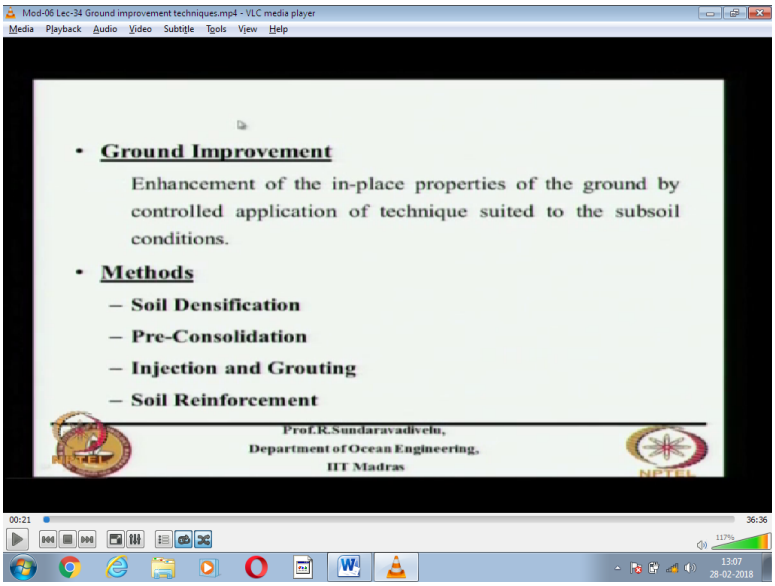
Port and Harbour Structures

Professor R. Sundaravadivelu
Department Of Ocean Engineering
Indian Institute of Technology Madras

Mod-06
Lec-34
Ground Improvement Techniques

This class will discuss about ground improvement techniques this photograph showing how they do the vibro compaction.

(Refer Slide Time: 00:20)



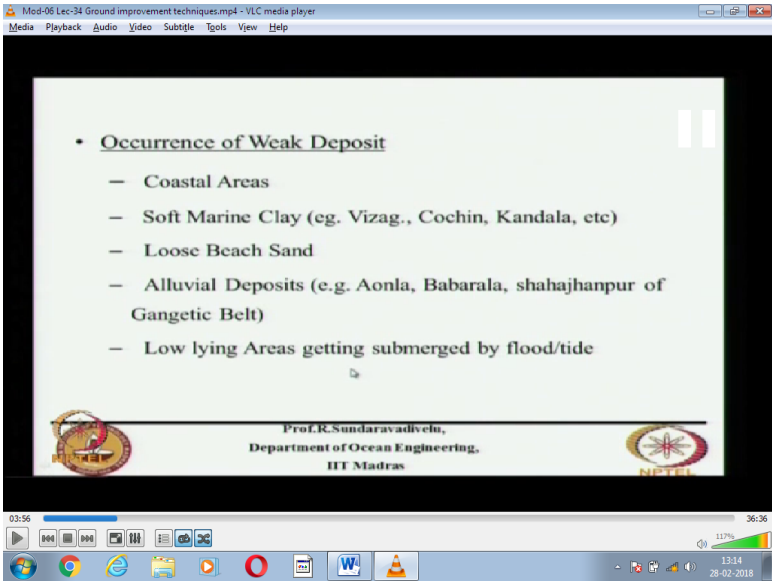
So what is ground improvement, ground improvement means enhancement of the place in place properties of the ground by controlled application of the technique suited to the subsoil conditions. Depending up on the type soil there are different methods are available which is listed here; you have to do that to increase the soil properties why this is required.

If we do not increase the soil properties there are many disadvantages I will explain about them, one of them is the caused you improve the soil properties the cost of the foundation will be much less compare to without improving the soil properties. Some time you do not improve the soil properties and do the constructions there is likely to be frailer not only for the foundation but also to the super structure.

There are basically four methods one is the soil densification, that is improve the density of the soil another is per consolidation that means you do the pre loading so the consolidation

takes place then injection and grouting that means use of some chemicals for grouting next is soil improvement either by jio grids are jio textile reinforcement so each one its own applications we will discuss some of which are being use for marine structure.

(Refer Slide Time: 01:56)



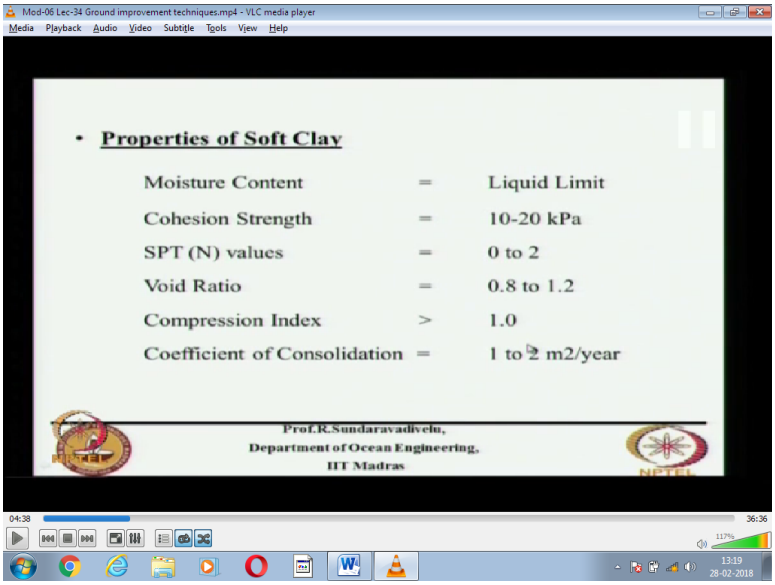
So we have weak deposit, the weak deposit are in coastal areas and one of the weak deposit is soft marine clay it flows like liquid these type of structure are in vizag, cochin and kandala. One of the structure which a was built recently as collapsed because it didn't take in to account a either improving the soil soft marine clay or they are not design the structure taking the correct properties of soft marine clay.

