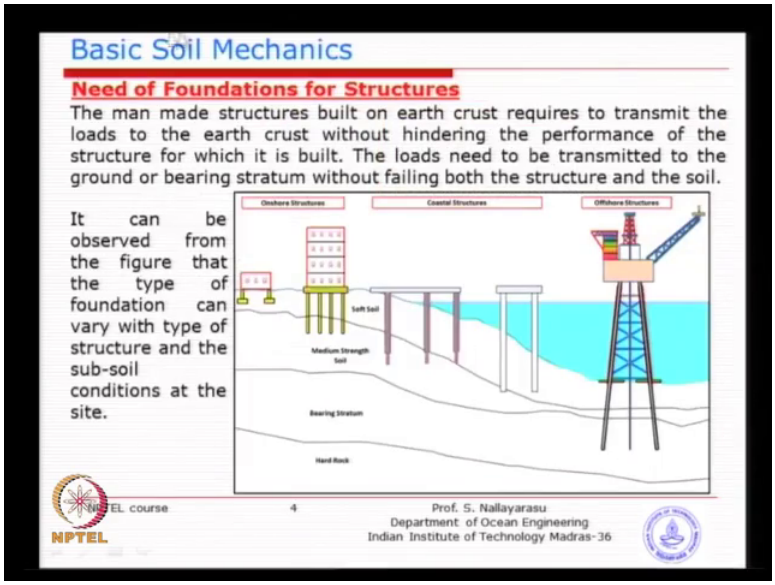

We will just quickly look at why we need a foundation, I think we spent a lot of time yesterday discussing about load transfer from structures, superstructure to the ground. So you can see the evolution of various types of foundations that require in terms of transfer of load. So if you look at the single-storey building versus multistorey building versus coastal structure where you have several activities. I think some of you might have seen Pearl Harbor, if you visited either Chennai Coast or other coast, you could see structures on the coastline which makes them interface between interface between land and sea, so that you

can bring in ships, you can bring in floating systems to a stationary position to transfer cargo, men and material.

So basically you can see a porting harbour structure is constructed near coast just because we need an interface because the interface in nature is not very good. For example if you want to bring a boat near the beach, maybe yes possible but if it is a big ship, it will get grounded, so you cannot move. So that is why you need to create an interface with sufficient water depth wherein you can go there. So that is the idea of the porting harbours, jetties. So you can see that variety of ideas can be looked at. For example, you can also do a pile foundation for the small building but you need to think about the necessity, do we need it, you know, the load is quite small, for a two-storey building, I do not think you will have a huge load, the brick wall and floor load.

So you do not need a pile foundation, whereas if it is a multistorey building and the loads are concentrated, multifold increase in the loads will cause excessive deformation to the soil just below, maybe a soft soil or maybe strong soil will make the difference whether we need a pile foundation or shallow footing. In some cases if the soil is good, you can still go for a very good footing type of foundation but then you need to look at the horizontal stability, whether you are able to provide that with such type of foundations. In many cases you know basically if it is a high-rise building, you will go for pile formation to get both, vertical equilibrium and the horizontal equilibrium.

So if you look at the right side, what we are trying to do is basically shift ideas, you look at the offshore platform, you can think of going for shallow foundation, yes, if the soil is very good but then the stability for horizontal and overturning needs to be established which we will talk about in detail. So you can see here the type of construction that we are looking at is completely different. If you look at this building versus, you could have this building as big as and offshore platform like we have shown some pictures earlier. But then you can see here the loading is different, there is no wave loads, whereas when you come to offshore platforms, you got a large amount of horizontal loads compared to onshore structures.

So the design shift is required. So that is why the foundation what we are looking at for any type of structure is integral part of the structure itself, you cannot actually separate them. So you need to understand the behaviour of structures as well the foundation so that we could design, all depends on what is the subsurface conditions. I will just put some typical profile, you see here soft soil, medium soil, and then bearing stratum and the hard-rock. Typically this

will bea kind of idea that you will encounter in many places but not necessary that this kind of sequence, you will see some places suddenly hard-rock in between or a very steep soil and then followed by or underlined by other medium characteristic material but.

So in such type of places you will have difficulties in installation, which we will talk about a later time. So the need of foundation is very important, what we want to try and transfer the load without causing problems to the structure. So what are the problems, for example, we take a simple single-storey brick walled building, if the structure settles vertically, just because the soil is too soft, so what will happen? Basic idea is the structure will start showing cracks if there is a differential settlement.

If it is a uniform settlement, nothing will happen in fact simply it will not be showing any cause of concern, except the building is going underground. So the next time when you want to go inside the building, you will walk downwards, is not it, which is not very good. So excessive deformation vertically, even though it is uniform, not preferred by, because we are going to occupy the building, so it is going down. But no guarantee that the deflection or displacement will be very uniform you will see a small difference, immediately you will see that the architectural finishes or even structural elements will start showing cracks.

So one of the important criteria is displacement based criteria to limit the deformation of the soil is within the limits so that the structure does not show any kind of distress against the loading that is going to be survived for during the design life. So we will just look at one by one and basically that is the need of the foundation, the foundation of variety of kinds can be developed, what is our idea is to make sure that the functional requirements are not violated. For example, you design a residential building and the purpose for which it is built has to be served.

If it is offshore platform, you are building it for drilling, you are building it for production, so basically we need to look at functional requirements which could be, it could be different for each type of category. For example, residential building, we do not want a crack of any kind because we will be afraid, the population will not be guaranteed enough safe survival. Whereas, you go to offshore platform, or deflation of a metre also can be accommodated because it is a different type of structure, different class of material used, you will not find any crack then. So that means there is no uniform requirement of design requirement for shallow foundation, pile foundation and same pile foundation for different types of structures will have different types of requirements.

For example use of pile formation for buildings, you will restrict the horizontal displacement to 5 MM, whereas if you use a pile formation to offshore structures, you will restrict nothing because we are not worried about horizontal displacement, what we are worried about is the vertical capacity and the horizontal displacement will cause more stresses, so you will have to provide sufficient material strength to take care of the stresses. So that is where you will find you could have multiple solutions for the same location depending on what type of structure you are building.

For example, building a factory building onshore, you know the factory building can have cranes, moving cranes or your verti cranes, they cannot sustain even a smaller displacement difference here. For example from left side to right side, less than 2 MM, the design criteria is 2 MM because if you have a differential settlement of the building by 5 MM, the crane will get stuck, it cannot move. So such places you design a foundation where it does not deflect more than 2 MM. So you can see such type of design changes.

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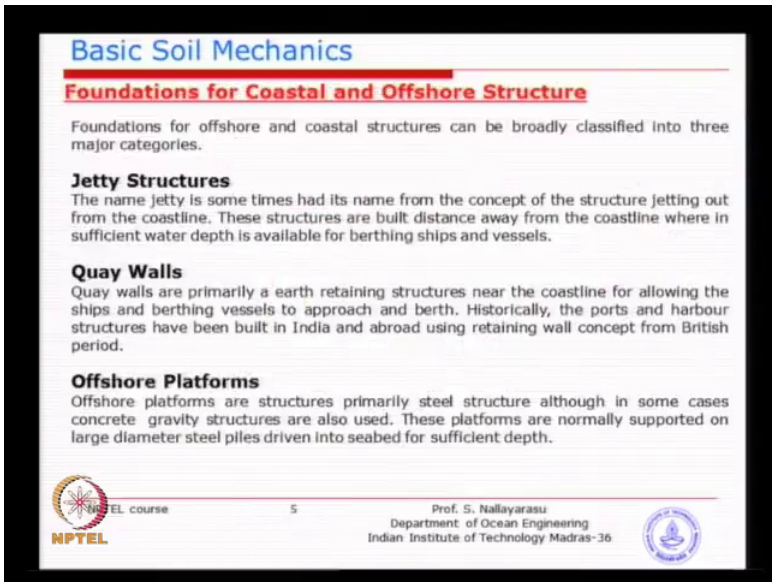

So same place if you look at another different type of building where Crane is not required, you do not need to design so stringent requirements. You can change the design criteria, so that is where the type of foundation changes from one type to other depending on what is required for the design. In this we are going to not discuss building, bridges and onshore structures, what we are going to look at 3 categories, you know retaining walls is part of the development, I think most of the places, if you go to ports and harbours, we call it Quay Walls, retaining walls, just to retain the air from falling down so that you can bring the ship closer to the coastline.

Or jetty structures, basically structures constructed slightly away from coast. You will see some photographs later on, you can see that the ships can be berthed against structure slightly away because water depth near the coast is very small. Then you can transfer the cargo by other means, either by constructing a bridge or by pipelines. Then the last one category is offshore platform wherein we use it for island gas exploration activities.

