Group Improvement

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Module No. # 01

Lecture No. # 01

Need for Ground Improvement

At the outset, I would like to thank the NPTEL authorities as well as the Indian Institute of science authorities for giving me an opportunity to present the course on Ground Improvement. It is in fact a video course, before I just commence the course, I would like to introduce myself so that you have an idea of what exactly I have been doing all these years and also, how I introduce this subject of ground improvement.

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In fact, I have done my doctorate in geo technical engineering in Indian Institute of Science in 1991; subsequently, I was in Central Road Research Institute. In fact, the area of ground improvement is an important area in ground in geo technical engineering, where when the infrastructure requirements are huge, when the infrastructure needs to spread out in large areas where the soil is very weak, you need to improve the soil. So, that it can take care of lot of loads and other things.

So, in this context, the ground improvement subject is quite important and I was in CRRI which is called in fact, the Central Road Research Institute is a national laboratory in India. Subsequently, I was in Purdue University, then I joined back Indian institute of science, after that I was in Germany. Subsequently again, I came back to institute I have been teaching this subject of ground improvement and also Geosynthetics for a very long time. Now, when NPTEL asked me to offer this subject on particularly the video course, I thought I should just offer this course, which has lot of practical inputs and then it has a great deal of effect on use of the improvement of the infrastructure in India.

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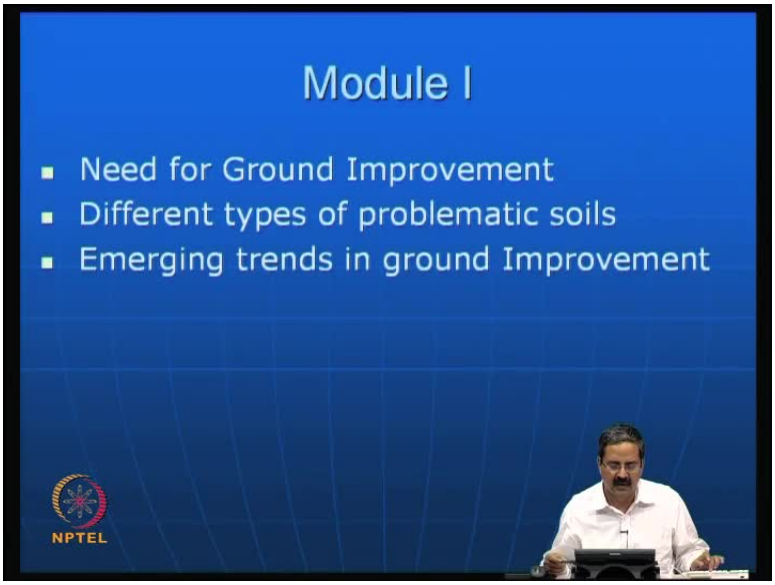

So, with this small introduction, I would like to just introduce you to what I would like to present in this course. In this module, what I would like to talk about is that, I would like highlight you the needs for ground improvement. What type of soils you have, what type of problematic soils we have and what are the emerging trends in improvement.

The need for ground improvement is something that is very vital; one should understand this because the bigger infrastructure were particularly roads, buildings, bridges and many more that you see, what you call physical infrastructure has to be founded on soil.

This soil properties are something that they are very unique like they have some engineering properties like shear strength, consolidation, permeability, compaction certain engineering features like if you have a building which is of high raised building,

it is supposed to exert lot of loading on the soil and the soil should be able to take care of it.

So, when the soil cannot take care of it, then we say that it is strength properties are not adequate or we say that it can go large settlements like you must have heard of buildings sinking into the soil. So, this is essentially because of that; that is what we say that the mechanical properties are not adequate. Mechanical properties I mean in this is that, the strength properties are not sufficient. So, the settlements are going to be larger.

So, when we say in this fashion, there is a need to improve this properties and this is where the ground improvement techniques come into picture. We do certain modifications to the ground whether mixing soil, mixing some with some additives or putting some inclusions into the system, which will make them to take care of the extra loading or the lot of loading that is expected to come and we say that the mechanical properties can be improved using the ground improvement techniques.

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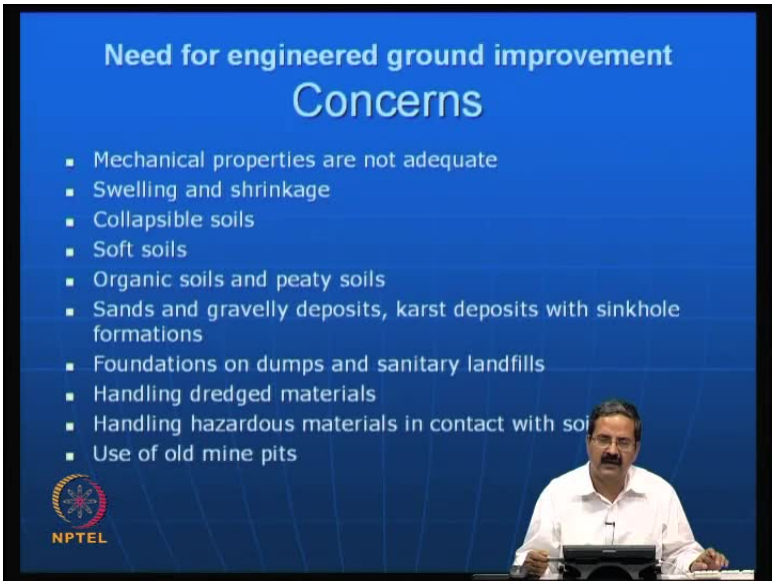

This is in a conventional sense for example, many places in India they have large great infrastructure and people are looking at this area in a very considerable manner, because this area is supposed to impact in a large scale in infrastructure development. So, we say that when mechanical properties are not adequate, we use this ground improvement techniques.

There are some soils which have swelling and shrinkage like we call them as black cotton soils. In fact, the cotton is grown in this area, in this soils and this soils exhibit lot of swelling like they swell a lot. They take water and then swell a lot and also shrink a lot, when there is an atmospheric conditions like temperatures are going to be high, we have a dry season. So, they shrink a lot. So, some soils they have lot of variations in water content like they swell a lot, they shrink a lot.

And we have a building which is on them, then the problem is that it gets totally uplifted and also it has lot of cracks; we have seen lot of cracks in buildings, pavements and dams and many structures, these are standard problem that one has in expansive soils. Particularly the areas in India, there are like whole of Deccan plateau has expansive soils, Chennai has expansive soils, and we call them expansive soil because they tend to expand, but they also shrink that is one problem. Then we have what we call collapsible soils, which are again another type of soils, then which are which have a tendency to collapse because of certain conditions.

Then we have soft soils, what is called soil is very soft in nature. Say for example, Kerala and Andhra all coastal areas have lot of soft soils and when you want to construct big port structures, definitely this soft soil improvement is required without which it is very difficult to increase a capacity of the even the port; this is one important area.