In kandala during burj earth quack there was some failure not complete partial failer to some other piles because of the earth quack induced slop insatiability. Cochin also we have very soft marine clay here the depth of the soft marine clay deposit is more than sixty meters, sixty meter means twenty story building so they have to go for piles they put the piles you have to go to at least six zero meter below the see bed or below the ground level in the land.

One of the problem of this soft marine clay is it will have what is known as negative skin friction instead of the pile taking load from sub structure because of the settlement of the soil more than the settlement of the pile, the pile will take additional loads that is called as negative skin frictions that means the total capacity will come down.

Then we will have loose beach sand then will have alluvial deposit these are on land then there are some low lying areas which will get submerged by flood dark tide so when this happens also the weak deposit further weakens, whenever there is submergence of this deposit by soil.

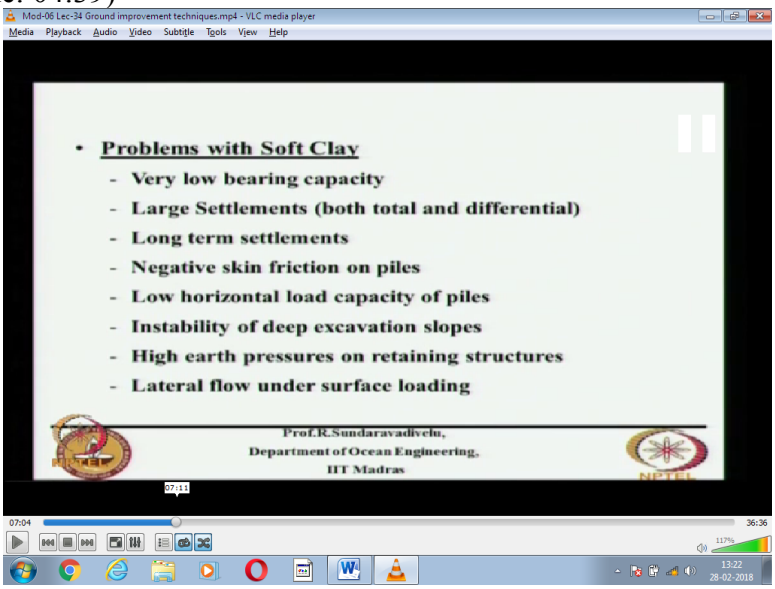
(Refer Slide Time: 03:57)



The soft marine clay the moisture content is very close to liquid limit and the cohesion strength is ten to twenty kilo pascal so this is very low value the SPTN value will be zero to two or less than two so when do the STP test where put a where they find out number of blouse penetration of the spoon you do not need any number of blouse it will do on its own self it.

That is define by this soft clay void ratio, compression index and coefficient of consolidation is given here these are used to calculate the settlement which is beyond the scope of this present lecture but these information's are required if you want to calculate the settlement.

(Refer Slide Time: 04:39)



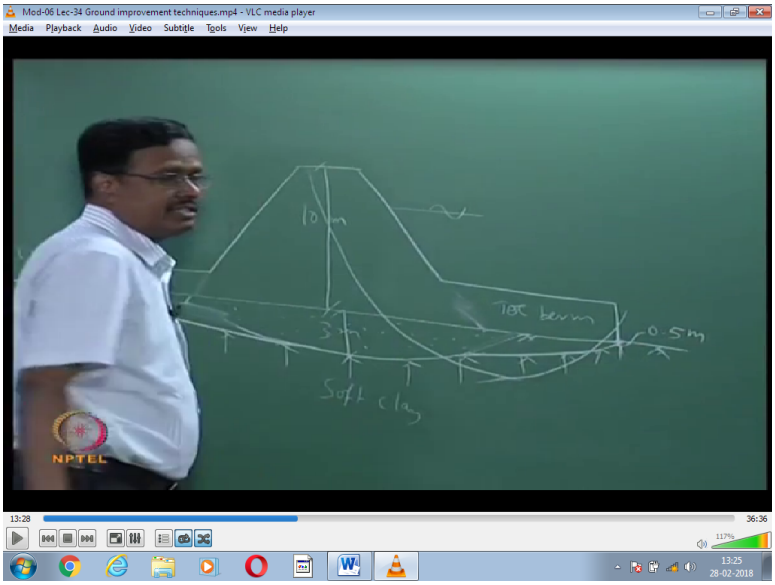
So what is the problem with soft clay, it has very low bearing capacity may be normally the bearing capacity very low value is five tons per meter square. Fifty kilo newton per meter square but it is very good soil it will go up to forty kilo forty tons per meter square that four hundred per meter square where is very low bearing capacity means it will be about five kilo newton per meter square very low.

There will be large settlements this is indicated in the last class the total settlement and differential settlement total means if there is structure how much will be the total settlement but there are two points in the foundation two ends they will not settle same way there will be some differential settlement, differential settlement permissible level is very low and some of the soft clay is deposits where we want to build a break water example is recently we want we are designing settlement for a break water at Paringi Patai which near Chidumbarum for infrastructure project for a power plant the settlement is about three meter on see put a break water stone.