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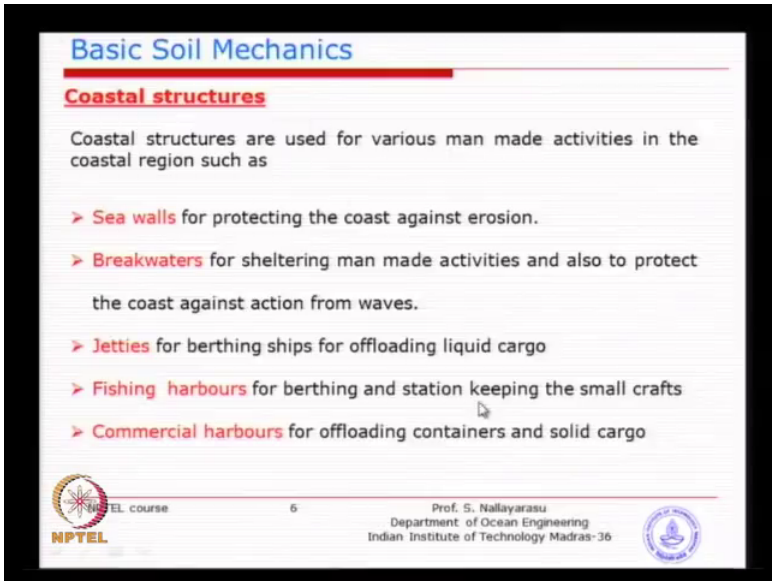

Just briefly, the purpose for the coastal structures, seawalls, primarily for coastal protection I think you can go around many fishing villages you will see that the erosion is happening, if you travel to North Chennai, you know, so these seawalls are the primary part of coastal protection for you know the coastal villages, coastal structures sometimes, you may have refineries, you may have power plants which are located most of the time near the coast because of the availability of large volume of seawater for cooling purposes, that is why most of the power plant will be located near the coastline.

In order to protect such type of facilities against erosion, you try to build either a seawall or breakwaters just to diverge the energy to other side. And then jetties and harbours which are primary part of the sea to land interface, you know you might see so many cargo berths all around the world. You can go along the east coast, many are there. Also commercial harbours which are meant for you know several commercial purposes, including tankers, high tankers, you have container berths and then passenger berths sometimes you have.

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A typical seawall you can see here on the left side picture is just a concrete wall, nothing else. But what it does is, it is doing 2 things, one is retaining the soil on this side exposed to sea activities. If this wall is not there, everyday some soil will be carried away and you will see the land is slightly reducing every time and then and it does also retain the earth and form a stable ground here. Otherwise we will not be able to use this particular place and that is the idea behind the construction of the wall.

Many places you will see of different kind, you see here, this seawall is made of just only rocks, just rocks dumped around the coastline which gives you such type of. Of course all depends on the durability and the sea conditions, here if the sea condition is very high, then this kind of rock dumping will not work, you may require construction of this kind.

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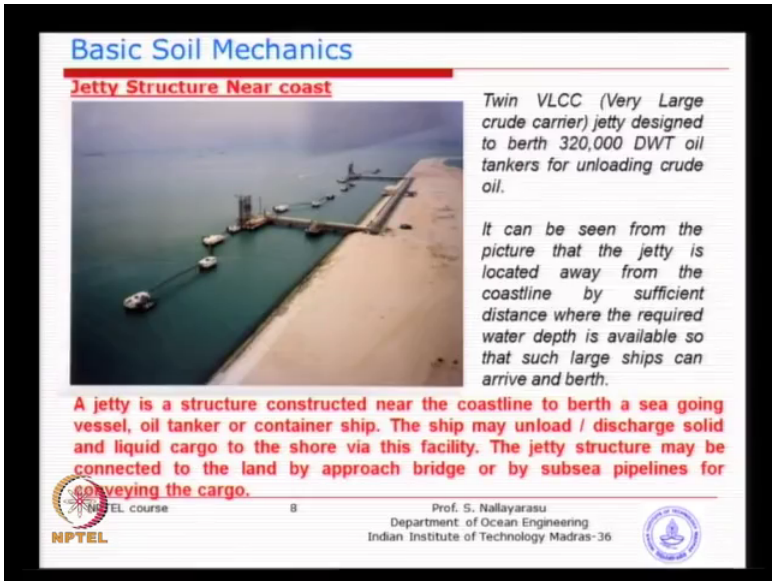

You can see this is one of the jetties which was built several years back. You can see there are 2 jetties around and there is a connectivity between the jetty and the, this is actually an island in, so you can see the oil transfer, so this is the place where the ships will come and they will transfer the oil from the ship to the shore. And this oil goes to the refinery which is located the slightly away. So this water depth is 25 meters, not small, so you can see why the jetty is constructed slightly away, I just to make sure the ships have sufficient depth to come there.

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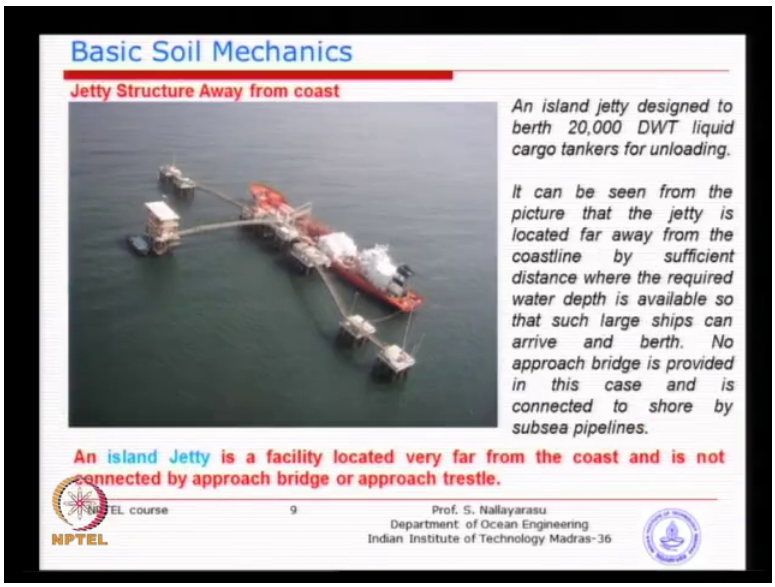

Of course you could do one thing you can construct the jetty very close to the coastline by doing this removal of the soil by dredging, which is another activity which you can plant. This is the jetty that is located off Karaloor which we designed in 2007 and 8, basically 2

kilometres away from the ocean, which is the purpose of doing such thing is basically to avoid dredging. Because if you keep the jetty very close, every day, every year you have to do the maintenance dredging which is very expensive. So you just put the jetty on the waterside, only thing is the transfer of cargo by pipeline from jetty to land, there is no bridge.

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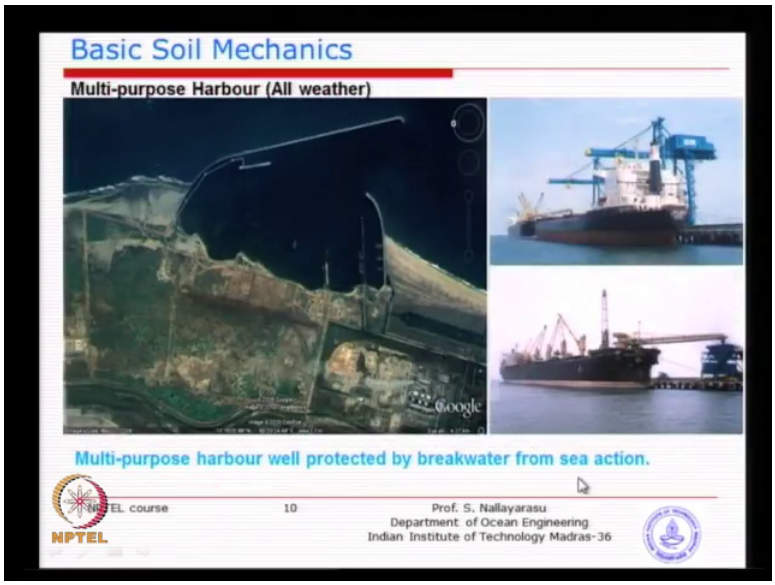

So you could see the purpose and the structures are designed in such a way that this can survive for open sea conditions, cyclonic conditions, in fact they jetty has survived 2 cyclones within last 2 years. Every year we get a cyclone exactly crossing at this location. Multipurpose Harbor, I think this is something that you will see around you know many major ports and harbours in our country. If you go to Chennai port, this is basically the Ennoor port.

You can see the breakwater and this breakwater is protecting the inner area from external sea conditions so that the berths located inside is exposed to lower sea state condition so that ships and vessels coming inside can transfer cargo without much problem. So comparison to this, you see this is an open sea condition, you cannot use this jetty all the time, whenever there is a high sea condition, you cannot bring the ship closer. Whereas when you are inside, you could do most of the time, except maybe a severe cyclone so that the difference can see between all-weather and open sea ports.