And organic soils is something that is again another component in soil mechanics, where certain materials because they have a lot of organic matter into that and because of the poor drainage conditions, the organic soils are also quite tricky like marshy areas are the something standard in many places. And when we add or treat the soils in some form, these soils become usable like one can construct roads on them or buildings on them; this is only possible by means of ground improvement techniques.

Then we have what you call sandy soils and gravelly deposits; this is another peculiar problem because in some areas, we expect some cohesion to have in soil mechanics, but then if the sands are there, the pure sands and gravelly deposits, then it is not easy to handle them. So, we try to improve some interaction properties like we add some cementation into sands and gravels.

So, that they behave as a coherent mass, that is possible by ground improvement techniques. Then there are certain cast deposits like it is a geological formation, where some soils they have particularly a tendency for sinkhole formation like when contact with water, there is a cavity formation like cavities do form and definitely, it is a big risk like if you are trying to construct particular structure and after one year there is a sink formation there, then the whole structure will collapse. So, it is a big problem.

Then there is another thing what you call nowadays in India, there is scarcity of lands is there; like you want to construct particularly in urban areas, lot of real estate because of the real estate issues, you would like to use every piece of available land in some form or other, you can construct the big buildings or structures to make the best out of the investment that you have made. So, people are looking towards dumps and sanitary landfills like particularly the waste material that is collected in one place, dumped in some areas and then finally, after 10 years you would like to feel like using it.

Then the problem is that, it is not easy because the soil these dumps are something very tricky like that they are bad odors are there, then you have lot of settlements, you have lot of biodegradation material into that, it is not easy to handle them. So, how do you construct foundations on them is something very critical that one needs to understand.

So, here the ground needs to be improved, the dumps and the sanitary landfills. In fact, the dumps are what you call waste material dumps, but then sanitary landfills is something a scientific land filling is done in some places. Of course in India, it is just taking up in a big way in a recent years with the ministry of environment and forest vigilance and but still, even the landfills after some 20 30 years when all the landfill gases and leach ate is completely removed.

Then, the landfill becomes inactive, and then you would like to place or use that area for some construction of some buildings. So, you should be careful because these landfill materials are again very complex as I just mentioned now. And one needs to really stabilize them in a proper manner, before you use them for engineering applications. Another important point is the use of dredged material particularly in berthing operations the areas are in which this ships move, the soils are very soft.

The dredging becomes very big task and then when you try to stabilize them, even dump them the dredged material in some form they do not create much nuisance. So, one can use some sort of additives in stabilizing some of the dredge materials and see that they do not really create troubles.

The other important thing is nowadays, a lot of hazardous materials are there and the hazardous materials are like they are supposed to be toxic, they could be many categories in which they can be ignited, they can have lot of issues which are in fact harmful, when some weak or when we get in touch with them.

So, this hazardous materials need to be really immobilized in the sense, they should not move from one place to another. So, we have some sort of techniques where you try to add some additives so that the permeability of the whole soil is something very low and the movement of this hazardous material whether in the solid form or liquid form is minimum.

Then we have what you call old mine pits particularly when mining is complete, the area has to be used for some purposes and then the problem with mines is that they have lot of holes they are not really properly handled in the initial stages, but when you want to use mine pits there could be lot of other issues like slopes ability and bearing capacity and some other geotechnical issues. One needs to make use of the ground improvement techniques to see that the mine pits have been stabilized and one can construct proper structures which you want in this.

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Actually the beauty of the ground improvement techniques is that, you need to specify what you need and techniques are evolved to see that. You are able to achieve that requirement in an economic way and in a satisfactory manner that is what is called the ground improvement techniques. The advantages are well known and what would like to show to you is that a few examples. In fact, what is that problem with soils and how do you understand them. In fact, you see the leaning tower of Pisa is in fact, it is a classical example of geotechnical engineering practice and ground improvement techniques.

This is in Italy and it has right from 1400 AD it has some tilt into this because of the differential settlement that the area the soil beneath the foundation has, but then they wanted that they should not fail at the same time, you should not be erect also. Because once this leaning tower of Pisa has become an attraction in the western world and if it is straight forward, then it has it will lose all the charm.

So, again if it collapses again is another danger, it is a problem. So, people want some sort of inclination where it can be stable and people have used lot of ground improvement techniques right from the beginning stages of its construction particularly in the recent years.

So, when the tower showed lot of inclination because of the dewatering, people have geotechnical engineers in fact, have stepped in and then showed that you can have a

main, you can have a proper inclination and then see that it also does not collapse and also becomes maintain its status as a tourist attraction with the tolerable tilt.

So, you see the leaning tower of Pisa here, which is something very interesting. Here another example Kandla port trust building after the 2001 earthquake, this is another classic example this is also inclined.

This is inclined because the soil below that is essentially a sandy soil and the soil the sandy soils have the tendency to get liquefied under the presence of, due to the presence of the earthquakes or the occurrence of the earthquakes. What happens is that, the earthquakes have it is an impact loading such that there is no time for dissipation of pore pressures like the pressure is not dissipated. So, what it what may the soil strength beneath the foundation momentarily comes down with the result that there is a tilt so you can see that even because of this, you have a tilted structure in India, but then one needs to understand the phenomenon of liquefaction and how to stabilize them to see that the structure is back to its position like whether it is acceptable tilt or near vertical to see that, this structure satisfies its function properly.

So, the liquefaction and understanding and its ground effect of ground improvement techniques in trying to stabilize the foundations is another important component of the ground improvement. One need to have a great deal of understanding of soil mechanics in this area and in fact, the ground improvement technique comes after all the soil mechanics is thought and the entire foundation engineering subject is thought.

Because one should know how and to understand and they classify the soils and also how to understand the behavior under loading. Once you understand the behavior of soils under loading then, you know how to design the foundations. So, there are different types of foundations one can think of shallow foundations, pile foundations, rafts there are so many developments in foundation engineering.

So, one need to have the understanding of soil mechanics and foundation engineering to comes out with proper foundation systems. But then, that alone is not sufficient nowadays because the foundations can be designed say for example, pile foundations are there, but if it can be replaced by shallow footing when you have a treated ground that becomes very cost effective. So, that is a reason that you have people has been exploring

the use of ground improvement techniques in foundation engineering to a great extent because you have very cost effective solutions to many of the foundation problems.

