Foundation for Offshore Structures
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Module-1
Lecture-2
Basics of Soil Mechanics II

So today we will just see the classification, so the piles, I did not go into too much of you know the material classification because in olden days people used to use timber piles, concrete square precast piles which are low load carrying capacity for onshore structure. You might have seen in many industrial applications, you know normally people use precast concrete pipes of smaller size maybe 200 MM by 200 MM square size or maybe 300 but not more than that. But in some cases we also have used precast circular concrete pipes for marine applications in the smaller water depths, but not very common because of the complexity during installation.

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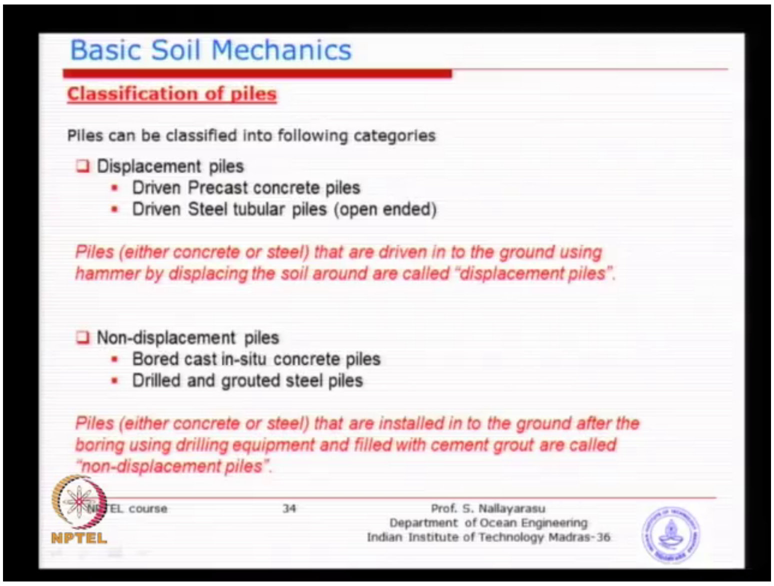

You know the precast concrete piles when you are driving, it may actually crack depending on the resistance of the soil. So commonly used piles are steel or concrete, concrete also is used but mostly last in situ. Safe have a precast concrete piles or steel tubular piles, you need to drive into the ground. So when you are doing that, you know the erection of the pile into the soil by penetrating, by displacing the soil that is supposed to be occupied at the location of the pile. For imagining, you take a 1 metre diameter shaft, circular, square, whatever cross-section, you try to drive by means of hammering at the top.

When you do that, what happens is the soil is getting displaced, so during the process the soil gets densified in around the pile surface, which actually makes slightly better in terms of capacity. So that is why we call displacement piles which are better than the non-displacement piles. Basically you do a boring in the ground and take the pile and erect it inside and you leave it, you know you can just leave it without doing anything. Over the period of time the soil may come and get in contact with the pile or region create an artificial interface, after making a hole you put the pile inside and just do a grouting interface.

That means the pile to the soil is connected by better material like grout which gets bonded, so you can either do that. So basically what is the difference between the displacement pile and nondisplacement pile, one of them is creating better characteristic of oil, the other one maybe degrade, during the process of drilling you are disturbing the soil, you remould the soil, so it may take several months and years to get back into its original quality and characteristics. But then depending on the situation we apply to one of them most of the time we use driven steel tubular piles beyond certain water depths because of the strength requirement, for example if we have 10 metre water depths, maybe any pile can work.

But if you have 20 metre water depths, maybe making a concrete pile to take the slenderness and the strength characteristics you may require a very large diameter, for example 2 metre diameter, maybe difficult to construct. And that is why at that type of water depths you go for steel pipe piles which you can make a 1 metre, to metre, 3 meter, any diameter you can make, it is quite easy because you are going to take a steel plate. In terms of nondisplacement piles you can use cast in situ concrete piles which I think we described in the last session how a cast in situ concrete pile is being erected at a site.

You make a driving of a casing and do a boring, pour concrete after placing the reinforcement, with and without the liner. Sometimes what happens, people want to economise, while the concrete is being cast, they actually slowly pull the liner upwards. You know you drive the liner, bore it, put the reinforcement inside and just pour the concrete in stages, stage 1, stage 2, when you reach certain stage, you just pull the liner up and then put the 2nd stage and liner up. So once the concrete is set to a reasonable extent, pull out the casing fully so you can reuse the liner for another place.

It does 2 advantages, it actually creates an interface with the concrete the soil directly, number-one and also you save the material for the liner because you are not going to include the liner in the structural calculation, it is only a very thin plate. And basically can save some material but again there are advantages, disadvantages because when you are pulling out the casing, you may actually disturb the concrete itself which is not very good, sometimes we do not recommend so bored cast in situ pile with and without liner, the calculation for the soil capacity is different because now we are looking at the soil to pile interface.

If we have a steel to soil interface is different than concrete to soil interface, which is better, for sure, concrete to soil interface is better because it is rough, at the surface it is not very uniform. So the interface is going to give you a increased soil resistance. Mostly we will not go into calculation of bored cast in situ and drilled and grouted piles, basically it will not be applicable to the offshore platform. Whereas we will use driven steel able piles, in fact 100 percent, you will not even think of using concrete piles for offshore platforms. Concrete piles are purely applicable to the coastal and near coastal structures of smaller water depths and maybe reduced loads.

But for offshore structures, even if it is located in 20 meter water depth or 30 metres water depths, we will not use any other piles because the magnitude of loading is larger. I think that gives you an idea between the displacement pile and a nondisplacement pile, how and why we need to know this is to get an understanding of the soil behaviour. Yet you are disturbing the soil, where the other one is your better densification, especially in the coastal region soil.