All of them involve one thing important, the retaining structures. For example if you look at this, you have to retain the this soil in this particular area so that the soil is not getting eroded

and basically you will construct some kind of wall, that is why we need to learn about what is that, it is basically retaining wall, or sometimes we call it seawall.

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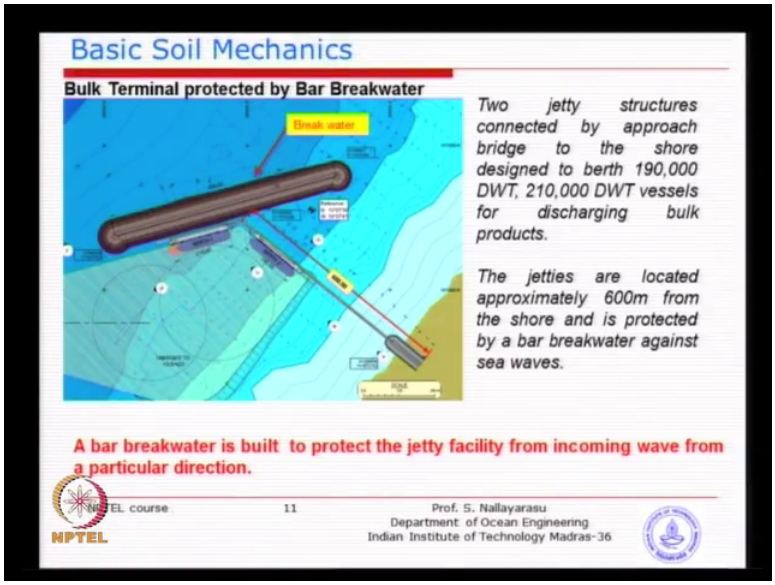

You see this jetty is also located outside the coastline but then protected by a big breakwater on the seaside, so that the incoming waves will be diverted and protecting the jetty within that area. So this is another type of idea where you can have design of a breakwater. I think some of you might be already having some idea breakwater is nothing but barrier wall. You can actually construct in RC Wall, in some places we do actually instead of random, we construct a wall using RC, but then the customer itself is quite difficult because it is in water.

So you need to think about how we can do a construction of a seawall in the middle of the ocean, you have to think about it, it is not feasible. So you need to 1st fill up the soil, then construct the wall, then remove the soil, so many times people do that. But the easiest way is to do a rock dumping of certain height, certain width so that it will be stable against the sea waves coming from outside. So this side is exposed to see waves and the jetty is well protected. All of them involve one important aspect is the soil mechanics because this is going to be a huge structure which is going to be resting under seabed.

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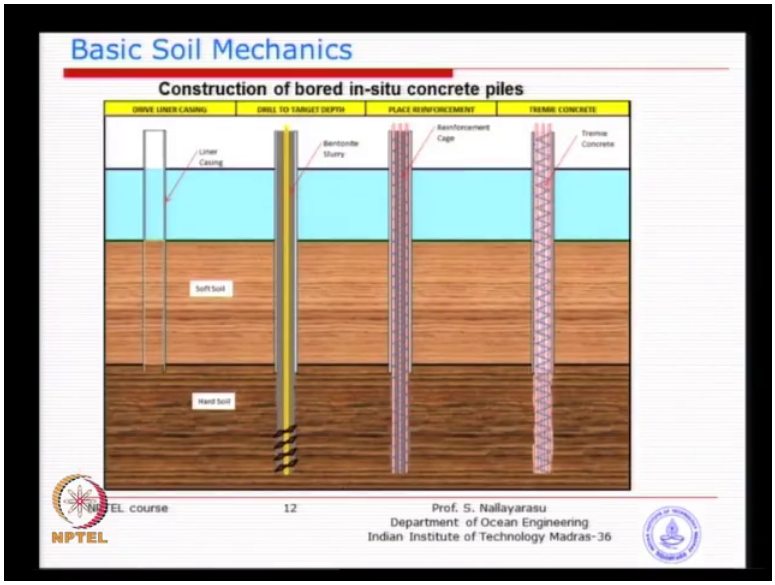

Over a period of time if it is going to settle, we just need to make sure that the calculations are made for the soil mechanics. How do we build pile foundation in coastal structures? Most of the times, you know you will see 99 percent will use concrete piles. I think you will see the difference in cost very high. If you look at the still pile versus concrete pile, most of them will be circular in shape very rarely we use square or rectangular cross-sections for onshore structures.

Sometimes people do use but for coastal and offshore applications we never use, I think we learned about that last semester regarding the circular sections providing efficient form of several kind, including strength and hydrodynamic efficiency, so that is why we use circular shape. So these circular shapes helps also in construction and you can see here circular shape means you can use the circular hollow section pipes, readily available as pipes. So you can use it. So in construction of circular solid RC pile, the sequence you can see in the picture when you actually make a hole in the seabed or in the side, it has to be stable.

Like if you go to villages or even in cities, open excavation foundations you might have seen, just do an excavation and make sure that the soil does not fall down, we may actually do we side shuttering in some places, some places if the ground is very good, you simply make an open excavation and just make the foundation because it is only shallow depth. But here we are talking about several metres, so when you excavate inside, something like this, what will happen, the soil will collapse.

So what we need is the shuttering, so while we just drive a steel pipe of smaller thickness up to a depth where the soil is stable, after which even if you do actually excavation soil is going to be almost not going to fall down. So the method of construction of concrete pile is very simple, drive a liner, excavate the soil by several means, you have either boring or chisel and bale, many many methods are there, so you just remove the soil somehow and stabilise the soil by means of a denser fluid pump inside. That means the pressure created by a fluid inside is higher than the outside, so that your the soil without the liner is going to be sustaining without falling down.

So normally the denser fluid is nothing but bentonite slurry, it is very similar to cementers material but with the specific viscosity and density you pump inside continuously. And basically will sustain, this soil will not fall down and then you replace this area with concrete. So what will happen, concrete is denser than this fluid, this fluid will come out and before that you lower the reinforcement cage and pump in the concrete, the concrete will displace the bentonite slurry out and leave it for several days which will make the concrete cured.

So the construction of marine concrete piles is obviously a long-term process, it will take probably 2 days, 3 days, the whole process of driving a liner, excavating the soil, pumping bentonite slurry and putting the reinforcement cage and filling concrete by tremie and then curing it. So you could see it is not a very simple process, so if you have several piles, it may take a longer time. So this method, why we need to understand, why I was just talking about this?

Now you have created an interface between the superstructure which is going to sit on top of this basically here on the soil and the interface needs to be understand because the interface partly having a steel casing and partly the concrete is directly expose. You see here at the bottom, concrete is directly in touch with the soil. Now the load is applied to the top, we need to understand how the load transfer going to happen from the structure to the pile, pile is also a structure, in fact it is a, it can be a concrete structure, it can be steel structure.

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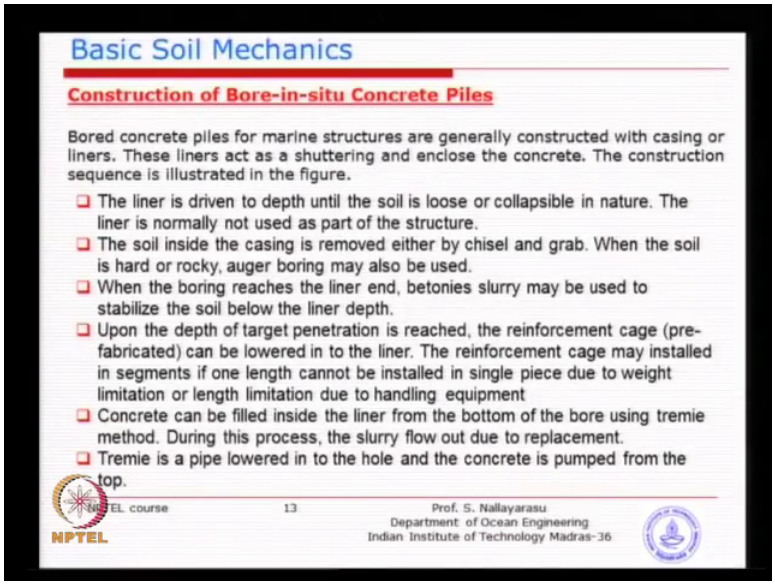

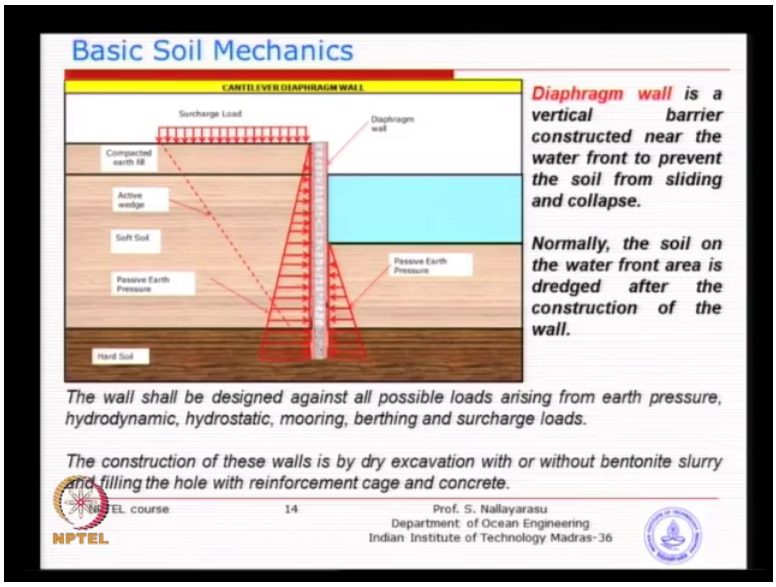

Then from that part to the soil, somehow we need to transfer and that is where we need to understand so that the design can be easily performed. So that is why we need to know how it is constructed. I think I have explained that procedure in this line from, so if you are asked to write, you can read this procedure, it is exactly what I have explained there. How do we construct a retaining wall for coastal structures? Very similar, except that it is not circular shape, it is in rectangular but along the length of the wall, only difference is the liner may not be used.