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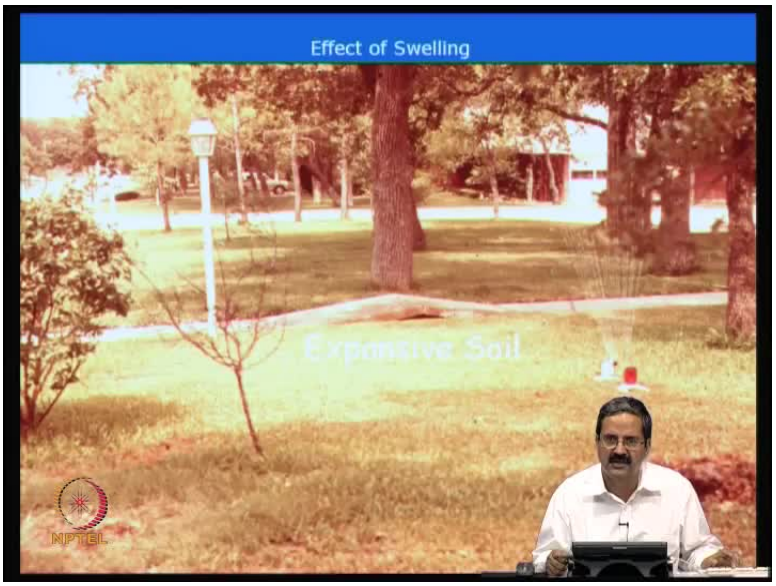

What I would like to show here is that, in the case of an expansive soil you can see that the particular area as I just mentioned about a few minutes back, the expansive soil which is called actually it is in fact, a black cotton soil in India it is called, but then expansive nature is because of the presence of montmorillonite in it is clay structure.

So, when the water is added to the system like in during the rainfall or something so, there is a tendency for the soil to heave and all the soil structure has a tendency, it imbibes lot of water and then in the pavements on this could heave like you can see an example, where you have a small mound here, where it can just there is in the form of a projection.

So, one can see that this is already in a small place, but you have lot of problems with this expansive soils in India, where people are not able to construct small structures because the problem is the swell pressure that is associated with that. Normally the expansive soils will have a swell pressure of about say for example, 100 or 200 k p a under fully when you allow the water to get in touch with the expansive soil, but the load that you have apply is only 50 k p a, but particularly in the case of canal linings small

buildings; so definitely, the small buildings and canal linings will have lot of problem with the expensive soils.

So, this expensive soils have to be treated in a proper way and the problem, otherwise you have lot of difficulties with lot of damages essentially. In fact, Texas in USA has lot of studies on this and in India also we have lot of work being done on this line.

You will understand how to stabilize the expensive soil that is one of the objectives here. So, the next one is as I just mentioned, this expensive soils also have a tendency to shrink like in fact, the variation of water contents in a soil is represented by it is liquid limit and it is plastic limit and shrinkage limit. So, the expensive soils because of their ability to take lot of water, the water content is going to be high. So, it can be as high as 100 percent then, when it dries, completely dries it can go down to a shrinkage limit it can be as low as 10 percent.

So, it is very risky like yeah at 10 percent it dries up totally then the buildings you have lot of cracks. In fact, you have in Anna Nagar in Chennai and many other places expansive soils are quite common and you see that this is a serious issue particularly when lot of dry seasons are there, there is a drought season and the water everybody wants water at that stage and even trees also want water. So, with the result that water is taken from the soil and then soil does not have any water.

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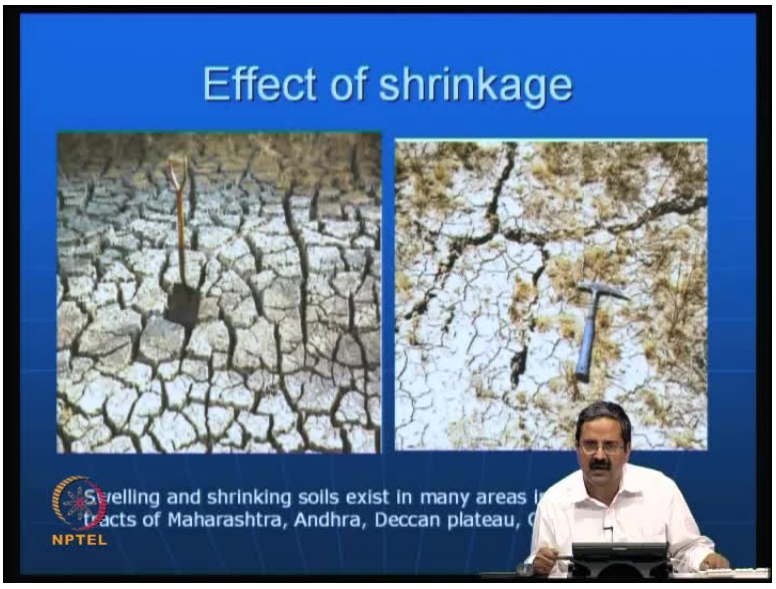

So, the water content is close to its shrinkage limit. So, what happens is that under these influences you have lot of shrinkage problems and this is essentially because the soil has big variations, water content can be 100 and it can be 10 also which is something that 1 needs to take care of it. So, what we do sometimes in this case is that add some treatment like you add some sort of lime and other things, where the water content could come down the liquid limit water content from 100 can come down to 50 and the shrinkage limit can come down to 20.

So, with that the water content range is something like 50 minus 20 which is 30 percent as opposed to 90 percent in the previous case. So, that is what we do, that is what is essentially a ground improvement technique we will go through some of this techniques in much detailed way, I thought I will just cover given an idea a flavor of what we are going study in this subject.

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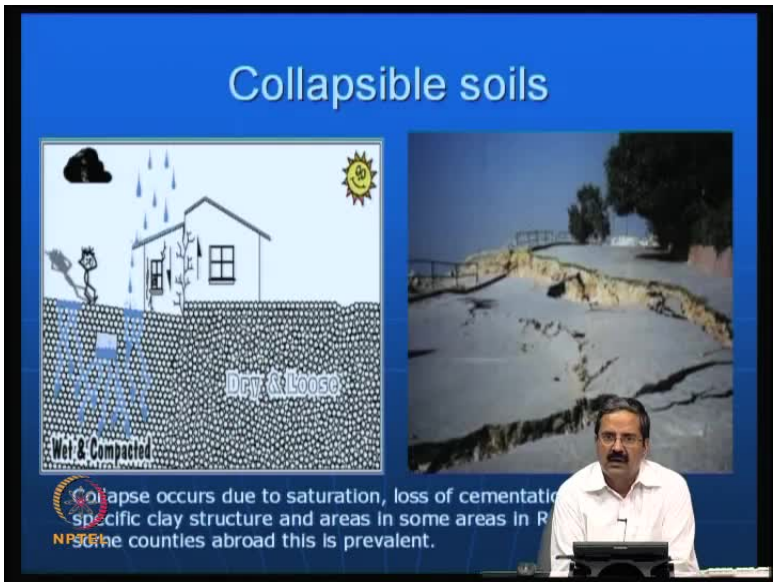

Then there is another problem soil which is called collapsible soil. This collapse occurs because normally the soil is partly saturated; in the sense the soil has air water and so, we do not say that if the soil is fully saturated it has only water, but when we say that it is a partially saturated air is there. So, when you add water due to compaction or because of the rain, water comes in contact with that, the negative pore pressure or the air water, air present in the soil disappears and then that there is a collapse of the soil structure. So, what happens is that there is a breakdown of the structure with the result at there is a

whatever if you have suppose the soil is suppose to be a collapsible there is a problem that you have lot of build difference in settlements in the foundations.