If you do not treat the soft clay than the settlement is coming about three meters at the where the height of break water is soil but other ends it will be less about half a meter that means the total settlement is about three meters the differential settlement is about two and half meters. This settlement is a long term settlement, the settlement will not be immediate it will take years, years means ten years twenty years to achieve the settlement. Maximum settlement what we are calculating about ninety percent will be reach in about ten years' time where is he balance will take another ten years'.

There will be negative skin frictions on pile and these piles will also have low horizontal load capacity. There will be instability of deep excavation slopes whenever you excavate there will be instability than there will be high earth pressures on retaining structures than there will be lateral flow under surface loading, these are the various points to be discuss about low bearing capacity related to soft clay deposit.

(Refer Slide Time: 07:10)



Did we discuss about break water design no we discuss about Watson's formula and other things, all these things are based on views, how much view absorption is required to resist the view what should be the weight of the stone, there no soil properties are coming to picture right.

So what happens is, I will draw only the outer boundaries of it, break water this is your water level we calculate the ormer units and other things based on the view height and view period. We have never discussed anything about the sub soil, the sub soil is drain sand or rock there is no problem. Suppose there is a soft clay deposit here bottom what happens is whatever material you are putting these materials makes this, suppose this is a soft clay layer, this soft clay layer because of the weight suppose let us say we are putting for about ten meter, because ten meter means the weight will be about ten into density of rock density of the rock with ormer units is let us say two point six five into one minus point three.

The point three is the wide ratio whenever you put the stones there will be some openings suppose you take one meter by one meter box and you put the stones you cannot pack it like

water you put the water one meter by one meter by one meter will have the volume of one cubic meter. Where is you pack it's with stones the volume will be zero point seven cubic meter that what it is given as one minus point three, point three is a wide ratio so this will be the weight, so the weight will be approximately if you calculate seventeen point five five tons per meter square so about ten meter height will give a value of seventeen point five five tons per meter square.

Some of the soft clay is deposit the bearing capacity will be much less than five tons per meter square this is the lowest value but some of the soil clay may have only one tenth of that. So if you put where the capacity is five tons per meter square if you put seventeen point five five per meter square what will happen what will happen what it is cannot stand what will happen, the settles what happens to the clay (())(10:14)will be excuse out, if out this on top of the soft clay deposit all the soft clay will go to the sides or go to the forward end it won't remain then it will called as mad flow that is what is given in the last point lateral flow under surface loading suppose the last point is given in this power point when you put the loading the lateral flow will take place.

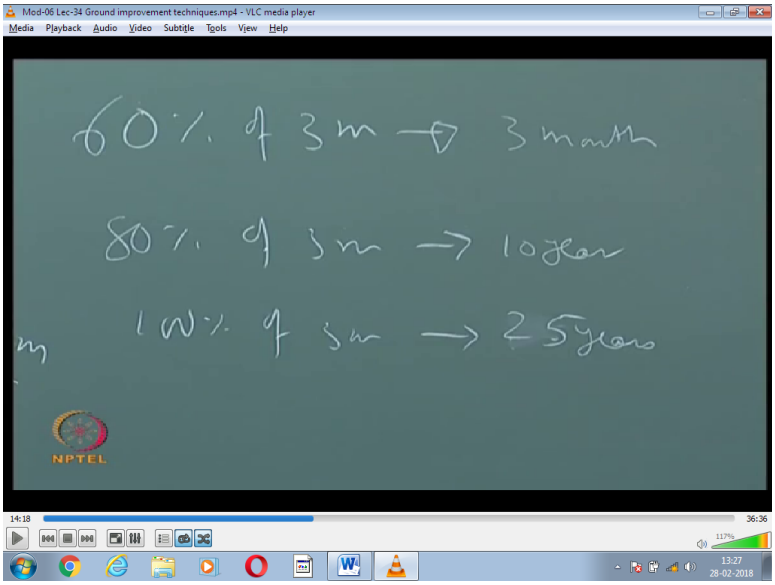
So here the intensity pressure will high here the intensity will be less suppose let us say here actually what we have to do is, in this type of situations we have to put what is known as toe beam so that the so this toe beam is required so this will avoid the slope instability problem also there will be a slope failure the whole thing may collapse also suppose you do not put the toe beam on it either side what will happen is whatever stones you are putting the whole thing will collapse see there are two things will happen one thing is the soft clay get excused out the stone will go inside this is a place where the stone will inside another thing is whatever you are going putting it will get collapse,

You know these quicksand conditions so there are some places near Kodia Karie in Tamil Nadu and some other places bears know where this quick sand is available human beings do not know so if you are going there if you step into that you will get in sake nobody can save you. There are certain patches where there are weight lands which are having some quick sand condition it is not you cannot human will not be able to recognise properly, you cannot walk just like that if you get into that you are get buried into the quick sand condition like that only here also the whole thing will collapse and sometimes you may not be able to build the break water.

So the slope also will be unstable so there will be some slope failure which will take place and avoid the slope failure we can have the toe beam that means you are increasing the weight of the foundation the whole thing also will get so you will have some kind of pressure distributions so here only you will have the upper pressure to resist the soil got the point, area is increase to take the foundation this is what we have to do.

But in some of the clay cases what we are doing is we do not treat the soil if it became very expensive we calculate the settlement, settlement may be about three meters here, settlement may be about zero point five meter here, the differential settlement is about two point five meters total settlement is about three meter.