Because driving a liner of such kind is not feasible because it is longer in length. So what we normally do is we try to do this construction without the liner but of course only up to that certain depth, maybe we can put a guide wall, which will be either steel plate or it can be

concrete wall but only about 1 metre, half a meter just to avoid collapsing of topsoil. But the remainder has to be self-sustaining using bentonite slurry. So the construction is not feasible when you have water on right side, is not it, because it is exposed.

So what we normally do is we fill up soil here on this side and make a slope stable flow and construct the wall, after the construction of the wall to remove this soil by dredging or by other means. So you can see the difficulty, if it is a pile you do not need to worry because the liner is providing interface between the water and inside, whereas here we have a problem of construction. So in here, of course one thing is very clear, you cannot get any strength from this soil on the left side because the right side there is no soil.

So you will be able to transfer the load only the part of the wall below the dredged level which is basically this. Most of the olden day berth is constructed using this type of idea. If you go to Chennai port or many of the British time ports you know basically construction using either the step of ideas of making concrete walls or sometimes gravity wall.

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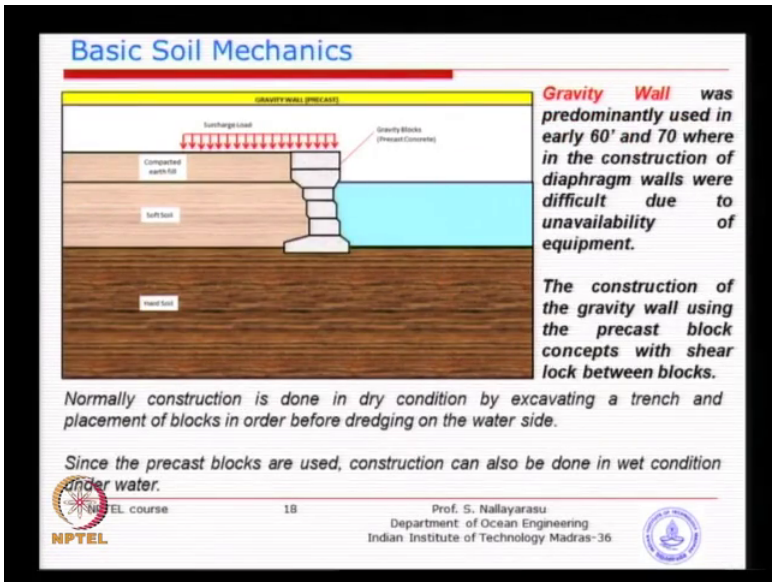

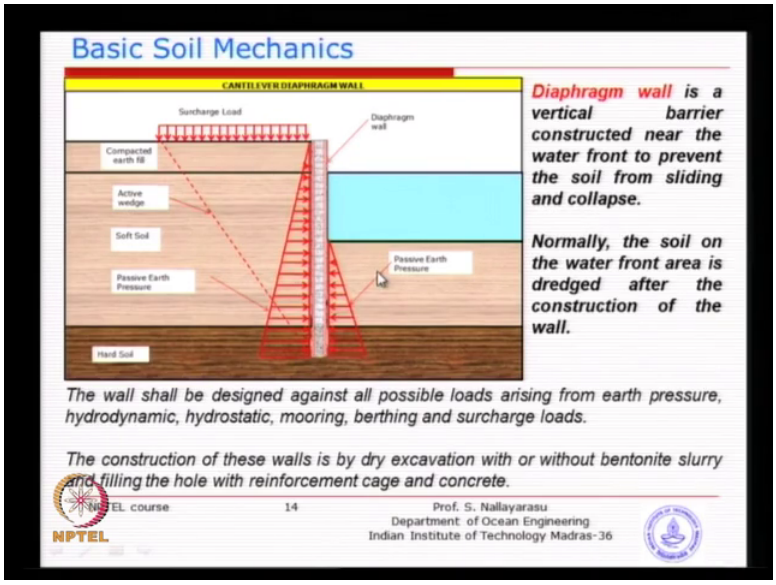

You will see from this type of picture, something like this. Many of the olden days ports constructed during British period is simply aligning and just keeping big big concrete blocks or even rocks so that they are stable, but of course this is feasible only when you have very good ground below the dredged level. Otherwise what will happen, it will keep sinking. See the other idea is a retaining wall needs to be taking sustained loading from the activities of the portal harbour.

So that is why we need to have sufficient strength in the wall itself as the structural element and then sufficient strength in the soil to take the horizontal load because you will see that the surcharge is going to be very large. The portal harbour activity, you will have cranes, you will have transfers, so you will have stacking of material, so you will have a huge surcharge where in this is a simple soil mechanics to transfer the load horizontally and sustain reasonable deflection. What is that reasonable deflection, we need to verify. Whether it is a 1 metre or 5 MM, that will govern the design of this wall and the penetration of the…

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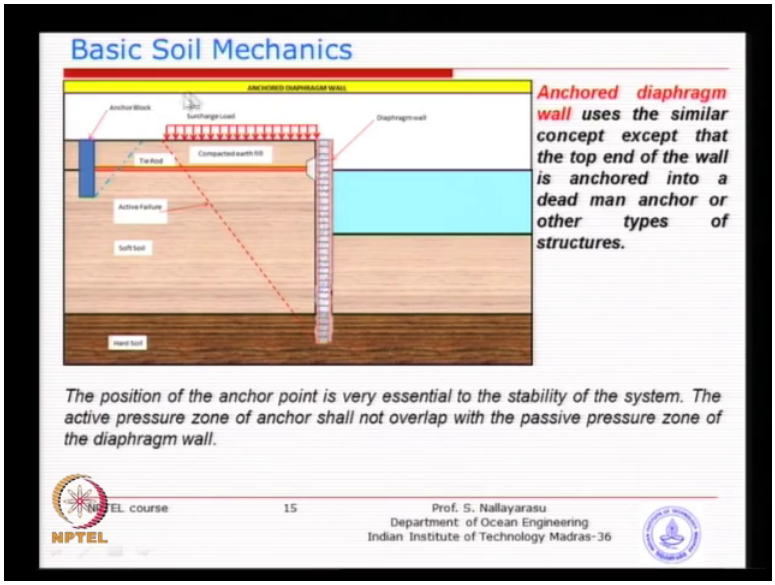

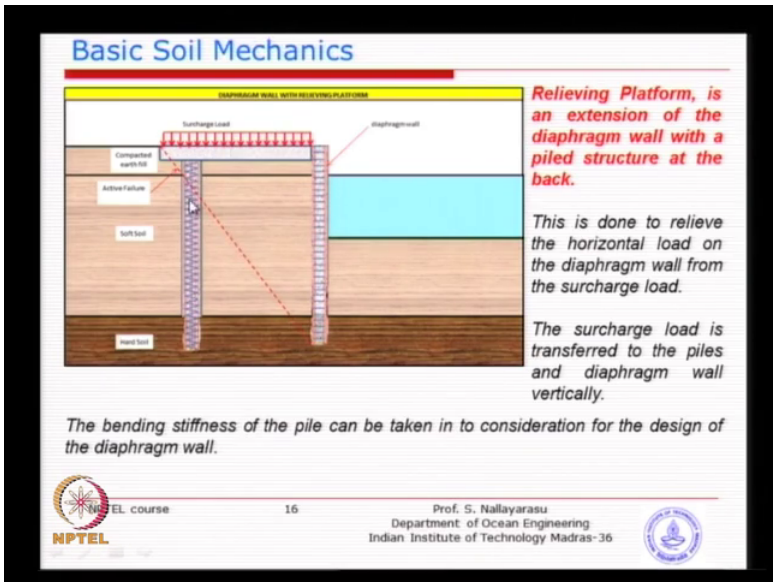

Imagine if this wall is not penetrating so much, it is just half a metre, what will happen, the whole wall will be drifting horizontally. So we need to have sufficient embedment of the foundation into the ground. Or you could also come up with an idea of sustaining lesser deflection by means of holding this wall backwards. But one of the important thing is the failure plane. You know when you have such a system, you have to have the retaining wall to hold this anchor, it should be away. If this is whole thing within this failure block, the whole thing will, that is the major important activity that you need to look at when you are designing anchor wall, you need to make sure that anchor itself is away and the failure plane that not cross each other.