Collapse can also occur because of loss of cementation bonds, some collapsible soils beyond some loading they tend to collapse because if the loading is higher than the bond strength at which they have been formed. So, definitely if you are going to higher go up go for higher loads then definitely collapse occurs. Then also me specific clay structure in the sense that, if the soil is more open and it has tendency for lot of compression, particularly if the sand content is going to be little higher and then cementation bonds or the strength is little lower than the possibility is that collapse can occur because of loss of saturation as well as loss of cementation bonds.

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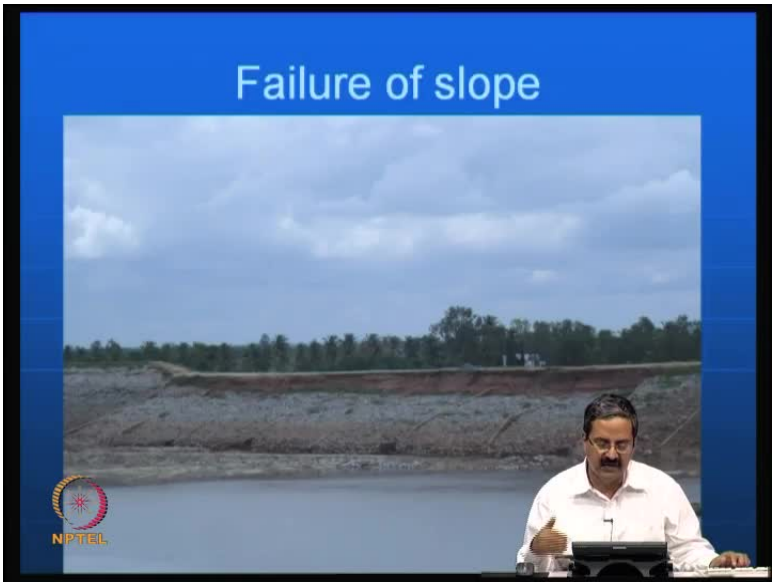

So in fact, in some areas in Rajasthan this is a problem and there are some problems that people have studied that this is one area that could be really serious. You will see another classical example here, it is a slope failure it is called a land slide. In fact, we are not new to this land slides in India particularly whole of Himalayas have this landslides.

This is another example this is actually a land slope failure in some of the water supply tanks for which you have northern embankment, actually the water is being stored here (Refer Slide Time: 23:00). This is in one of the places in Sindhanur in Karnataka, where when water is when doing the when the water is completely full there is no problem, but when the water is supplied to the people the water withdraws water is withdrawn and the soil is also along with that, the soil also there is a collapse.

So, we call it is as a slope failure. So, this is a serious problem in many cases, the landslides then many slope failures occurred in India and slope failure is a classical problem. The problem of landslides in Nilgiris, in Tirumala, then Himalayas these are all well-known, these are all called, we call it slope failures. There is a need to perfect and understand, how this slopes can be stabilized using ground improvement techniques.

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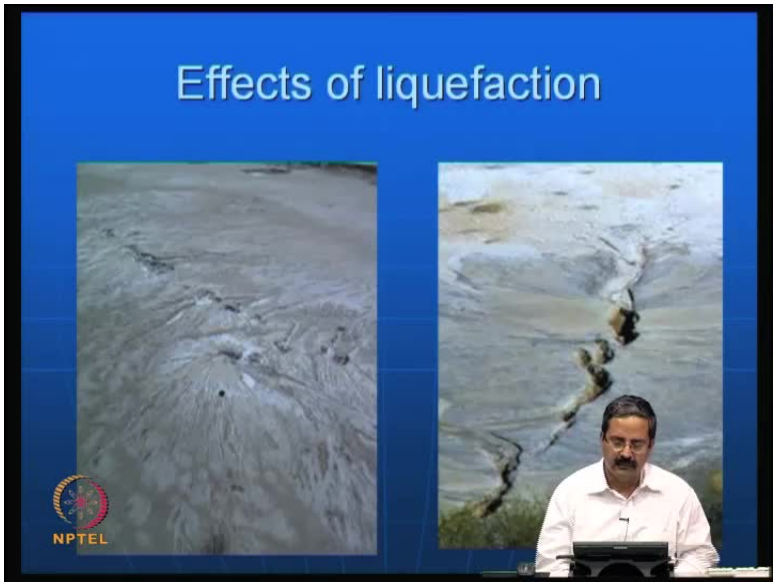

This is what we are going to learn today. Now to brief this course, I just gave a small introduction to liquefaction earlier, where when we are talking about the Kandla port trust building this is actually what happens, you can see that there is a boiling in this on the earth. Now in one place, you see a small tiny hole where actually… Then the other one is you have water dressed oozing out of the ground, this is immediately after the earthquake of Bhuj in 2001 in Ahmadabad in close to Gandhi dam in Gujarat state where because of the earthquake occurrence, such a high low the sand material which is in incite could not take it and the whatever is a water that is present there it just is ejecting out.

So, what happens is that under those conditions, the strength of the soil is very less. We are familiar with what is called quick sand condition where the material can get in, get sucked in. So, that happens because the earthquake force is so high and water is not allowed to come out.

So, under that conditions if you have any buildings also, it gets totally into the system of the soil. In fact, a Chang dam one of the dams in Gujarat that filled is a classic case on which it has it was founded on liquefiable materials and it totally sank into the ground, fortunately that is been rehabilitated now. Now it is satisfactory, they have used some ground improvement techniques to use that area, rehabilitate that area and then reconstruct the whole dam, this is one classic example.

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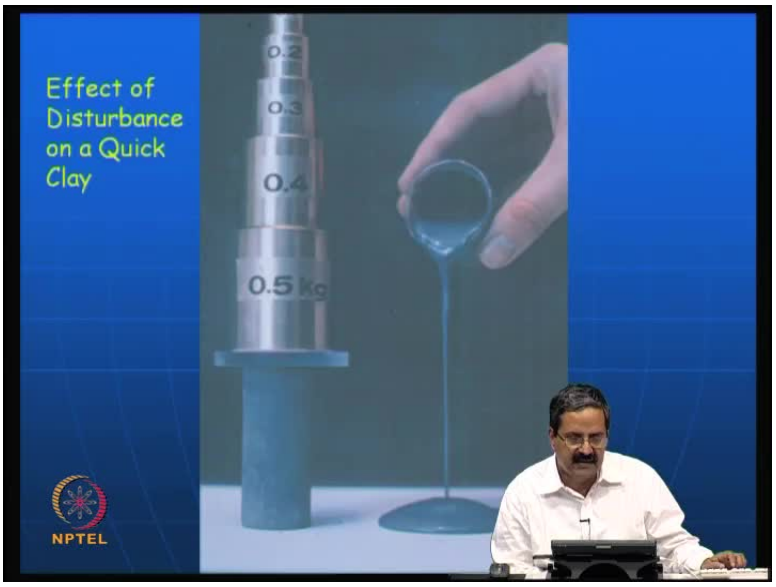

This is another classic case of soft soils. In fact, you can see that the sampling disturbance on the case of undisturbed soil, it is able to take lot of load like you can see 0.5, all that loads you can say an undisturbed sample.