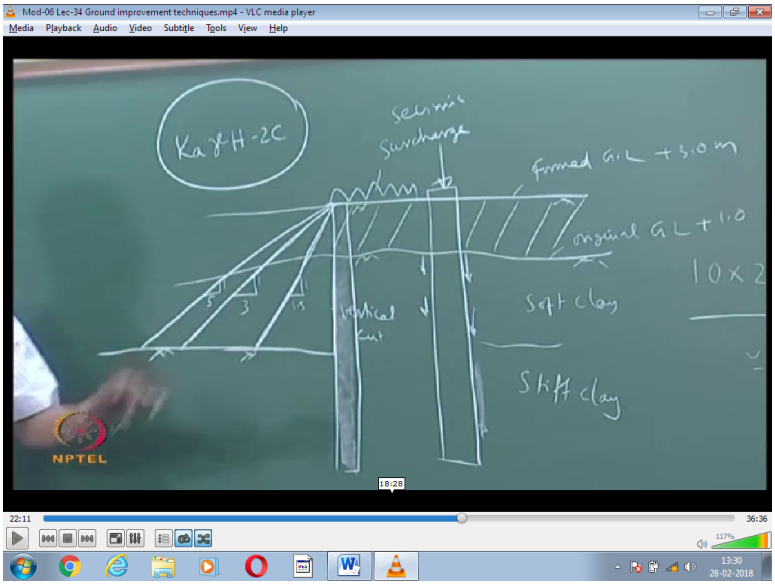
(Refer Slide Time: 13:46)



This total settlement also this immediate settlement about seventy percent or sixty percent of three meters is expected may be about three months or two months, eighty percent of three meters will take ten years, hundred percent of the three meter may take about hundred years also or may be about twenty five years, ninety nine percent I will tell so it takes years to achieve the settlement.

So what happen if the settlement is more and more, is increasing the top surface is uniform so it will get there will be undulation, settlement may not be uniform along the length as well as along the weight it is to be avoided.

(Refer Slide Time: 14:44)



Than we have written anything something about negative skin friction, anybody knows about negative skin friction suppose you drive a pile so this is your original soil original ground level this is your formed ground level here only you have the load coming from may be storage tanks the Cochin and other places we have the L and G terminals where they have a large tanks. Tanks may be of even eight zero meter in diameter may be twenty meter height very huge tanks supported on piles ok.

This was your original ground level you increase the ground level to form to ground level let us say original ground level is plus one point zero formed ground level is three point zero. That means there will be loading on the existing soil, let us say that this is soft lay this is stiff clay so will the pile have settlement yes or no when you load the pile will pile settlement yes or no, what about the soil ? will it settlement or not settlement yes why it settlement, why the soil settlement why dose the soil settlement because we put the over burden pressures originally this load is not there now this load is there, so, which settlement may be more, soil soil settlement more than the pile settlement than there will be this will be dragging the pile down this is called as negative skin friction. Is it clear to you ? soft soil will settlement more than the pile that means it is dragging.

How many of you have seen any temple festival ? have gone any temple festivals. You are not answering anything yaar. Which temple you have gone ? you raised your hand yes sir which temple behind that fellow which temple you Kerala, Kerala which temple

Guruvaayur, ok will take the procession of the ideals, will they take the ideal around the temple, yes sir, I do not know.

Which temple you have gone?nearby my home town, which one. What is your home town? Shylum, what temple it is?Sir it is Koteymeryum, will they take the ideal around ok. Nobody has gone to Mahilapur temple. How many of you have gone to Mahilapur temple?Which month? two months were go. This month you did not go why. What is so especial of this month? how many fellows are from Andhra raise your hands, only this many, why you people go to this Mahilapur temple. This month there is a festival you know that or you do not know? where are you from Srhiram Sundari, Jaygundda, you are not have been from Chidumbarum, you did not go during temple festival.

See what happens during temple festival there is ideal, ideal kept top of some chariot people will be lifting ideal wait till not be more than hundred kg, how many people required to be lift to the ideal? four people will be sufficient but how many people will be lifting at least forty people will be lifting actually only four people only will lift there that other thirty six people will hard load on to the other four people, that is called as negative drive, if you go and see the temple festival so many fellow will go forward to lift the temple ideal, there will be some higher sitting on the top of that chariot and all but its weight will not be seventy sixty kg but instead of four forty people will be lifting.

But out of that forty people at least ten people will not be actually taking the load there will be loading on to the other people also where there will be hanging to the chariot that's what happens.

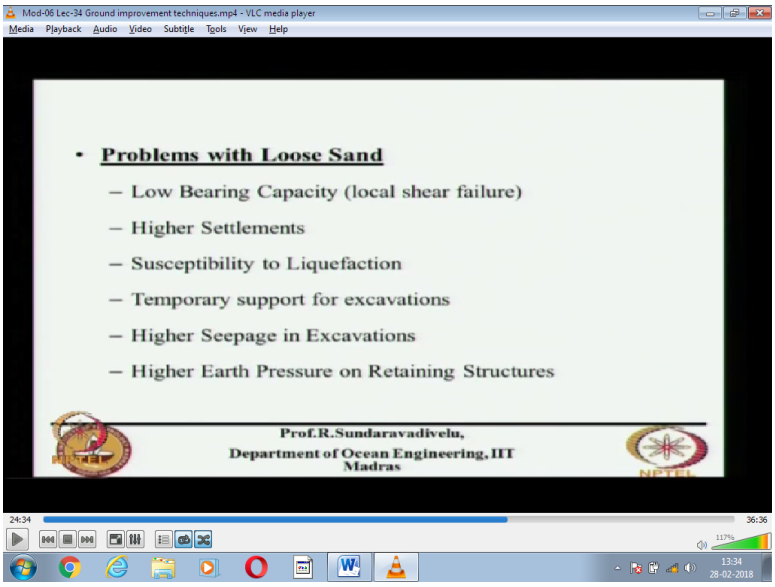
Than this low horizontal load capacity of the pile, because when you put a pile the soft layer will not take any load than instability of deep excavation slopes, so this instability, suppose this is a soft layer deposit so if you excavate like this for a berthing structure you can have various slopes like this so this is vertical cut this is possibilities put you say weak rock or rock. You can cut vertically the slope will stable then we can have slope like this one vertical to one horizontal or one point five horizontal so if you dump some stones and form the slope you can have or if you put some jio textile material you can have the slope.