The failure plane of the retaining wall and the anchor wall or anchor block have to be separated, so that they are otherwise what will happen, the stresses on the soil from this and this will overlap, there will be double stresses, the soil will fail terribly. And then sometimes we do this kind of idea, most of the recent designs we have done for ports, Chennai port or the others, we will be using relieving kind of platform where you see here the loads from the harbour activities is directly transferred to a pile, not going as lateral process to the front wall.

So you can see here how we have manipulated that the load is taken directly by this and going down to the soil here so that the surcharge pressure, horizontal pressure on the vertical wall is limited only to the soil behind it. So the surcharge is taken directly to the, so this is some idea where if the soil conditions are very bad, for example the retaining wall here are the soil is very soft, you will not be able to design. In such cases, of course slightly expensive but then at least we are able to find a solution.

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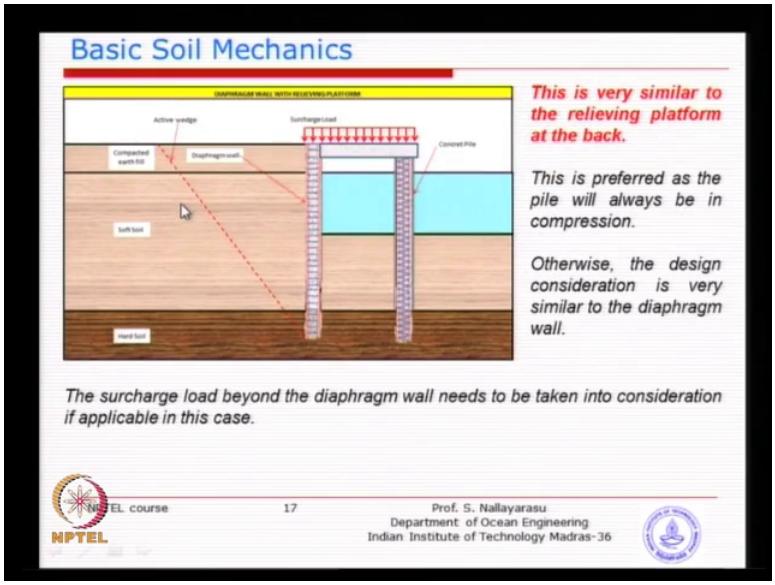

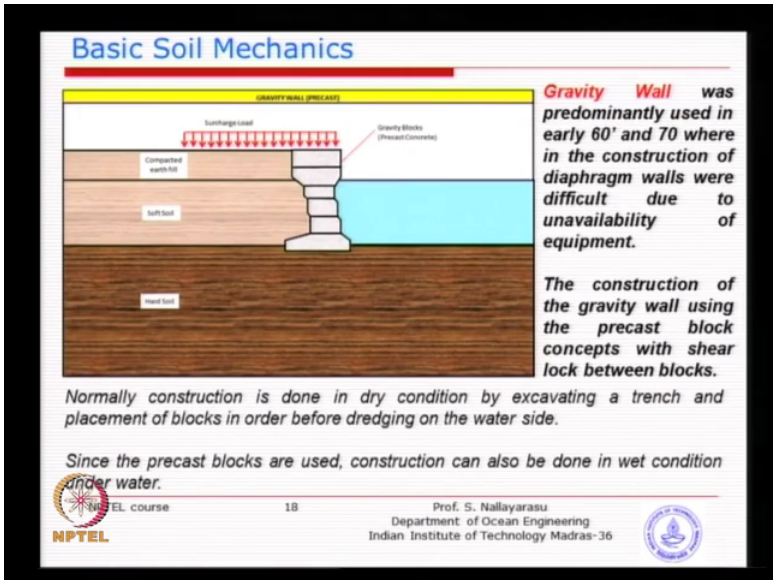

Just give you an idea of variety of kinds, some cases we have done this kind of idea where the pile is in front, wall is at the back, again depending upon the situation you have to design it. Anchor block versus the gravity type, gravity type is almost similar, only thing is the stability is obtained by its own weight, provided if the soil and ground conditions permit because otherwise it will not work out.

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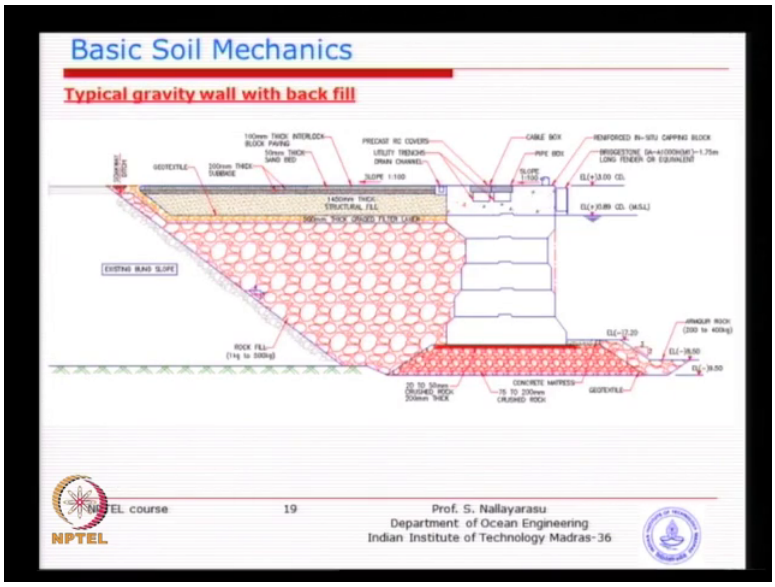

A typical picture of a recent project which we were doing in Qatar, you can see here the existing ground conditions are like this, so simply prepare the ground, dump the concrete blocks of prefabricated with variety of sizes with interlocking. You can see here interlocking, shear interlocking and then just fill up the remainder of the portion by layered engineered fill

and prepare the ground. So you can make this idea, what we are doing here, if you make this one up here, you need to drift this area.

So by doing this you avoided completely any removal of the seabed soil by dredging which is quite good. And also you have created a new space which is basically not occupying the existing land space. So reclamation is together. So most of the reclamation is like this, you create a wall and fill up the gap between the land and the wall itself.

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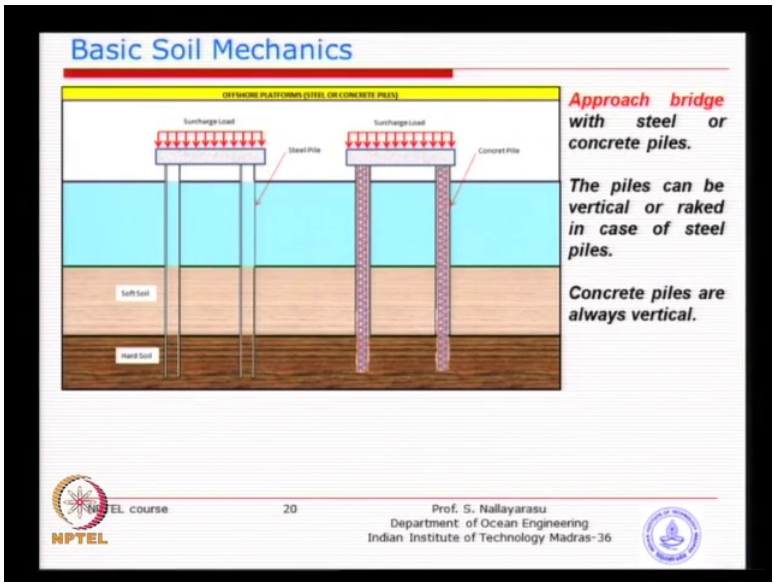

Some other type of constructions where you have jetties built away from the coast, it is nowhere near. So you can see you can use steel pile, simply driven into the ground and construct the deck or you can construct a concrete wall, concrete pipe and then construct a deck. The only difference is every material has to be transported from coastline to this particular place, no access, so that makes slightly difficult for construction, but otherwise the procedure is exactly same.

So you see here in this one, there is no concrete involved, you take a circular hollow section, drive it and achieve sufficient capacity from the pile depth embedded into the ground. Now you see here this, this and is open, this is not closed, after not having clear idea, the pipe is open-ended, that is why sometimes we call it open-ended paid pile. Because if you close it what will happen, you will not be able to drive the amount of resistance that will develop during driving will be very large that you will not be able to drive.