But then you just a bit a disturbed bit, then it becomes like a liquid this is something very unusual as I just mentioned in a previous slide, the cementation bonds are there they can take care of load, as long as load is less than the cementation bond strength, but the moment the cementation bonds are exceeded then it becomes like a liquid. So, just you can see this (Refer Slide Time: 26:40).

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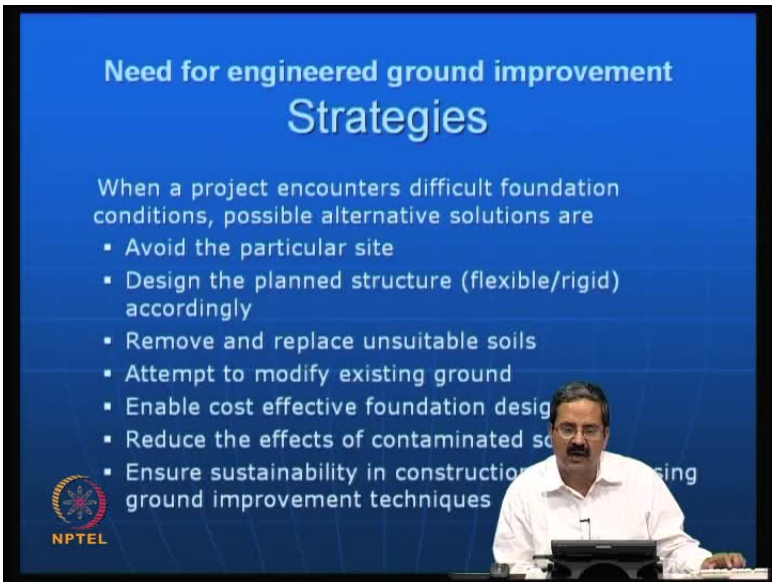

So, this is a very problematic area problem and we call this as sensitive soils. In fact, many of the places in Kerala and all these places they belong to this category, we try to call in terms of what we call sensitivity of the soil which is defined as undisturbed strength of the soil divided by remolded strength of the soil. The sensitivity can be as high as 50, like in undisturbed state if you can really do not disturb it too much it can be 50 times stronger, than the remolded condition, but it is very tricky. So, it is just become a liquid.

So, this is actually in Canada and many places it is there even in India, the sensitivity is of the order of 10 or 5 or it could be 2 to 10, but one should really do lot of detailed work on assessment of field behavior and lab behavior. So that this is understood in a better term, so that infrastructure can be constructed on soft soils in a proper manner.

Other problem with the soft soils is that they have lot of settlements; in fact the Kerala soft soil is so notorious, that the length of the piles is going to be very high. In fact, people have been still doing that and then they are not using much of the ground improvement techniques.

A bit are being used, but then there is a lot of scope for bigger operations in many of the coastal regions in India, whether from Calcutta to Mumbai all of the coastal areas need to be handled in a proper manner because, the soil in this case is very soft and the shear

strength is low then the settlements are going to be large, all these issues are there. So, it is very important that we should be able to handle some of these problems in a proper way using ground improvement technique that is one thing.

So, some of the alternatives that we have for example, you have to when you think of ground improvement techniques what we understood was that, yes to some extent ground improvement techniques are required. Then when that becomes very important, we have to look at what are the ways that one can think of or what are the strategies.

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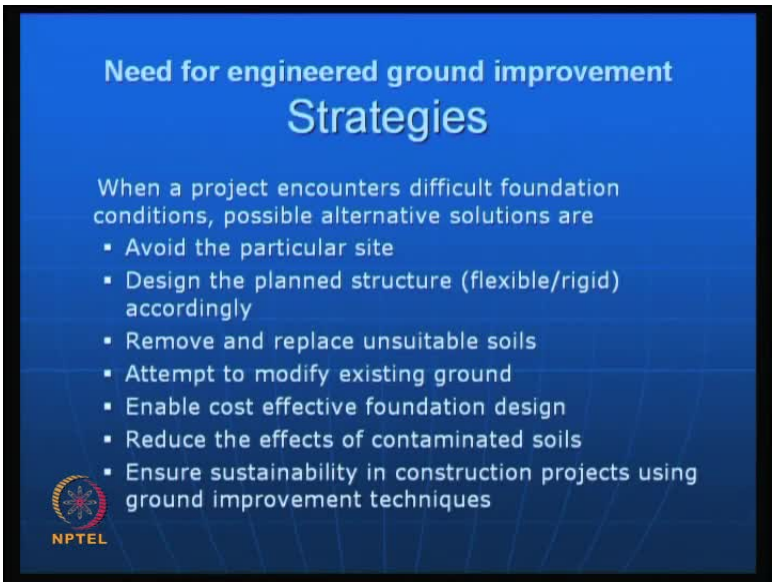

So, when a project encounters difficult foundation conditions like, you are trying to construct a road or a building, what are the solutions. So, you have an expansive soil, are you going to construct a road on an expansive soil? The problem would be that, the moment you construct an expansive soil after two seasons, all the payment is just get curled up and you are treated as a bad engineer, we do not want that.

So, some of the solutions would be that avoid the particular site, is it possible to avoid that area like the alignment of the road itself can be in a different direction. Of course, most of the time that is not possible nowadays, because you would like to reach to all sites and see that on the way if you can use ground improvement techniques, then you are able to use a area properly.

So, the other way is design the planned structure say for example, your payment; it can be the planned the it can be flexible structure or rigid structure. So, there are two systems here say for example, particularly in the case of buildings, one can say that the structures can be very flexible, in the sense that they can take care of the differential settlements that occur. Likewise, there is a small movement that can occur in a foundation that gets transferred to the building. And if the building can take care of that movement, then the structure is flexible.

For example, the reinforced earth wall is a standard example, we will see that later, but then it is very important that some of this R u walls you know, they are all flexible structures one should, you could see that they are able to replace a rigid structures, like a rigid retaining walls in a big way in India. Like for all the flyovers nowadays, you have only flexible structures made of R u walls compared to rigid walls, where either you have to go for counterfeit retaining walls or cantilever walls and then the cost is going to be huge.

So, here, what we are doing is design the planned structure either flexible or rigid. Rigid means, you have to make very thick sections and see that even the settlements that are there are really not, they do not influence the actual structure. So, the thickness of the foundation will be so huge that whatever small movements that will occur in the soils may not really impact the actual structure, so this is what we will see. Of course, this is another; many of the alternatives people have been looking at, the other one is remove and replace suitable soils.

In fact, people have been using say for example, if the expensive soil is only of one meter thick deposit, replace it, anyhow you are going to have 1 meter of say for example, 1 and half meter thickness everywhere it is there, you are trying to even, a our road thickness about 1 meter or 1 and half point 8 meters or something like that.