Normally this slope recommended one in three one vertical to three horizontal in this region but it can go to one in five alsook ,but suppose you put some sur charge load on this you stack the container than the slope may fail, suppose you excavated like this the slope will fail

and that pile is to be avoided because of this sur charge load. Another thing is when you have this seis mic condition the soil which is being retain in slope that also will give exhilaration due to that also it may fail so this is one aspect which is to be considered and suppose you put a retain structure here you want to have a vertical face and put a retaining structure here this retain structure may also subjected to heavy horizontal forces right.

For a soft clay the value is K agama H minus two C. C value can be very close to zero right and the C value is very close to zero it is Ka into gamma into H. Gama is the density of the soil so it will retaining a liquid mad, there one be any C so the depth pressure is very high so these are the problems related to soft clay layer so you have take all these things into account while designing the structure. So this lecture is not restricted only to the ground improvement but also the design aspects when you do that.

(Refer Slide Time: 22:33)



So the properties of loose sand is given here, the N value will be four to ten, the angle of friction is between twenty to thirty degrees, this is compressibility modulus and permeability coefficient these are used to calculate settlement, I said first void ratio is point three where for loose sand it can be very high point seven five to point eight five so I have not given the properties of silt here between clay and sand we have silt.

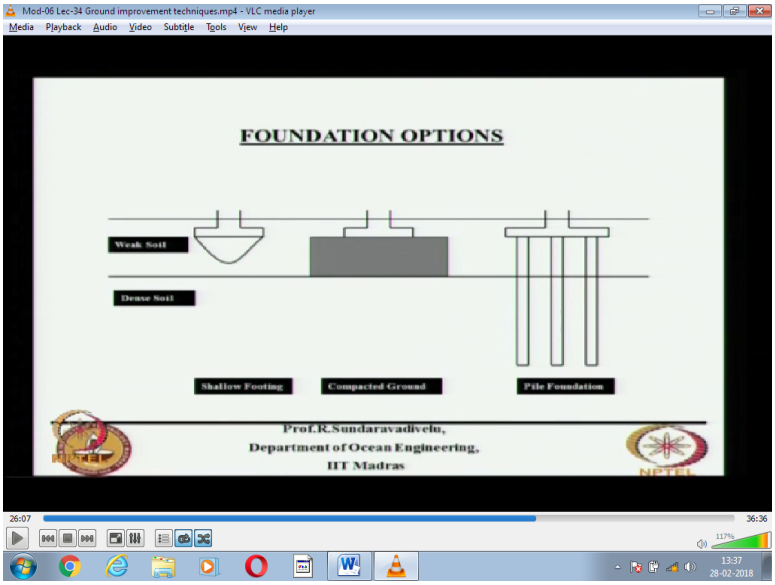
Silt also will become, liquefy during seismic condition so if the silt is there specially for atomic power plant and all is you have silt or loose sand the value is less than ten you have to necessarily do the ground improvement than only you should put the foundation because

statically you may be able to satisfy the designbut dynamically during seismic to become a quick sand whatever you are doing the whole thing go down.

After this sonami this happen in two thousand four I think there was earth quack and sonami both together, there was one structure was build whole structure has done down there is a (()) (23:49) more than three hundred length. It has gown down about thirty meter it is not gown down up to the see bed it is gown down by much below also so much liquefaction has taken place, whole structure from the top it has totally fall down.

So these are similar problems are with sand low bearing capacity higher settlements, susceptibility liquefaction than we need a temporary support when you want to do a excavation suppose you want to do excavation than you to provide temporary support than there will be very high seepage also then there will be large earth pressure on retaining structures because of low angle of intel friction value.

(Refer Slide Time: 24:36)

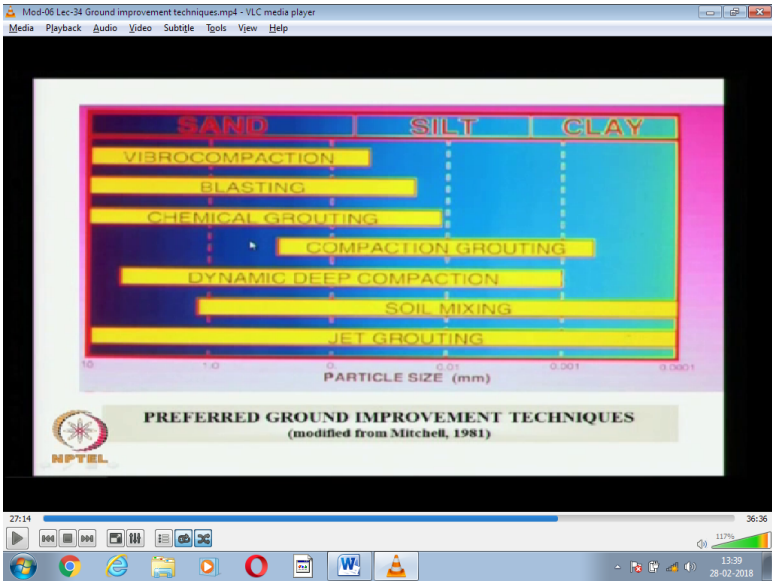


So this figure shows what is a shallow foundation what is a deep foundation, so if we have a weak soil than you have a dense soil than we are necessarily going for a deep foundation which called as pile foundation you go into the deeper soil, this is possible even if we have weak deposit may be three meter or four meter even six seven meter you can take it deeper I have shown in the figure also where we are taking the pile you have to taking care of negative skin friction in this region plus you have to take sufficient embedment depth so that you can get the reaction.