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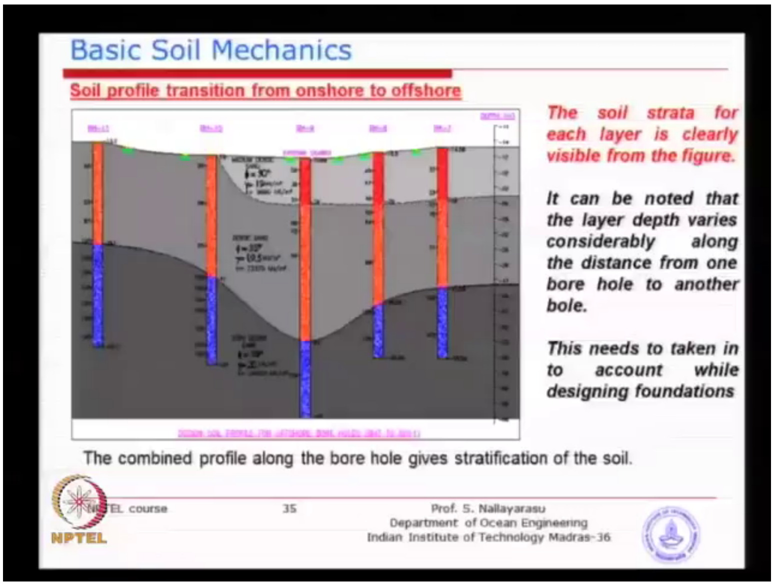

A typical picture I just wanted to show you how a soil can vary a long distance because we need to make a decision how much information is better. More information is good but then it becomes time-consuming and then also expensive. So if you are constructing a bridge, say 10 kilometre bridge, you know how many locations you want to do a bore to find out the soil strength along the length is to be determined. You know, you can say every 10 metre, that means 10 kilometre if you do, every 10 metre, it will become separate project for bore investigation itself, it takes a longer time.

So what we need to see is, you identify certain course of spacing, look at the soil profile, for example you look at this picture, you can see here layers, there are 3 layers distinctively, one of the layer is intermittent, you know basically the top layer is not continuous over the length. But the 2nd layer is throughout the length and the 3rd layer also and varies considerably. You can see here one location is about 50 metre depth the other location becomes 40, so there is a considerable variation. But after getting this profile you can easily find whether you need intermediate bore hole or not.

Sometimes you can make a decision, if it varies vary considerably, for example in the starting you make everyone kilometre boring and find out if the variation is almost uniform, maybe you can say it will want to do intermediate bore hole. But if there is changing in the profile, changing in characteristics, then you do a, the bore hole at the middle or somewhere you can decide. But that such problem is not there for offshore structures, mostly our structures are isolated. For example offshore structure is based with 50 metres by 50 metre, within 50 metre if the soil changes, then it is a bad luck but most of the time we do a bore hole at the centre of the structure where you want to construct.

So typically, the profile, it needs to be obtained if you are having a complex of structures, for example 3 or 4 structures in the region, you collect information from structure 1, structure 2 and structure 3. You look at the profile how the soil changes, then you can interpolate, the idea of whole this activity is to make sure that the information at this location we do not know but what we have done is, based on the bore hole on the left side, bore hole on the right side we think the soil could be of similar characteristics, variation could be like this. It may or may not, actually can change from here to go like this and come back but nobody knows.

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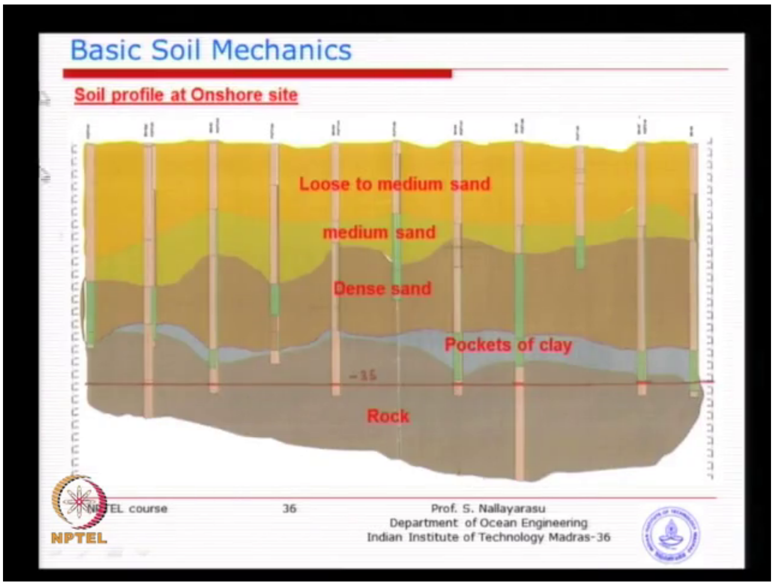

But that is the best possible assumption that we can make, so the closer intervals of bore hole, you can get a profile reasonable correct, because we are going to use this information for foundation design. Similarly if you look at another site, and onshore site, you can see here, some places the pockets of clay is larger in thickness, in some places it is not even there, some places very thin. So you can see here this blue colour, the pockets of clay is sedimentary in nature, probably happened several years back and the position of fact the material on top, this is a stall, this is very close to Ennoor port, one of the new ports is being planned to construct.

The soil investigation reveals that there is a packet of clay varying in nature spread over all the area and the top 3 layers of sand over a period of time we can see here dense sand, medium dense and then beach sand, loose sand. So deposits and keeps happening and that is the characteristic of sedimentary material near the coastline, so you can see them. So basically with this we want to continue with the construction, whether you want to finish the pile, whether you want to stop the pile here, I want to stop the pile here needs to be decided.