So that is why we drive it open-ended, but alternatively you can also make a hole in the ground and put this pile and do a concrete all-around. Sometimes we do this whenever you

encounter a very hard rock, for example, but still we want to go for still pile, so you can actually drill hole in the ground and simply place the pipe and do a concrete ground but very expensive, that is why many times we do not prefer to use this.

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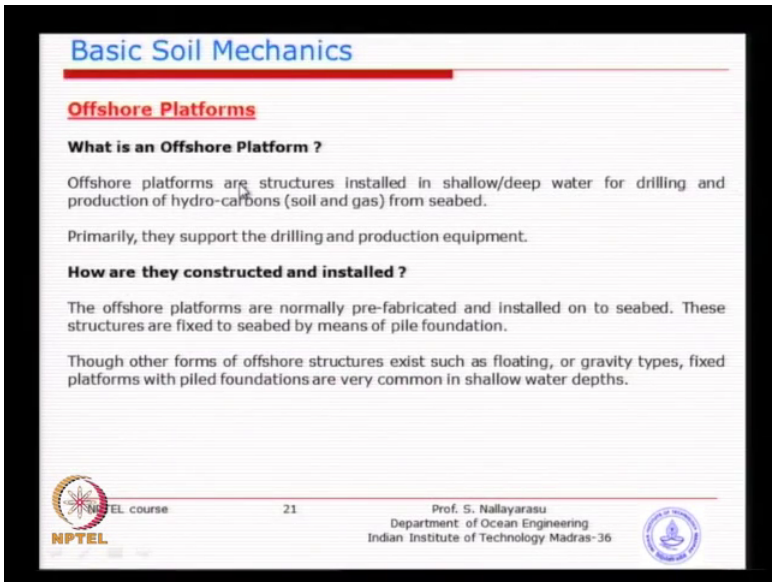

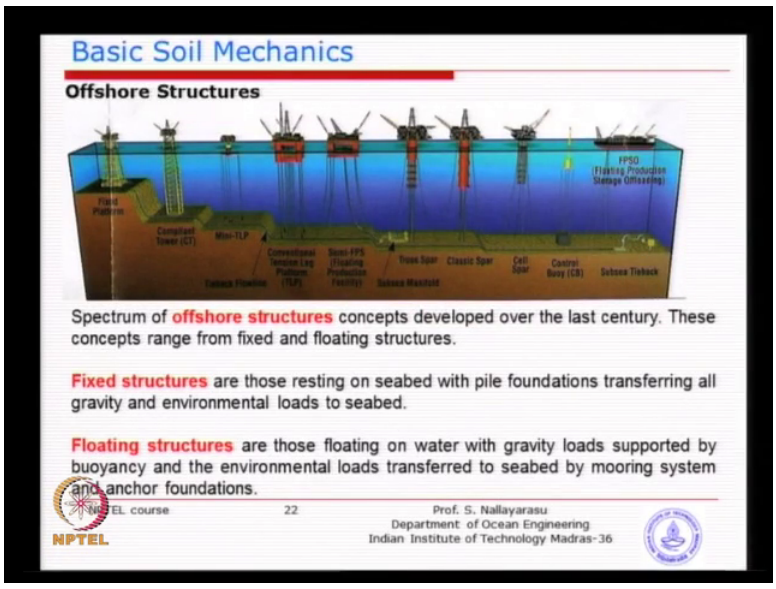

So so far I think you have got a clear idea of the class of structure that is being constructed on coastal areas or maybe on land. Now we will quickly look at offshore structures basically for hydrocarbon exploration. I think most of you are very familiar. So the purpose of the offshore platform is to do drilling and production of oil and gas. You might see this picture in the earlier lectures, variety of class of structures wherein we require some kind of foundation. Either it is a fixed still pile foundation here or other classes of foundation to hold back the floating structures, it could be section anchors or it could be gravity type anchor.

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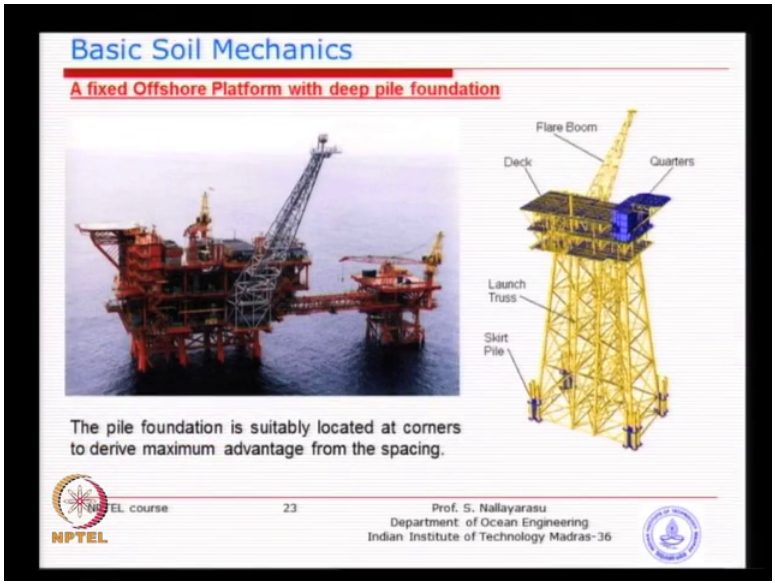

So you cannot leave away from the foundation design for any offshore type of project. A typical jacket where the pile foundations are focused at the 4 corners. So you can see here the purpose why we do this instead of distributing the number of foundations to everywhere. This will be effective because all the loads are decoupled at the extreme points of the structures, especially when you have a rectangular portal frame and you have a horizontal load and you have a vertical load. I think when we were looking at design course, if you apply the horizontal load, it will be decoupled to the maximum at the extreme points.

So if you put a pile formation at the middle, it will be of not much use, it can only carry the local, vertical load coming from the deck structure. So if you locate them further apart, 2 things will happen the decoupling distance becomes larger, the magnitude of the load arising from the horizontal load will be reduced. I think we did a simple problem, if you apply a horizontal load the decoupling will be moment divided by the distance between the 2 foundation locations.

So that is why we keep the foundations as much as to the corners so that the decoupled forces on the foundation will be minimal. Also you do not want to have too many piles in offshore systems because as you know very well, many more you can actually instead of having 12 only here, you can have 20 of them. But then as we discussed yesterday, minimising risk is the most important in any offshore projects because you want to reduce the time that you spend offshore.

The more the time that you stay, the higher the risk with respect to many aspects, is with respect to exposure to see conditions, risk with respect to accidents, risk with respect to supply, so you can see the lesser the time you spend is better. So that is why minimise the number of foundations that you require to construct drive or install. Many times we keep 2 corners, some cases you may actually have foundation here and here, all depends on the design configurations. It is a typical platform you can see here is an 8 legged with 12 numbers of corner piles.

You could have many number of solutions to this, this is not the finished idea that every 8 legged jacket will have only 12 number of piles, you may have 4 piles, you may have 8 piles, depending on the magnitude of loads that is coming at this location and the type of size that you actually have for the site.

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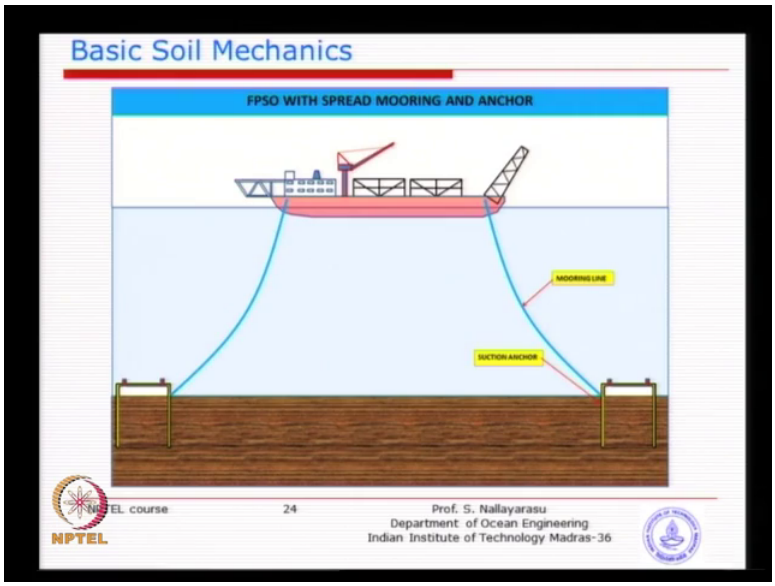

The other types of foundations normally used for FPSO, section casings or mooring lines. You can simply replace this one with a gravity type big concrete block. Many times we do this depending on the magnitude of the load. What it has to survive is the drag load coming from the floating systems and has to sustain with a minimum displacement. So that several times we use fluke anchors. If you see ships standing outside the harbour area, they have the anchors which are simply a big size weight with a specific shape so that it can go into the sub ground.