So, when you are trying to do that just go-ahead and replace the whole expansive soil area and then put these regular material what you want. So, removing and replacement is something sometimes is ok, but then it is not easy all the time, because again you have the same soil next to that it may create some more additional problems.

So, other best way is to attempt to modify existing ground. In fact, this is where the ground improvement techniques come into picture and in a significant way one can modify the existing ground to what you want, the performance in terms of I want only very few mm of settlement instead of 100 mm settlements. So, one can really use some modifiers or reinforcement and change the state of the existing ground and see that the ground is improved. And one can use it in a very confident manner.

So, you have lot of techniques for this that we will see. The beauty of this techniques is that the foundation cost is cheaper like as I just mentioned, why you have this ground improvement techniques required is that as I just mentioned, instead of providing thicker foundations or its reinforced earth reinforced concrete foundations, you are providing thinner sections. In fact, sometimes you are eliminating total concreting, which is something very unique, particularly in a foundation system if you are reducing a number of piles or removing the possibility of piles itself, it is a very good beginning because we are nowadays talking about the use of, saving of some of the materials like steel and concrete because they are all going to be very expensive.

So, we try to say that one can come out with cost effective technologies or methods for foundation design itself. Another point is that the effect of contaminated soils; in fact, nowadays with increased demand on the public infrastructure contaminated soils do they have been existing and they need to be used in a proper way.

So, the contaminated soils should not influence our buildings, like if there is a soil that is contaminated any water that goes into yet should not come to your area and then create problems. Like you know, say for example, the underground water tank of your building. If it is close to a contaminated soil, one should see that there is a proper system, lining system in which the contaminated soils are there only, they do not allow the water or the seepage to come to your area and see that the soil is contaminated.

So, what we want is that the contaminated soils should be properly handled and containment is possible; containment as the effect of contaminated soils is possible using ground improvement techniques. The other important thing is nowadays people have been talking about sustainability in an engineering design. The sustainability is something that one needs to understand in a bigger way, because as I just mentioned,

nowadays with lot of stress on construction infrastructure, you are using lot of steel and concrete and many of these materials.

So, if you try to minimize the quantity of steel and concrete, the amount of energy saved say for example, they say that 1 meter cube of concrete releases so many C O 2 emissions or if you are able to save one cubic meter of concrete in construction, it helps in carbon credits.

So, this is a thought nowadays and one can use the ground improvement techniques in a very effective way in this manner. There are some more things like even use of natural materials like, say for example, if I am talking about road in a rural area, one can use bamboo as the reinforcement and also coir as some sort of reinforcement. And one can use some cost effective techniques at least say for example, in a rural areas where the soil is very soft, marshy, still people have to live with and need to have lot of good facilities whether in the form of roads, buildings and all that.

So, ground improvement techniques are the significant tools there and I am sure that there is a lot of scope for use of the ground improvement techniques in sustainability engineering.

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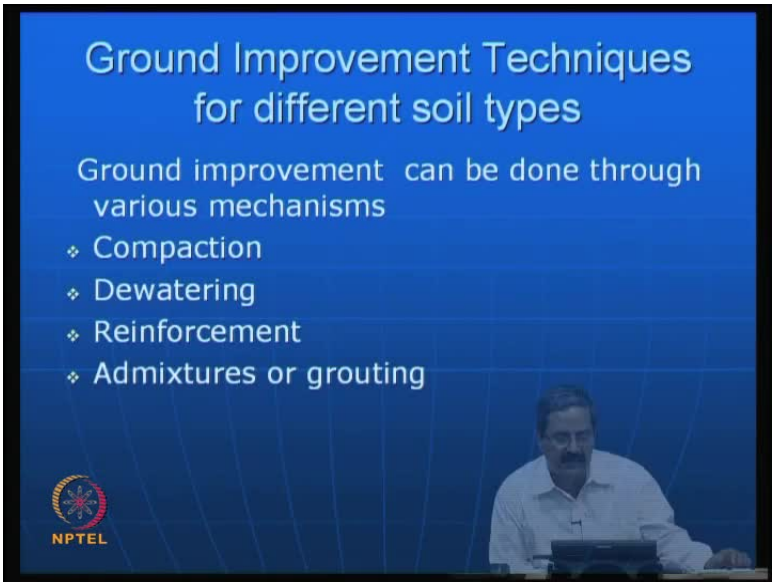

So, I would like to just give some idea of what type of techniques you have and what are the various mechanisms. We will take it in a detail way, but I would like to just give a

capsule of what can be done. One is the compaction, the ground improvement technique can be one of the techniques is a compaction, see the thing is we are all used to the soil is not very good, but you bring a road roller and then compact it.

So, the compaction has to be very good. So, compaction is a means of improving the strength properties as I just mentioned if the soil is loose, so it will not have enough strength, like normally the strength of the soil is expressed in terms of the cohesion and friction of the soil and the cohesion friction properties will improve if you compact the sample.

That is what we see in the most of the road work compaction is a normal one, because that once you get a standard proctor curve from the laboratory, one can give the specification to the contractors dealing with road work to tell that this is the compaction that you should achieve in the field.

So, once a compaction is done and we expect that the strength is less, the settlements are less. And then, you have many varieties of techniques here also, one is called shallow compaction where you only compact up to 1 or 2 meters and deep compaction say for example, if you want to compact 10 meters, how do you do that?

So, these techniques will discuss this is under the process called compaction. Another way is dewatering. Dewatering means actually the soil is has strength of the soil is very less, when water content is high. If there is lots of water says for example, that is a problem in coastal areas, you have lot of water next to the area and the soil is also very soft, so it has a water content of 100 percent. If you remove that water content to some level by some - what do you call that there is some - technique called preloading and all that accelerated consolidation, we consolidate the soil.

So, we consolidate soil what it means is that the strength will be improved, if the moment you remove the water from soil the possibility is that the strength gets improved. So, one can consolidate in a proper manner and get whatever you need like, this dewatering is a standard technique, people have been using like removal of water using some dewatering machines or applying some loads. So, that water that is in a present in the clay structure slowly comes out.

Then, we have what is called reinforcement. Reinforcement means like say for example, a typical operation where if one of the bones is not working properly and if there is a breakage, you add some sort of an iron material like, some sort of reinforcement, we call it some member which can really help you in putting proper connection.

So, the reinforcement is something that we will see that it has an excellent advantage here. So, what we do here is that sometimes you may compact there is an improvement and you may do dewatering there is some improvement, but you need more improvement, you want say for example, the bearing capacity like of the soil is 10 ton per meter square, because the soil is very soft. But my building wants the designer wants 30 ton per meter square, how do you get that? I cannot get from the native soil, because it is only 10 ton per meter square that is its capacity. Whatever I do I will not get beyond that, I may put some sand on it and I will not get more than that.

So, what we do is that the reinforcement in the form of steel strips, geo grids that we will see, they can influence the similar to our RCC - Reinforced Concrete, we what is called reinforced earth or reinforce soil. We use reinforced soil technique in a very big way and improve the soil behavior. In fact, whatever you see in the case of flyovers, which has metallic strips or geo grids is only because of this.