So this gives an information that the clay layer is going to potentially create a problem if you happen to tell me that you have pile in that layer. So that is exactly why we need to do more number of borehole because if you have done only one borehole at this location and it happen to be at the location where there is no clay layer and you think it is representative of the whole site and construct the foundations everywhere and terminate the pile foundation at that level, then you will end up in lower capacity than what actually you printed using the properties derived from one of the bore holes. So the danger is very very imminent if you do not have enough information. Especially when you have the structures spread over a larger area.

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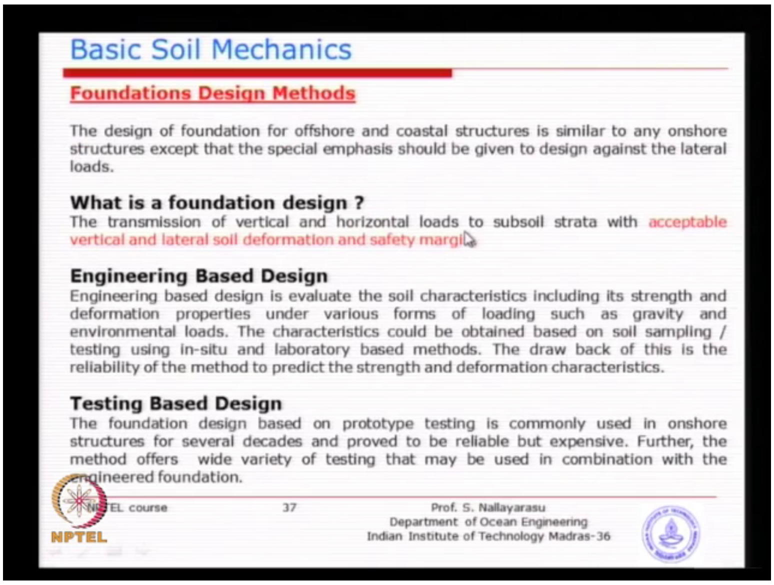

So that is why bore hole investigations or the site investigations becomes a predominant component in the foundation design. So how do we do the design of foundations, there are several methods which are recommended in the past by codes, by experts. One of the best method because now by this time you should have understood the variability of soil as the material and the characteristic changes with respect to place, with respect to time to some extent due to degradation and the best method is to construct the structure and do the testing.

For example you construct the foundation itself, prior to constructing the superstructure you do the testing. And once you establish the relationship between the load and its displacement characteristics of the prototype, I think that is the best form of proving that the foundation has the sufficient capability and the capacity to receive and transmit the loads to the foundation soil without excessive deformation. But how many of those things you can do, for example you take a jacket structure, you have say 4 Corners, 4 pile foundations and you need to test 4 of them. If you want to get 100 percent surety that the structure is the structure is safe for the foundation is safe, you need to do all 4 of them.

But if you have onshore structure for example industrial building having several hundred piles, you may have, if you look at some of the structures on land you will have several hundred piles. And if you have to test all the piles in that particular site, it may take a lot of time, lot of effort. So what we normally do is, we do the testing of samples of piles. Out of

100 you do testing for 10 percent of the piles. Pick and choose the location of the piles, for example you have a grid of piles, you select several locations which will represent that particular locality and then do the testing.

Once you do one of the pile is tested, that information can be used to prorate the design of new piles. For example you do the testing of one pilot a particular location on site, gather information with regards to the load carrying capacity with respect to the displacement, use that information for your future design, because you might have designed the foundation using this characteristics derived from borehole, you have taken a sample, taken to the laboratory and tested and you have derived some strength characteristics, similar to steel, steel for your design purpose you have yield strength as a design characteristics.

Similarly you can derive from design characteristics which we are going to discuss in the next few hours. So use that information to design, purely based on borehole. After that you obtain the testing and compare the capacity. You have done your calculations, for 10 metre of depth of penetration or 20 metre of depth of penetration, some capacity you have tell quilted based on what you have understood from the laboratory testing characteristics + your understanding of the soil and applying mechanics, principal of load transfer, either by shear or by compression, you calculated the capacity based on the theoretical methods using the results from laboratory and field testing.

And now you have constructed that foundation, then the testing, you compare these 2 capacities. If they match very well, it is very good because your assumptions in your analysis or assumptions in your calculations is matching well with the behaviour at site. If it does not match, then there is a correction to be made, what we do normally is you take the correction factor back to the engineering room. If the capacity predicted is higher, you correct it, you bring down.

So you will go back and change the parameters of the strength of the soil iteratively because you do not know which layer has contributed higher or lower, unless you have the layer wise result which is very hard to get because the pile load test will not reveal such type of information because you have constructed the pile to the total depth and then you have done the testing. It is not like every time you try little bit do the testing, you are not doing that which is also not feasible. So that is why testing base method is very helpful because you collect information from prototype testing, use that to correct your design parameters, calculation backwards and again come back and find out what is the penetration required.

For example 20 metre penetration originally I have assumed, have calculated the capacity as 100 tonnes and I have installed the 20 metre penetration pipe, did the testing, capacity comes to be say 80 tons. How do we say that 80 tons basically acceptable displacement? The capacity can be larger if we displace the pile by larger displacement. So you will get the load displacement relationship. So if it is 80 tons and you have calculated 100 tons, you have to correct the design parameters to get 80 tons, use that reduced parameters to calculate what could be the increased penetration for 100 tons.

So that would be the future, so all the new piles will be installed with 25 metres, if you come up, so that is the correction factor that you will apply. Testing base methods, very very expensive, I will show you the photographs of some of the pile load test, it is very massive, I do not know whether you have seen somewhere in the Chennai city some of the places pile load testing has been going on but not recently. I think a few months back the CMR CMR L construction sites, Metro sites, they were doing a few places but now I think all removed.