Suppose you do not want to do that if you want to have a shallow foundation itself what you should do is, you should compact the ground below the foundation what you are going to do, and increase the properties of the soil. So the N value is about four to ten can be increase to fifteen to twenty if you do the ground improvement, so the bearing capacity can be increase so your bearing pressure will be much less than the capacity compacted ground.

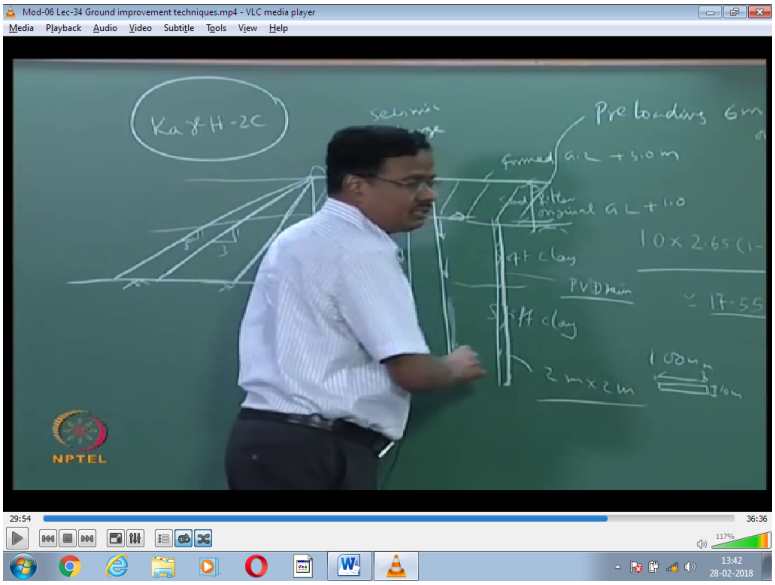
Suppose you are putting a break water here you cannot put a pile foundation for a break water it will be very expensive so in such a case it is better to improve the foundation allow the extra stones to be filt that also is possibility when you dump it the soil will flow and the stones will go down than allow the settlement to take place.

(Refer Slide Time: 26:10)



These are the various methods that are given here you have talked about sand, silt and clay here we have shown the particle size starting from zero point zero zero one mm to zero point zero zerozero one mm this is the clay silt is from her to somewhere here to here that is silt and sand here up to this jet grouting is method which can be adopted for whole range of sand silt and clay we recently recommending this jet grouting for birth number one to six at Kandala to improve the soil property than we can have soil mixing that is also possible and dynamic deep compaction or we can have compaction grouting also than we can have chemical grouting also than we do blasting also control blasting to improve the capacity or we can do vibro compaction. These are the various methods,some of the methods will explain.

(Refer Slide Time: 27:17)

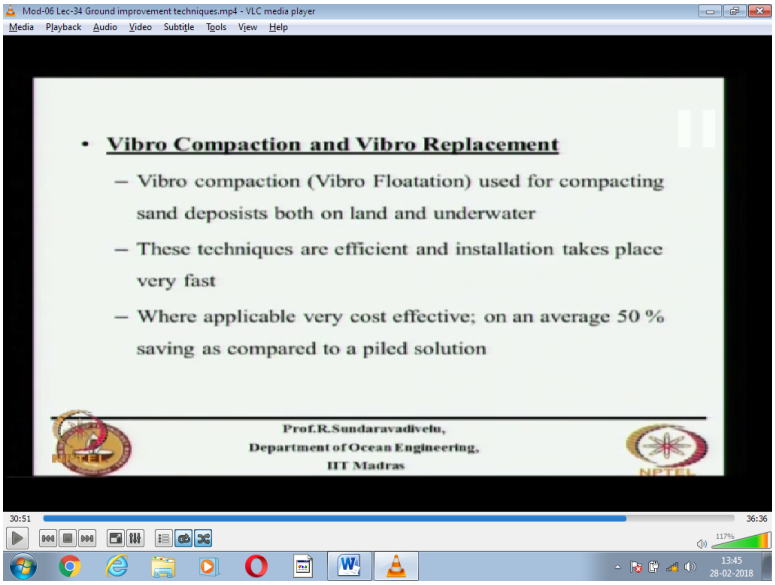


So one is called as replacement methods that means you replace the soil if it is a very loose sand we can dynamically compact and replace with the drain sand than we put vertical drain, vertical drain is nothing but a this soil, you provide some drains called as PV drain and here you put sand as a filter layer actually whatever you are doing here called as preloading it is typically done about six meter to ten meter, so this PV drain is nothing but a jio textile member it is about hundred mm in size it will be like rectangular size hundred mm may be this gap ten mili meter this will be hundred mm, you punch it through this than you do the pre loading than what happens is whatever liquid is there that is water is there it will get into this and it will come right up to the top than this will be draining to both the regions than we have consolidation we have two components called as consolidation that is also that is not centilment the consolidation is for clay layer it takes a very long period for a soil to consolidate.