And when the load is applied it will be resisting against dragging, so we call it drag anchors sometimes. But they are temporary because you want to remove them next time when you

want to relocate the ship, you simply have to pull out and remove them. Whereas these FPSOs are going to be permanent for a longer period of time, so you want to have some kind of better system. So you can also drive a pile, instead of this kind of large diameter, many many options, you can drive a pile, very similar to (())(36:16) platform or you can have a large cup, like what you see here, it is an inverted cup simply put down to the ground.

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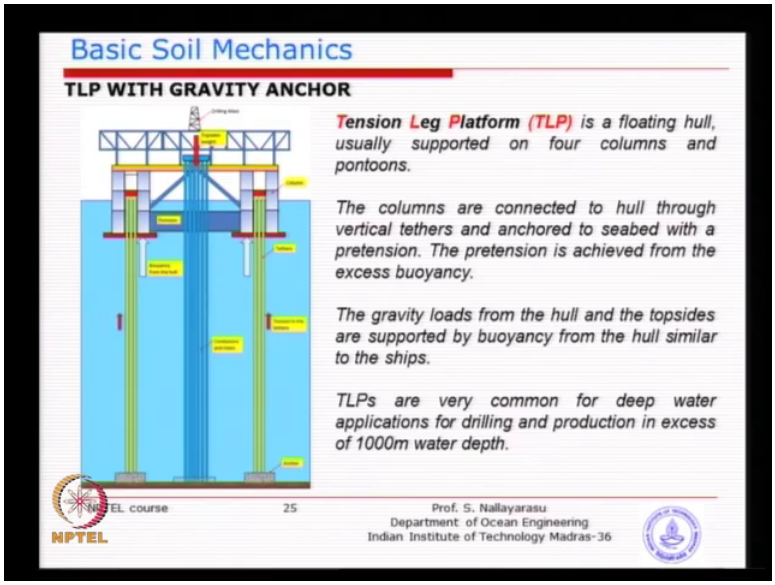

We will talk about this section casing and the concept by which it is achieving its capacity in I think in several classes later. Then we have TLP, you can see here TLP, the load transfer is slightly different, you know part of the load is taken by the buoyancy because it is the floating system. But then you also have tethers or so-called vertical mooring lines you can call them and holding them in vertical position from the movement. So you need to have sufficient anchor capacity so that does not come out. And basically of gravity type, pile type, you can design either way.

But the gravity loads are taken by the buoyancy, horizontal loads will get transmitted to these tethers but not fully because they are flexible, so you will be allowing the system to move horizontally, so part of the load will go as the tether moves but most of the loads are resisted by buoyancy in vertical condition. So TLPs also do have pile formation of gravity formation depending on the magnitude of loads and design.

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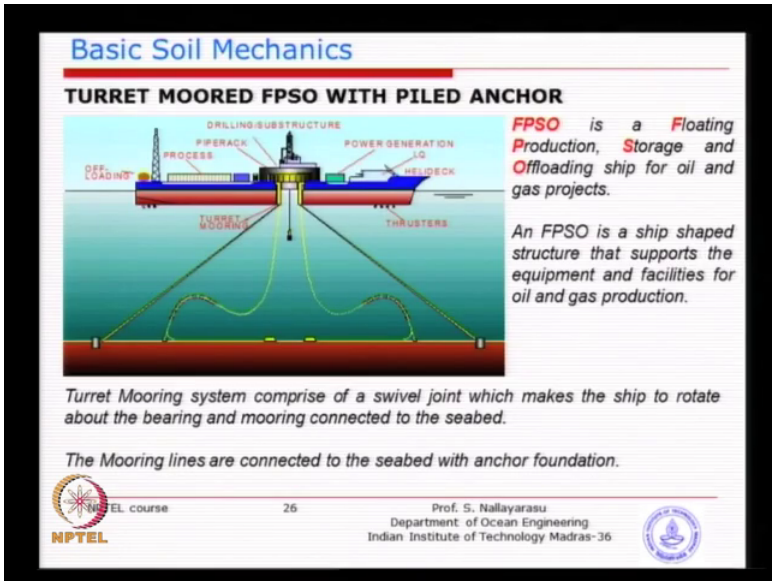

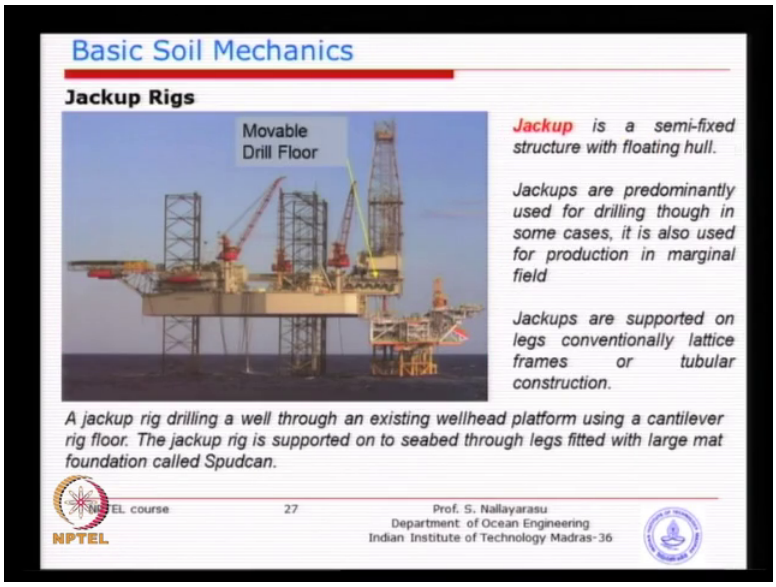

Like the FPSOs, talk about the FPSO with the Turret, so you can clearly will require a good-sized foundation, it could be anchors or it could be pile foundations. Jack up, I think last time we discussed the jack up whenever design class quite substantially. And you could see here the computation of bearing capacity for the spud sitting on the seabed. It is an important aspect in the drilling time because everytime you are going to relocate this jack up. So everytime you have to do the foundation design, make sure that it is able to sustain the loads during the duration of one year or so for drilling purposes.

And basically everytime when you relocate, the jack up will be a new project. Unlike jacket is installed one-time and one design, whereas the jack up, you have to do this as time you type of soil, new type of environment, new type of load conditions.

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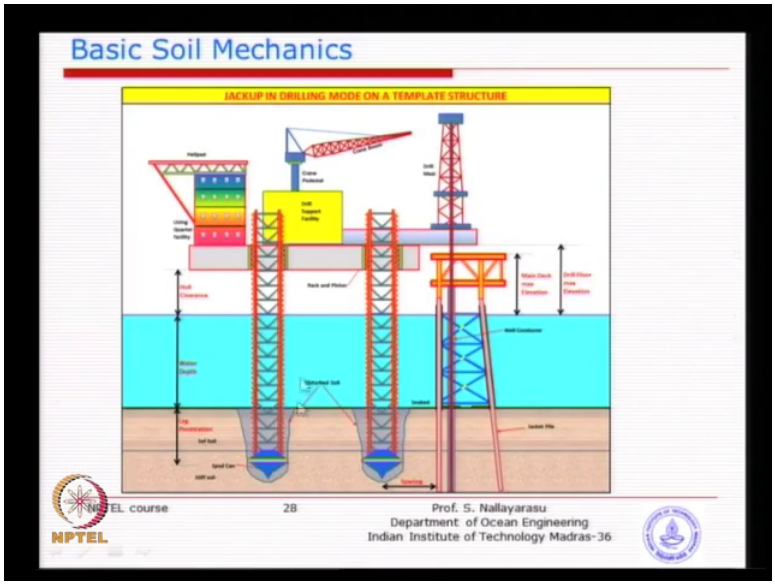

I think this picture you might have seen, soil plays a major role in the stability itself and you must make sure that it does not also have instability against rotation, I think we discussed about this problem in detail. Basically the levelness of the ground, evenness of the layers, so a lot of study needs to be carried out before you can establish that the jack up can be lowered at this particular site.