It is massive because you have to mobilise so much deadweight to simulate the superstructure loading and time-consuming and occupies large space. So it is a lot of trouble there, so we have to minimise the number of testing, normally you do not more than one or 2 piles in a site, because of you know the cost and time. The next method is purely engineering-based method, for example if you have onshore site, you could do this testing no problem because you can mobilise all this required. If it is a coastal site, also can be made because you can construct a temporary platform by which you can do the loading.

Whereas if it is an offshore platform, 100 meter water depth, doing testing by any means is impossible. For example when you do a pile foundation for jacket, we cannot do testing, that means we are going to 100 percent rely on what the engineering calculation has been carried out and now testing can be possible because of the nature of foundation and the depth of foundation and we are installing a pile foundation through a jacket through which you cannot do testing. One of the biggest problem for testing is the reaction, I think every pile load that you apply, you need a reaction test frame which is very difficult to make it an offshore.

The testing we will talk about it I think later part. So purely based on engineering design, it is going to be a challenge because the amount of information you gather from the site is going to be used, so the more information is better. So that is where most of the offshore platforms, we rely on engineering-based designs. Whereas the coastal and onshore structures is testing but not 100 percent tested, partially and then we use that information to readjust the engineering so that we can correct the mistakes.

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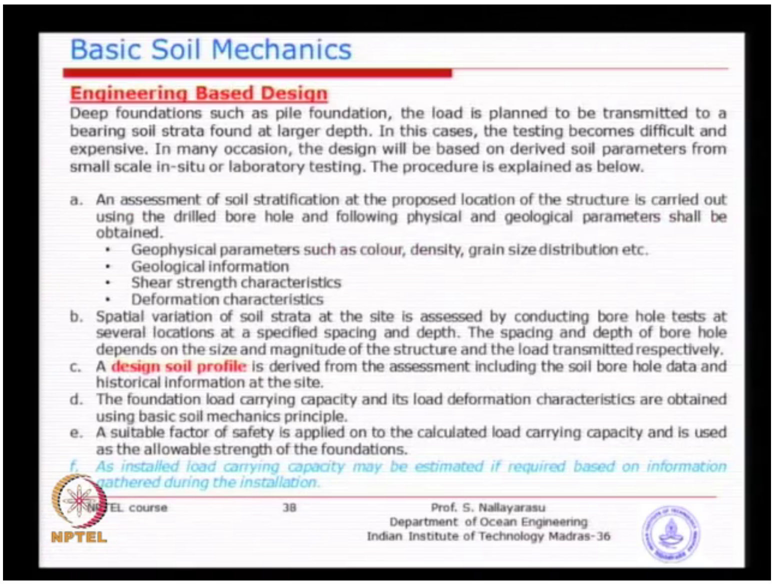

So that is the idea behind, the foundation design based on engineering is a very simple sequential task. The 1st thing is to establish the soil characteristics, so that means the soil stratification at the site has to be established. By historical means you can actually look at what has happened over several years for any particular confession activities in the recent times in that area, because you will get information with regards to soil bore holes, also when they were trying to do installation of piles in that vicinity, you could collect information and the world records, it will tell you whether it was hard-driving or easy driving or the pile was going through easily.

And then do a borehole at the site, collect information with regards to type of soil, strength characteristics either at the site or at the laboratory. If you bring the soil back to the lab without disturbing and then it is deformation characteristics like Young's modulus, I think that is very important. So you do a testing to establish relationship between stress and strain. So once you do this for one particular and look at the spatial variation if you have more information, if you do not have information, then you are going to rely purely on borehole.

That is why most of the time for offshore structures we do the borehole exactly at the centre of the platform itself, so that the distance to all 4 pile is equally distributed. The risk involved in installing a pile is equally distributed, is not it. So all 4 will have a same equal risk, but of course if the soil varies within the 50 metre, as I mentioned earlier it is a bad luck. Some projects it has happened, you know in the last year we were having a jacket, only 4 main piles, 3 piles perfectly installed without any trouble, means it had gone to the correct depth of design and stopped.

The last pile, it could not go more than 50 percent, so we do not know within that 50 metre what has happened to that one corner. And that is exactly the nature of thing that we are looking at. So if you purely rely on engineering-based design, you go offshore, you take for piles and you just go and try to install and one of them is not going. So what happens to this jacket? That jacket has to be downgraded because that is not mean that it has got, it has achieved sufficient capacity because you might be using the capacity of the pile throughout the length but the length is reduced, but of course increased base resistance. So when you calculate the capacity, you found that it is not enough.

So because of the foundation calculations, you actually can abandon the jacket because it does not have sufficient strength to take the superstructure loads. So such scenarios are very common, because we could not do the testing, we rely highly on. So you can imagine if they have done 4 bore holes at 4 Corners, that would have been slightly better but somebody wanted to save money just because we do not want to do 4 boreholes, we will just do one. And it is still continue to be doing similar fashion, we do want to do 4 boreholes because it is time-consuming, every borehole will take 3 to 4 months to do and laboratory and write report.

So again that mean that the risk always, when you are designing a foundation for offshore structures, the risk is higher compared to onshore structures because you are not doing pile load test. So basically sometimes we do back calculation, during the driving of the pile you can count the number of blows required to penetrate. For example you take nail and if the nail is going through very easily, it indicates the soil is softer, if it goes very slow per blow, for example for 100 blows it goes by very distance, means the soil is denser.

So the relationship between the depth of penetration versus the number of blows required of a particular size of hammer. If you gather this information during driving, you will be able to correlate this back with the strength because a lot of historical information is available. So you can also calculate, but again empirical because it is not going to be 100 percent similar to testing. So the engineering-based design has several several uncertainties I would say. Now you could see the difference, if it is testing based, the uncertainties have been removed by doing the testing. Whereas you do not have testing, then there is a large variation in soil characteristics going to happen if it is a larger structure.