So to exhilarate the consolidation the pre loading is to be done for one year or so, so you pre loads the soil, is it clear to you out some like (())(29:15) what you are saying, that you insert it about hundred and ten mili meter hundred mili meter by ten mili meter it is very small size like a paper it goes inside there is nothing inside just it goes in it's like a filter like coffee filter only just goes inside when you preloaded you have to do it preloading so what happens it water will get inside than this water will come out, once see there should be place for water to come out of the soil where exhilarating that, this will done in square pattern may be two meter by two meter great you do this.

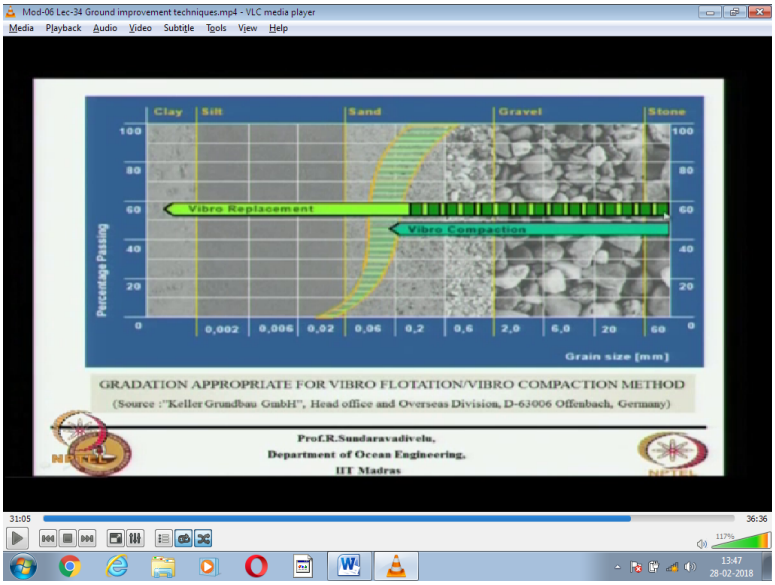
The most economical method of increasing the bearing capacity of the soil or improving the ground treatment this is done for many places it is very it's not very expensive also. For see condition it is very difficult to do but we do some other method that I will tell you.

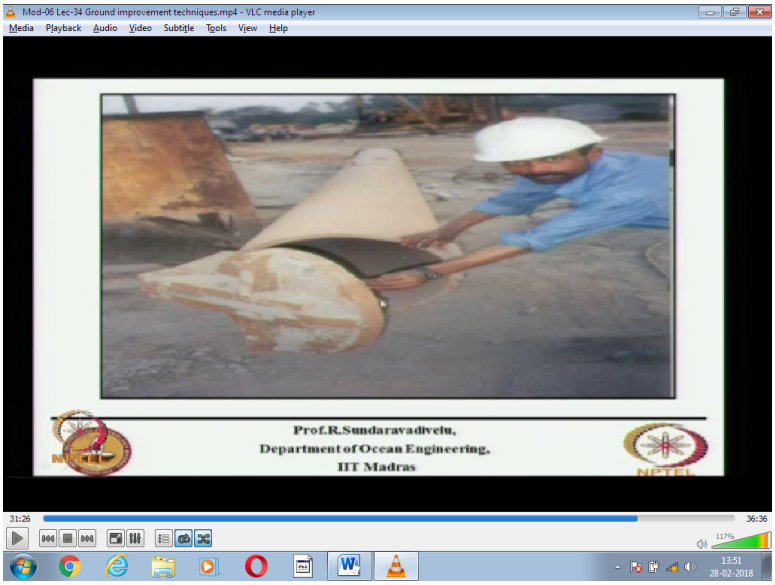
(Refer Slide Time: 30:20)



So this is a method which is use for a field condition vibro compaction or vibro filtrations, this is for compacting sand deposits both on land as well as under water jet grouting also can be done under water. These techniques are efficient and installation takes place very fast, the one of the main requirement for this vibro compaction is that it can be done very fast this is very cost effective and we can have a average of fifty percent saving very high saving as compare to piled solution.

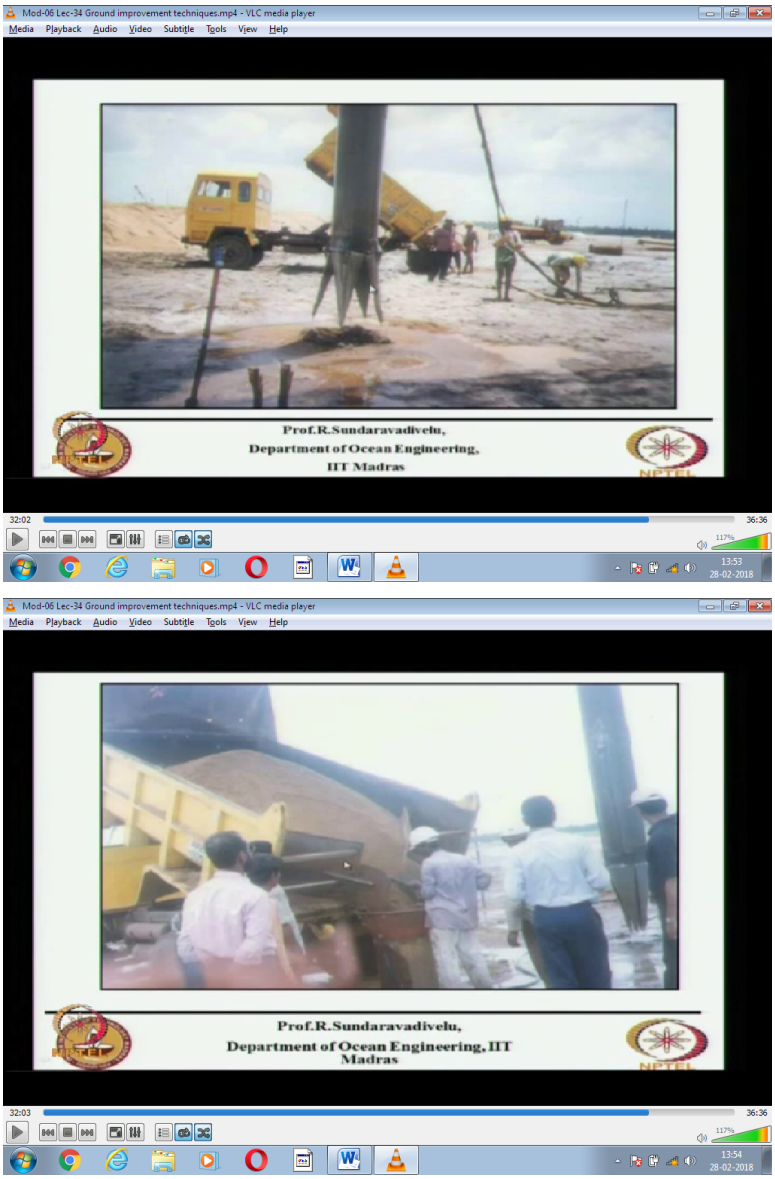
(Refer Slide Time: 31:09)