Then, another important thing is admixtures or grouting. In fact, when the soil is poured what we do is that we add something like, say for example, there in expansive soil. As I just said 100 percent is the liquid limit then you add a bit of lime and the liquid limit comes down to 60 percent. So, what it means is that you add some chemical agent, it can be even physical agent also, we will see that like many of the admixtures like chemical can be chemical stabilizers can be added, physical stabilizers can be added like say for example, flash.

If the expansive soil is there you add flash, because f1ash also has a same benefit, but then it is the effect is mechanical. In the case of lime it is chemical; in the case of flash it is mechanical. So, some people also use grouting which is something that is also very good like, as I just mentioned the grouting is nothing, but a cement slurry mix at some specified water content, where you can just say for example, strengthen the systems using some like, putting lot of grout say for example, as I mentioned the case of a sink hole formation in cast deposits.

Say for example, that is very tricky, so what we do is that when you have a sink hole there is no way that you can handle it or you cannot reach it, so but then if the sink hole is within your loaded area, what we do is that we grout it, we grout so that differently the grout fills up the hole that is formed because of the sink. And we periodically observe, how is it penetrating, how is it moving because the problem with some of the grouting techniques is that if there is a hole formed somewhere, we do not know where it is ending. So, one should be very clear that the grouting is done in a proper way and it is contained in a proper way and the loaded area that is there has the effect of this grouting material or the grouted material.

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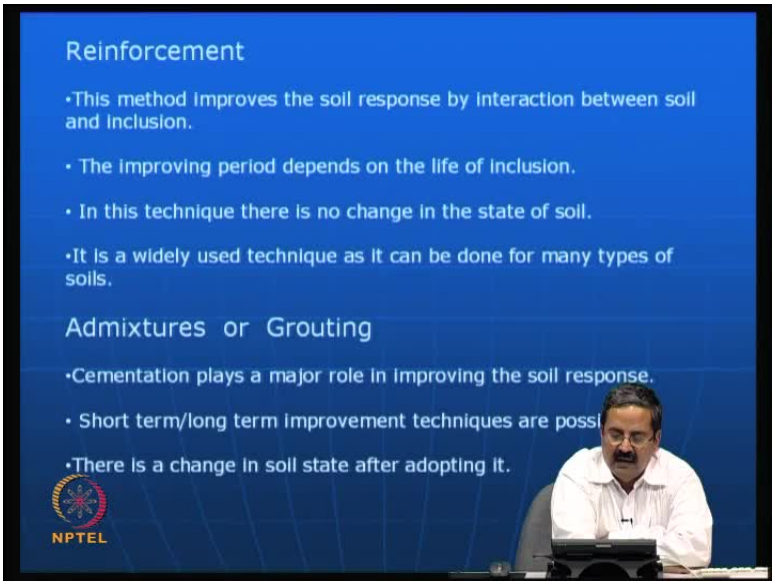

Then, so as I just mentioned the reinforcement is something that is very useful and here this soil response is improved by interaction between the soil and inclusion, because of the previous case, I just mentioned the both compaction and the consolidation or dewatering, there is a change in water content. What do we do is that we change the soil state like the soil is initially loose we compact it. So, that soil becomes dense or we consolidate, so that the soil becomes dense or less, it has less water content.

Here, there is a compacted sample already and I cannot change much. So, I want to improve it. So, I put reinforcement and the reinforcement will act in a way that when the load is applied there are some interaction between the soil and the reinforcement. That

reinforcement takes care of the effect of friction between the reinforcement and soil takes care of the additional load.

We will see those designs later and then, we have the improving period; actually the improving period depends on the life of inclusion in fact, one can say that one can use temporary reinforcement and permanent reinforcements also; like say for example, Geogrids are the permanent reinforcement whereas, materials like geo textiles which are biodegradable. Sometimes in fact, I have used it in some particular project, where in we have central road research institute, it has been able it has been possible to use the coir geo textiles for a construction of an embankment.

So, here the change of state of soil is not there like the water content is same, but at the same time the effect of improvement is because of the interaction of the soil and reinforcement. And this can be done for many cases of soils like say for example, right from sandy soils to clayey soils also in fact, friction is less in the case of the clay soils because the friction between the soil and reinforcement is less.

We try to classify or denote the effect in terms of the friction angle or the interfacial friction angle we call it that is between the soil and reinforcement that is normally two-thirds of the 5 of the soil. Like, if the friction angle is 30 degrees for sand and when you put this reinforcement into the sand two-thirds of 5 is what we take and it can be even 0.75 also, 0. 7 time's of the friction angle.

So, it has been one of the widely used techniques, then admixtures ground as I just said. Here, again there is a change in soil state, there is a change in soil state and then you can have a short time and long time improvements are also possible, because this is another important because it depends on the type of additive you add and it affect long term and short term performances.

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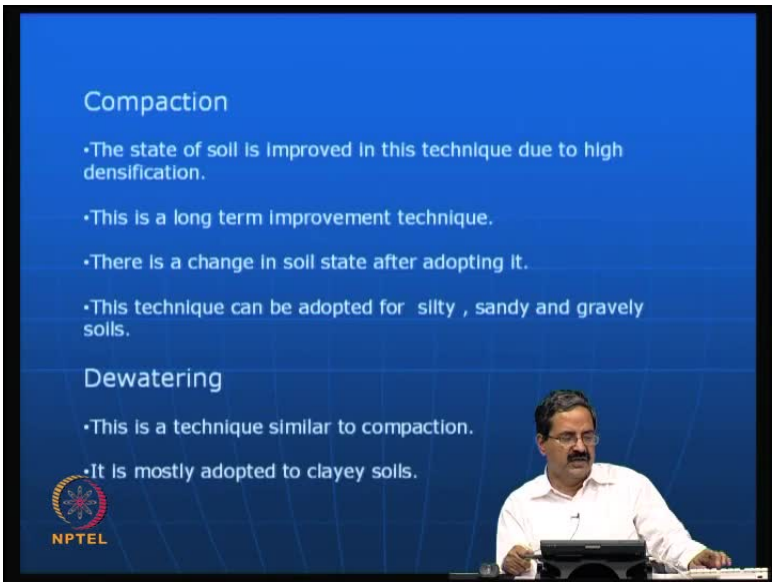

So, as I just mentioned the compaction is something very useful, it is a long term effect it is there and this can be use for sandy, silty and gravely soils. And dewatering is something that as I just mentioned, it can be mostly useful for clayey soils, because essentially sandy soils they are initially drained the permeability of the sandy soils is quite high. So, there is no problem, but dewatering is required in the case of clayey soils, because they are poor in permeability like the permeability values are quite low.

So, what we should do is that the permeability value is being so low, we should accelerate the consolidation process which we have varieties of techniques like band drains and sand drains many things. So, one can use some of this techniques to dewater either in terms of the applying load or even creating section.