And because of that we need to apply a margin of safety. I think when we discussed about structural design, it is a well-known characteristic of steel material, still be applied margin of safety where we divide the instant by 2, by 0.66, depending on nature of loading we take only a fraction of yield strength as a strength material used for design purposes. So similarly here we need to apply a factor of the strength of the soil at failure and that will be the strength used for the calculation of foundation depth, that is called factor of safety.

And for different types of pile, different types of foundations, wearing nature of factor safeties are recommended by codes, experts. But for steel pipe piles for offshore applications, they recommend a minimum factor of 2, that means you calculate the capacity as 100 tons at failure, ultimate failure, divided by 2 will be the load by which foundation can take safely without excessive deformation. So basically a factor of safety of minimum of 2 is required, so we are using 50 percent, very similar to what we were doing for structural steel calculation, we were using 66 percent of for bending, axial 60 percent, shear 40 percent, I think you remember.

Similarly here we are going to use a 50 percent of the shear strength of the soil as the allowable capacity in comparison to the ultimate capacity at failure. But if you look at concrete piles or maybe other shallow foundations, different type of factor safety, maybe they will allow 3, 4, sometimes some codes ask for 3. So it depends on the uncertainties and the potential problem with failure, you know the risk of failure and type of structure, you know residential buildings you want to give higher factor of safety where the risk is higher for human life, whereas for the low class structures where there is no human activity, you can actually reduce the factor of safety because only you going to lose the property but not human life.

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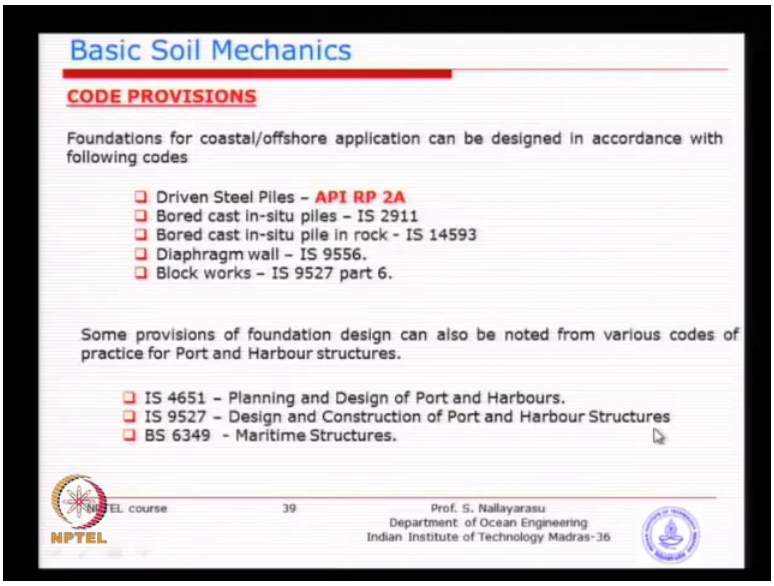

So the engineering-based design is the one that we are going to practice, of course we also will look at pile load testing because some of the coastal structures you may require. What are the codes available, we will just go through some of them and I think other codes will focus on API because for steel tubular pipes, that is the only code available. But of course you have other codes like bored cast in situ pile, IS 2911, there are 4 parts, I think it is available in our library also. And we also have board piles in rock, this is bored pile in soil either clay or sand, whereas bored piles in rock is a separate code because of the nature of low transfer between pile and the soil.

Diaphragm walls, I think I have shown you some pictures on that in previous session, the diaphragm wall is nothing but the retaining wall, only difference is one side is water and the other side is soil, very very often used in Port and harbour structures, that is just creating an interface between land and water, so that the ships can come closer. Diaphragm walls also used in onshore construction nowadays, you might have seen some of the high-rise buildings, especially when they have a basement, 2 or 3 levels of car park, you actually created diaphragm wall, it is just very similar to retaining wall.

And then the block work, basically I have shown you some picture of block work, simply precast concrete blocks stacked and with proper shear keys so that they just do not slide. So that is, but basically the calculations here is the bearing capacity, when you stack very high block of say 10 metre, 20 metre, the total weight is acting under the seabed or the layer bearing. So you need to look at the bearing capacity under water. In some cases, you know some of the codes that I have mentioned here, also specify some requirement for foundation, especially factor of 50, if you look at IS 4651 for ports and harbours, the factor of safety is specified there.

Similarly the IS 9527 is the construction and practice and then 6349 is the British code of course, is also a maritime structure which is applicable to coastal, like port and harbours, jetties, Wharfs, so you could see here collective information of codes, so you need to just use it judicially according to do necessity and the type of structure that you are designing. So we will focus predominantly on API RP 2A which is basically a code coming out of an American petroleum Institute which is applicable to you know US waters, specifically for Gulf of Mexico.

Most of the recommendations and the classification of soils are based on those areas in Gulf of Mexico, but of course more generic, many of them reasonably generic that you can use it without much problem in our areas. Of course if there is a special type of material, then we need to modify the procedure, not using blindly, you know it is quite obvious.