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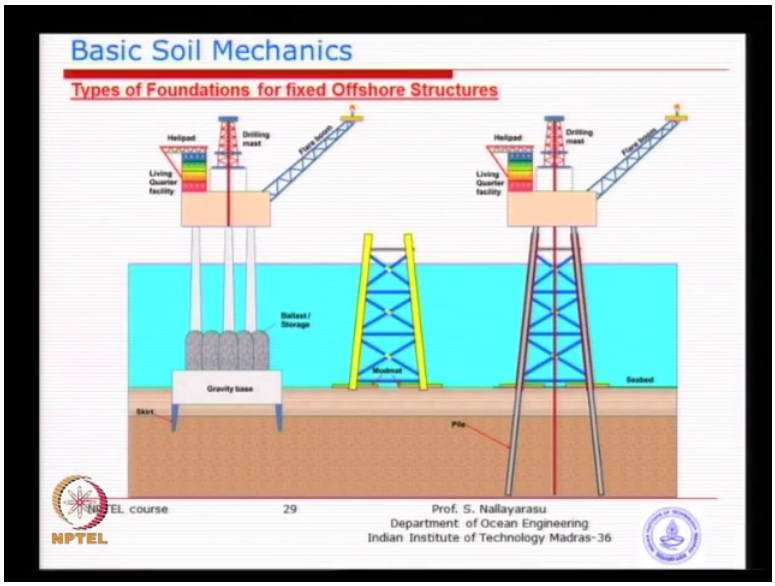

So now come down to final 3 foundations that we will go through in depth in this course is basically the pile foundation is primary part of this course and then we will also look at a shallow footing, very similar to shallow footing is the mat foundation which is used for temporary purposes to keep the jacket in equilibrium position without shrinking, without

drifting, because you are going to bring the jacket and place it on a particular site and make sure that the jacket does not sink. That means we need to have a temporary foundation prior to piling and basically just call the mud mat.

And the 3rd class of foundation basically for gravity type of platforms, we have a large base with ballast, it could be solid ballast or it could be liquid by ballast with and without shear keys to obtain horizontal resistance from passive side pressure. So these are the 3 types of foundation we will be looking at in detail. Of course most part of the lecture we will be focusing on pile foundation, the last few sessions we will be talking about design of mud mats and gravity type of foundations.

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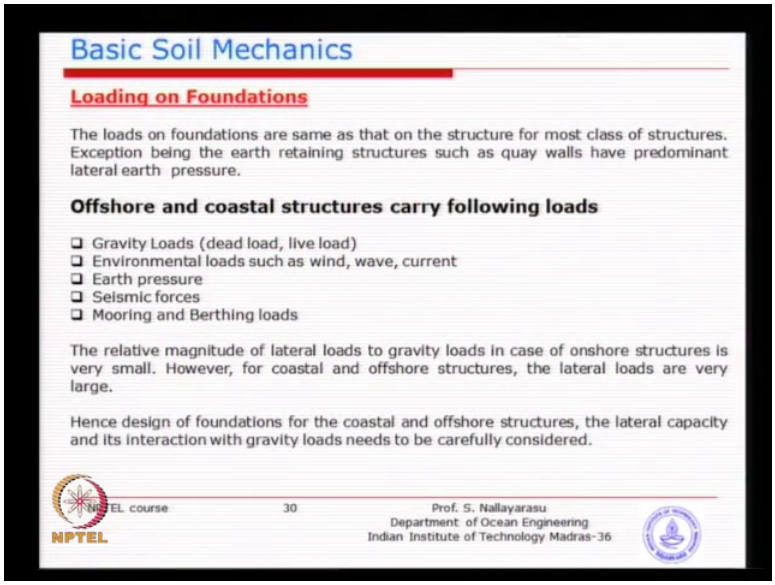

The loading, I think you will be familiar, predominantly gravity loads for gravity type of platform but for the class of structures that we are looking at for jacket type of structures, the larger wave loads or the environmental loads from wave, current and wind makes the design slightly different from onshore. Of course you will also be designing for Seismic process which is derived from your gravity loading. Earth pressure may not be an issue for offshore structure, except for coastal structures.

Mooring and berthing loads also magnitude wise will be very smaller for offshore structures compared to the coastal structures. There the jetties or port and Harbor structures will have a larger because you bring in a big ship, whereas for offshore structures we do not bring to bigger ships, there we may have smaller boats for supply.

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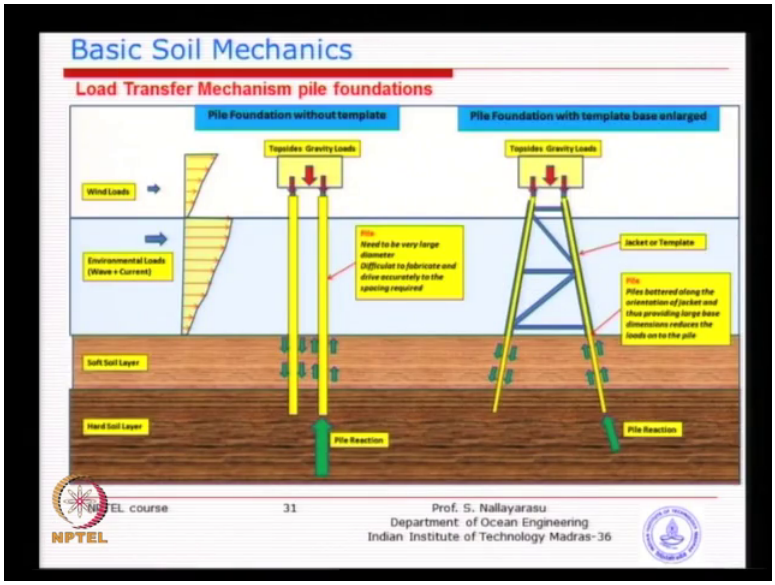

We have this picture basically last time, you know the load transfer, the spacing between piles, the reason why we widen the base, so the magnitude of reaction reduces is the best principle that he wanted to adapt so that you achieve, actually the material does not change, the configuration makes efficient form of load transfer, you know, that is the idea behind because you have the same diameter of the pipe but then you have made wide at the base. Of course you can do that here but in this particular aspect we want to keep the template for driving in accurate position.

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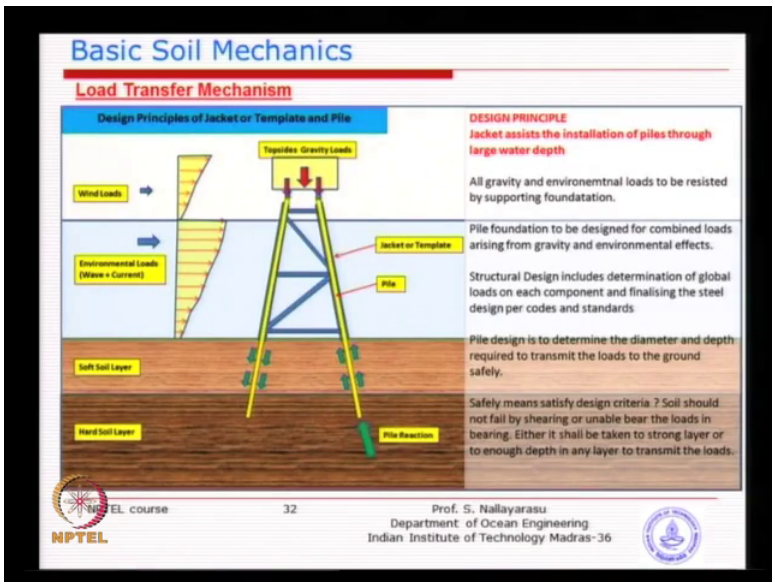

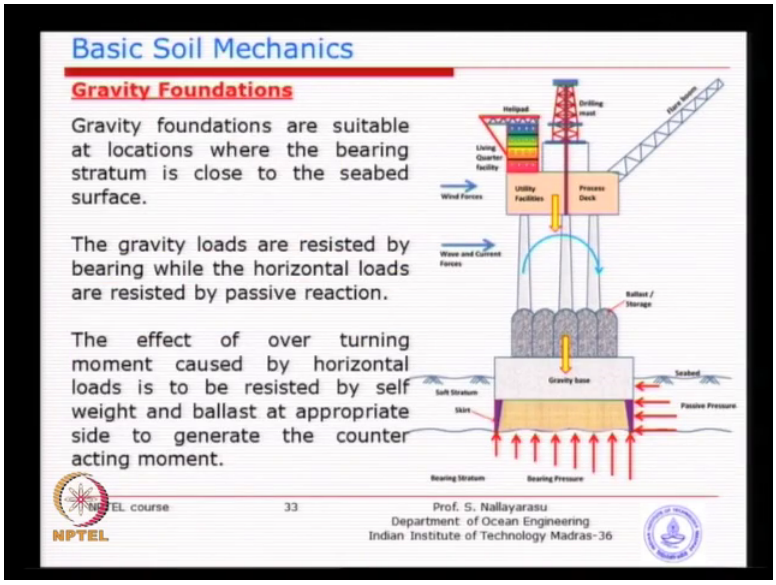

Similar idea and the configuration of the jacket is going to change the amount of loading that is going to the soil, so the types of load that we have on these structures. Gravity foundations, very similar principle, only thing is there is no depth, you know more than 10 metres, most of the gravity foundations will not be able to sink further. So what we are looking at is sinking the gravity type of foundation to a stable ground where subsequent time bound displacement will not happen. You know you need to find such type of layer and also you have reasonable depth of skirt which will provide you for horizontal stability.

Otherwise you will have to rely purely on the frictional resistance between the soil and the foundation. So the principle is very simple, the stability is achieved by its own weight and most of the gravity type of platforms are built where you have a very good ground below, 5 metre below or slightly higher.