So this vibro compaction can be done in sand and gravel and stone where as vibro replacement two methods are there one is vibro replacement another one is vibro compaction. This most commonly used in marine condition under water so here you are seeing so you have pile driving equipment what you do is you drive it, there is a bottom opening you see here this is a still casing the bottom opening so there is attachment to this to the top once you drive it to particular level you just release the hook which is attaching the bottom plate once you release the hook the bottom plate will come out than whatever sand you are filling inside it will remain there and you remove the top casing is it clear.

(Refer Slide Time: 31:53)

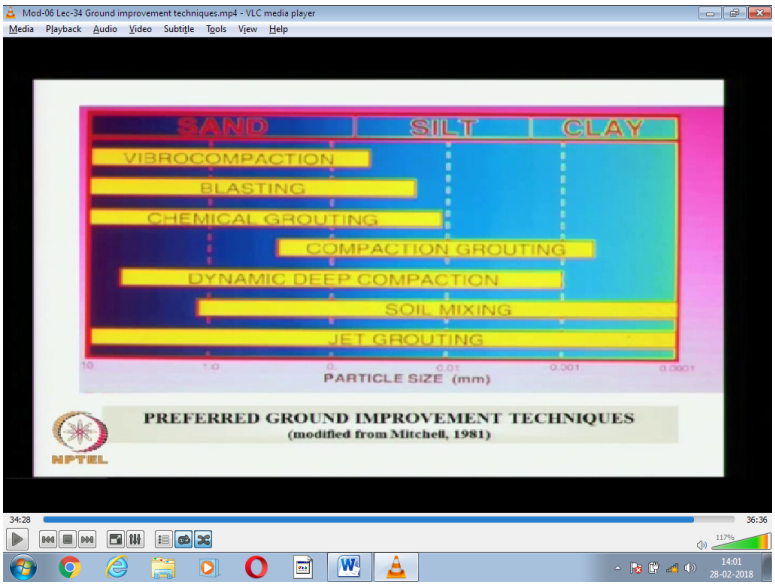


So you can see the figure here some other methods in which the bottom opening it's not like that bottom opening is like this and then you lower it than put the sand you can have the sand here so once you lower this and put the sand and remove it than you will have vibro replacement that is clay, may also if the diameter is vibro compaction pile you can have let us say diameter of the pile wearing from six hundred to thousand mili meters may be seven hundred it is not very big diameter so you just lower the casing pipe the bottom opening once you drive all those thing at very close spacing normally it is three times diameter may be two to three time diameter spacing and you replace the soil at that location by drain sand so it acts like a filter medium also like this.

The sand itself like a filter medium and its replacing the existing soil and it is compacting also so the volume of replacement may be about ten to fifteen percent existing soil you can also use what is known as stone column what you do is suppose there is a soft clay deposit here what you do is you drive one still casing pipe and you fill it with stones its likely go below the soft clay deposit fill it with stone and replace case the here what you are doing is, you are removing the soil by replacing the soil by stones so vibro replacement can be either with sand or with large size stones this also can be done to improve the property.

Vibro compaction is you just put some kind of pile and then don't replace it you do some vibrations through the soil will get the ground will get improve these are the various methods by which you will be able to improve the properties of the soil.

(Refer Slide Time: 34:28)



So many cases we may have to resort to this type of methods it is as shown here vibro compaction blasting means this we do some control blasting we drill a hole put some explosive than blast it so that the soil get improved. Normally after every earth quack youmay have some quick sand condition some time the soil also will get improved. The vibro compaction can also be done you using some large weight using a crane lift the weight than drop it from a height on the surface itself so that the vibro compaction takes place.

Chemical grouting means you may use lime or cement for grouting. This is compaction grouting and dynamic deep compaction and soil mixing means you mix the soil with some grout jet grouting means we inject cement than do the, here the replacement is about four

percent or so many you do that so that so, you do that so that soil will get improved the special methods are available, special machines are available to do the jet grouting.

So if you see some of the, internet go and put jet grouting there are some companies like Caller, Bhoomi those people are having special equipment's to do the jet grouting. One of the advantage of jet grouting is it can be used for any type of soil, whereas this vibro compaction and blasting can be use only for sandy soil cannot be used for clay soil and the soil mixing is snot possible for dens sand deposits ok. Ok will see tomorrow in our department