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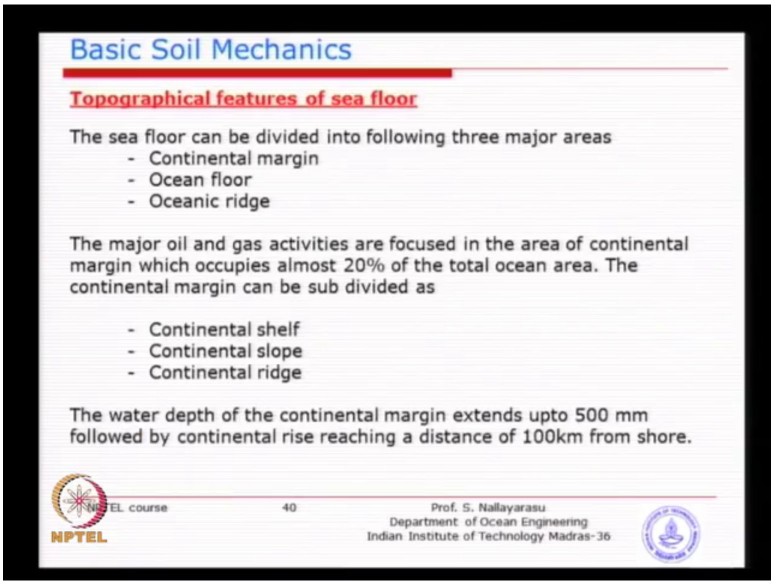

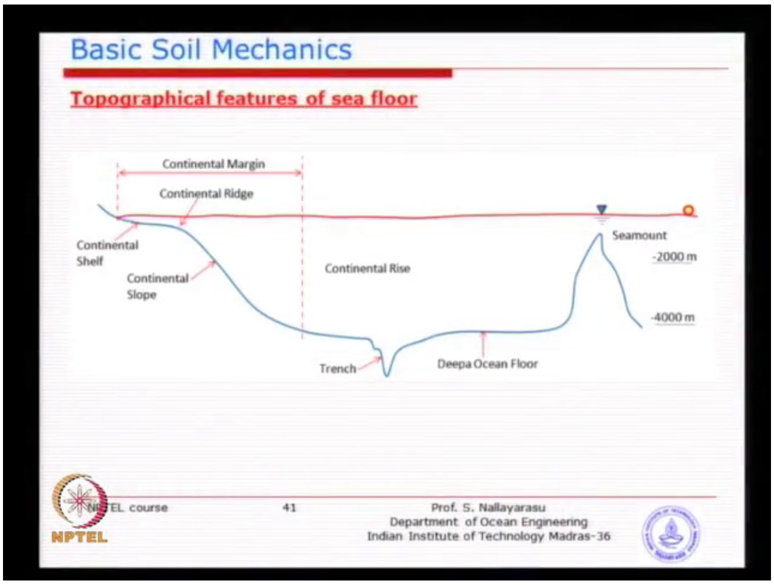

We will just quickly look at you know how it is different, onshore soil versus offshore soil. Basically it depends basically on the sediment in nature. Before we go into the layers of soil at the Marine deposit, we will just look at how the seabed varies and what are the activities related. And if you see this picture, will give you a better idea, most of our human activities, especially the offshore island based exploration is very well limited to continental margin. I think if you taken a oceanography courses there no, so you are going through, you will realise most of the human activities are very much limited to continental margin, at least in the last several decades.

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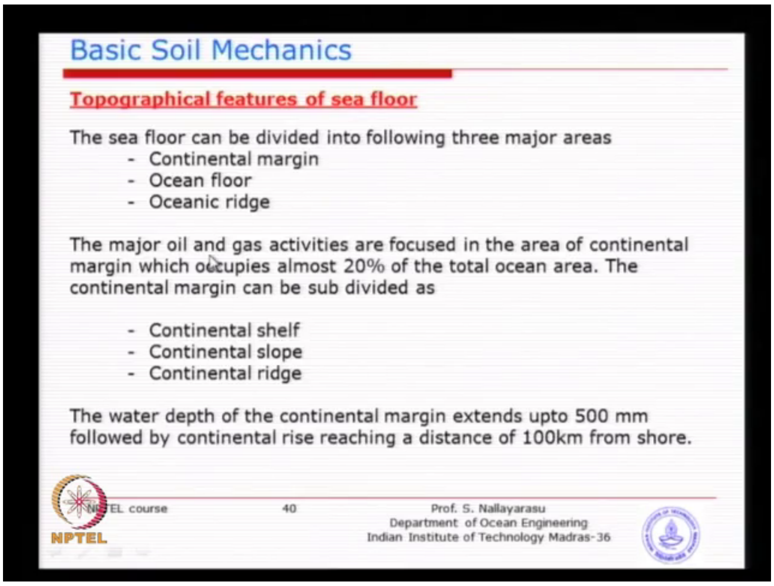

Slightly going into slightly deeper water is also happening for not for oil and gas reasons but also for mineral deposits. So you could see here the variation of the soil, I think I have shown

2 boreholes earlier, one from onshore to offshore, the other one is only onshore. So you see there some of the layers is actually purely sedimentary in the Marine deposits and area, whereas in the land or interface area, there could actually be a parent material. So that is why you will see that many times when you do a profile of the soils, some layers may actually exhibit in this area, some layers may there, but not necessary that the soil layers will actually go through the profile of the seabed, not necessary.

So that you need to understand because when you are doing a structure, for example when you are doing a pipeline, you cannot assume that the soil layers will be exactly following the profile of the seabed and that is why you will do a borehole. When you come closer and closer to the beach area, you will do a borehole very closer because sometimes you will not have a specific soil profile. A typical area where you will find problem is this area, sometimes you will not even have the particular layer.

So continental margin, ocean floor is quite far, sometimes you have oceanic ridge, something very similar like this, a shallow depth but not protruding outside water. If it protrudes outside, it actually becomes an island, that part you will see, in middle of ocean sometimes you see a small small islands, it is just basically a ridge coming out. And depending on the location, the nature of deposits, the marine deposits will be differing. You know, basically the recent deposits, at least the last 10 to 15 metre deposits could be a different.

The reason why we need to know this profile, where is the activity higher, especially the wave and current? The disturbance of the soil is high in this region because of the shallow depth, most of the currents follow the coastal profile. So you will see that the rivers coming from onshore to offshore or onshore to mix with disease also going to bring in lots and lots of material from onshore and deposits. So the more the position will happen very close to the coast and because of particles will start settling down, even if there is a velocity of flow, it will not carry for thousands of kilometre because by the time almost all particles would have settled.

So you can see here coarser materials will settle here and less coarser material will get carried faraway, farther to a deep ocean. So you can see here a specific nature of particle sizing, if you just look at distance away from the coast and if you go to a deep ocean, you will see the particle sizing is different than the particle sizing close to the… At the same time if you look at the depth wise, different timing, different particle sizes. So this kind of studies will give you a very good understanding, what type of foundation is suitable.

So as you can see here, 20 percent of the ocean floor is covered by continental margin and it is reasonably enough for us to use it for so much of your activities for hydrocarbons or for other minerals or coastal activities like port and harbours and so on, so that we need to understand reasonably enough.

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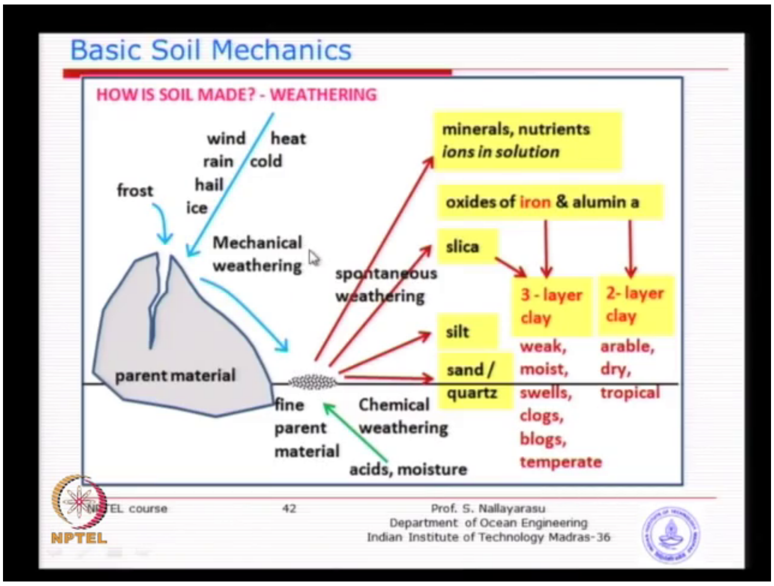

How is soil made is obvious reason, you could easily find out, basically it is the breaking down of particles from larger size rocks or larger size parent earth. Several layers of breaking them breaking them down either by environment or by mechanical or by biological, chemical or combination of several of them. You know you take a rock, if you do age study, you will find when it was actually formed, either from the parent material coming from the earth or due to solidification of the lava.

So you can see one material breaks down either by environmental means due to wind or rain or heat or heat and cold, you know some several places temperature goes extremely you know like 50 degrees. If you go to Middle East, it goes to 50 degrees in the summer and also summer itself, in the night time it goes down to lower temperatures. So the large variation can break the rock into pieces if it is a weak rock, of course not the solid rock. Mechanical weathering, basically due to abrasion, human activities, you know when you have a small rock on the road, it gets broken down into smaller pieces if something is going on top or other means.

Or you have chemical weathering due to due you know the Chemicals presentation the nature reacts with the silica available with the parent material. So you could see here a variety of choice, variety of actions on the soil can create particle sizing depending on location, depending on which action makes and gets carried by the primary form of transport is the river flow or by wind, you know wind can carry large particles from one place to other, of course depending on the size.

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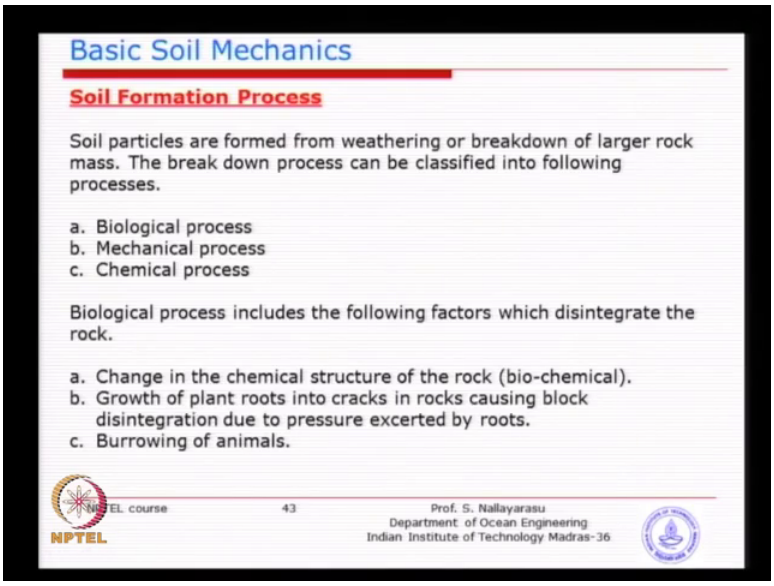

There are 3 processes we want to know as a geotechnical engineer, we do not want to know too much information about how the formation but at least we need to know the origin by which it is, because it is going to be used as a material for load transfer, especially if the material is biological in nature, how it will behave when you apply the loading. When it is Mechanical processor chemical process, how it is going to affect the foundation. So biological basically change in chemical structure of the rock by a biochemical process.

Growth of roots in plants you might have seen in many places, if you go to old temples you will see that rock is broken just because of the growth of tree over a period of time, you know it just comes out or animals doing damage to the existing systems, so you just open it up. And basically biological process is very minimal damage. Mechanical weathering is the predominant form of forming particles of various sizes, or chemical in very isolated places.

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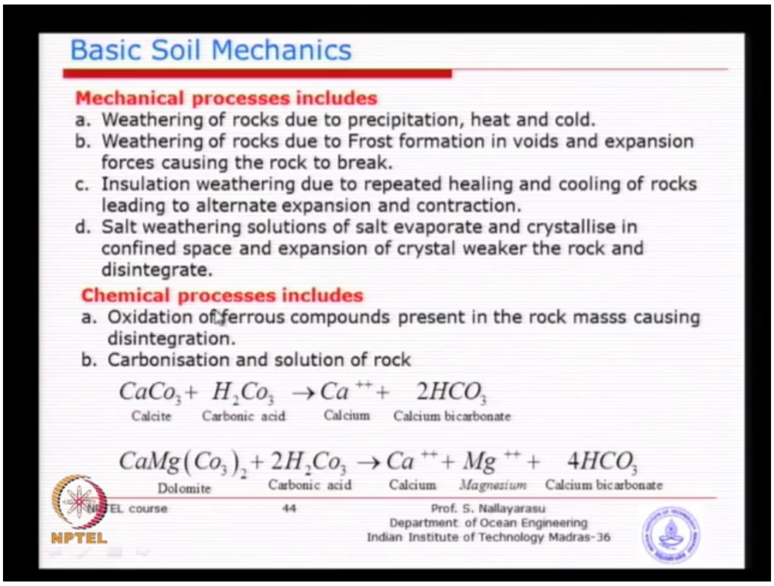

You know basically due to carbonisation or basically oxidation of ferrous components present in the rock inside, you know basically trying to, so during oxidation it actually will know becomes oxides and become porous, then the rock breaks. Mechanical process, I think several actions heat and cold, frost and basically salt weathering, if there is a salt present inside the rock and then it gets dissipated during evaporation, it can actually create the force inside the rock to come out, so that is basic Mechanical weathering.

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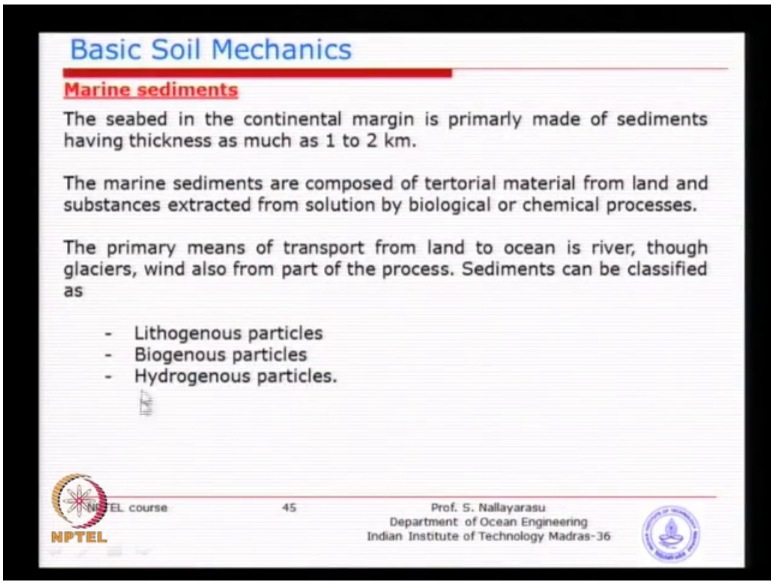

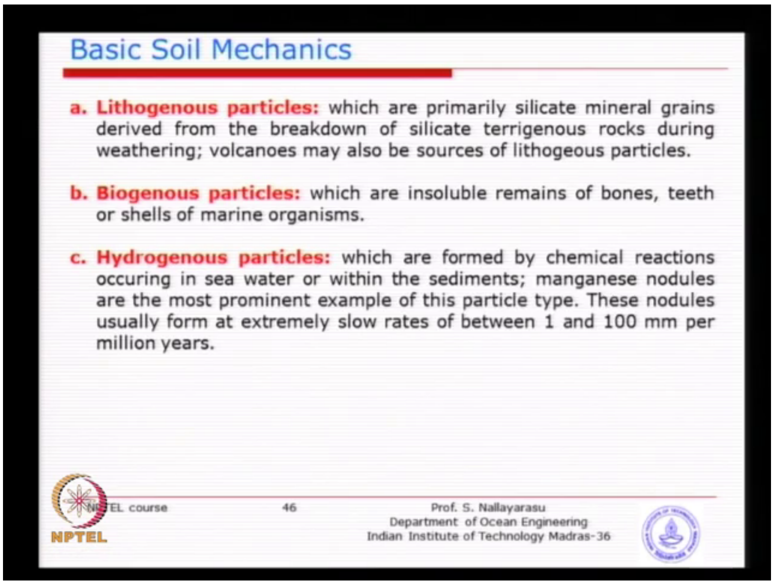

All these will be combined form, it is not going to be one and you know individual forms of disintegration of material. Marine sediments can be divided into 3 categories, as you can see here Lithogenous, Predominantly silicate type of you know material, very similar to sand that you can see a specific particle sizing. Biogenous basically reminds of animals, Predominantly bones and then Hydrogenous is the material formed by you know basically chemical reactions.

Out of all these 3 forms of formation process what we have discussed. Now what we need to know is what it does, if it is Lithogenous basically a silicate material it is very good because it is not going to break down any further. Those particles can stay together when you apply loading, whereas these particles may break depending on the strength over a period of time. These hydrogenous particles are going to be slightly risky because they can get change in shape during the process of application of loading. So when you actually look at soil borehole, the 1st thing you look at the composition, whether it is silicate material or there is any other forms of material present in.

So you do a chemical analysis to try and find out how much of silicate, how much of Biogenous material is available in the new look at any fairing particles in terms of chemical composition. The most important one is the carbonate material, you know many of these areas near the beach or at least near the coastline within several kilometres, you will find a lot of carbonate material, which will look like good silicate, dark in nature but when you apply loading it gets crushed and becomes powder. So that is the type of material causes lot of failure to foundations because it was not identified during the investigation process.

That is why nowadays almost all sites, chemical processing of soil is compulsory to find out what is the composition, irrespective of particle sizing.