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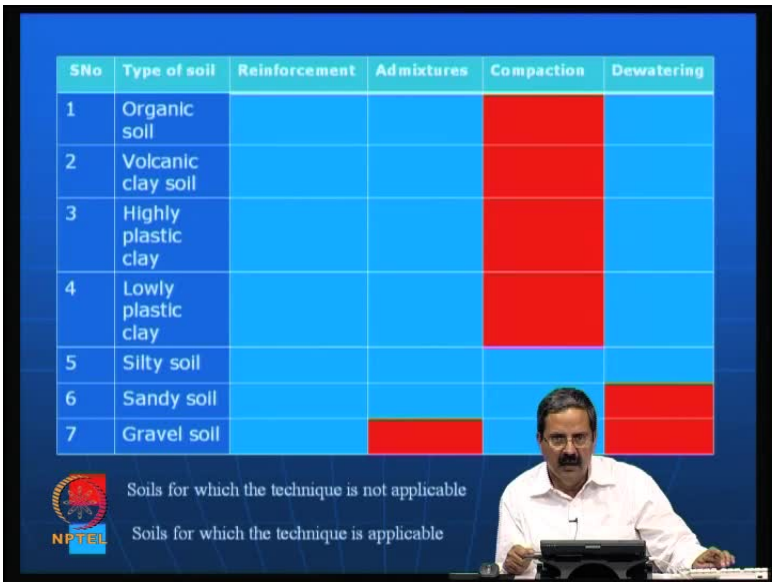

This particular table gives what type of techniques is in what type of soils. Say for example, you can see that on the serial number 1, 2, 3, 4, 5, 6, 7 we have mentioned organic soil we have mentioned, volcanic clay soil, highly plastic clay, lowly plastic clay, silty soil, sandy soil, gravel soil.

These are all a different types of soils that one can encounter and you can see that the red mark shows that the say for example, compaction alone. For example, you cannot do much for the organic soil or have organic soil or plastic clay you know, compaction may not really be so useful, yes, it is marginally improved, but then you can see that if you add reinforcement admixtures and dewatering. Say for example, organic I will take the example of organic soil reinforcement particularly is you add some admixtures for organic soils, put reinforcement also dewater because the areas are in marshy conditions marshy areas. So, all of these three things may work that is what I meant.

In the case of volcanic soil what it means is that say the volcanic soils are something that is also very interesting properties they have, they all there in Japan and many places where you have volcanoes. And reinforcement function is very helpful and if you add admixtures also they are going to be helpful, compaction the soils are something they are peculiar in nature, but so we should very difficult to judge their properties based on compaction or improvement.

So, we use all these techniques whether reinforcement, admixtures and dewatering to improve organic soils, volcanic clay soils, highly plastic clays, lowly plastic clays, but in the case of silty soil or a sandy silt or something, one can use all of them: reinforcement can be effective, admixtures can be effective, compaction can be effective, dewatering can be effective all these.

So, what I meant was that the one should use a rational choice here say now gravel. Gravel yes, to some extent one should use proper admixtures even in gravelly soils and dewatering of is not affective in both sandy soils and gravelly soils that is one important thing one should know.

This is just an idea that there could be there are many types of soils what one can have there are many types of techniques one should use in a scientific manner all these techniques, because otherwise, one has a lot of difficulties, because if you use a wrong technique then the problem is the purpose is not served. So, the contractor will have a problem, the project gets delayed and it is a very big risk in one needs to take.

So, one should really use proper precautions and develop proper ground improvement techniques, understanding the soil behavior properly and also see the suitability of the admixtures of the compaction dewatering reinforcement properly in a particular project and come out with proper alternative otherwise, we will have a big risk.

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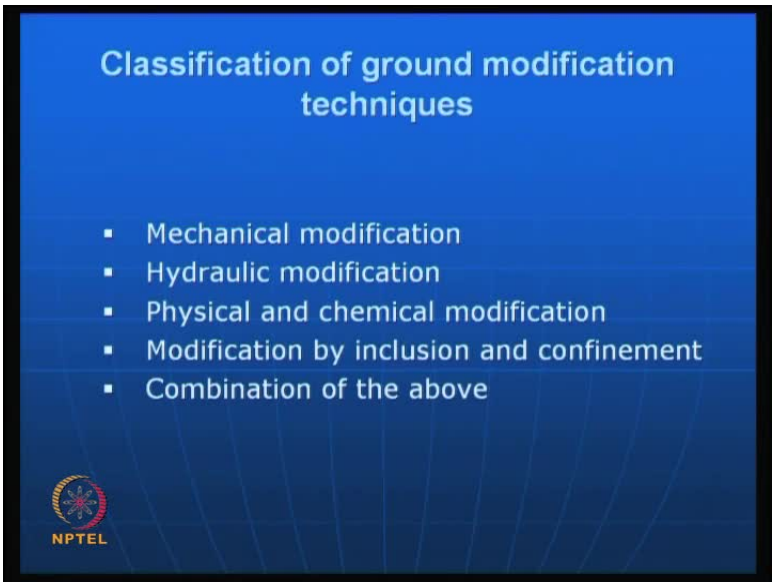

So, one can classify the ground improvement techniques or the modification techniques in a number of ways, what I just gave you was a capsule of what can be handled like, but then, we need more details on this in this course. So, in a technical way people have the classified some of the techniques like, mechanical modification, like you are only trying to modify by mechanical means; what it means is that, the road roller what do you see is a mechanical means.

So, you try to improve the ground using the mechanical means that we call it mechanical modification in fact, deep compaction is also mechanical and we will cover in detail some of the techniques. Then, hydraulic modification, you are only trying to remove the water and in this consolidation. So, we call it hydraulic modifications in fact, varieties of techniques are there as I just mentioned, we have prefabricated vertical drains, dewatering techniques and all that.

So, in both mechanical modification, hydraulic modification there are many methods of doing it, which we will be able to discuss case by case and see that how they can be implemented in a particular project.

Then, physical and chemical modification is something that like, as I just mentioned you add a bit of flash or a bit sand in a clay, if you add a bit of sand or a flash definitely the liquid limit of the soil will come down. Why I am referring to the liquid limit is that, that is one of the properties that can give some idea of the properties of the behavior of the soil.

Like, if the liquid limit is going to be very high say for example, Cochin soil it is about 116 percent, we call what we call Kuttanad clay is there the water content is about 116 percent and it is quite high. So, what we do, one can physically modify in the sense, add some admixtures like sand, flash, any other material like a dust material that is available.

You know, which are inert actually there is sand flash and all as comparatively inert compared to clay, because the clays have a negatively charged surface particles on them. And when you add when there is lot of negative the charge is going to be high, the problem is that they take lot of water. So, that way if you can modify the physical state by some additives then it is nice.

Then the second one is a chemical modification, as I just mentioned lot of additives could be added in this particular case, where it is possible to enhance the response of the ground using chemical modification. And modification by inclusions like, as I said inclusion of the reinforcement, like if you include the reinforcement what happens, we discuss the fundamentals of that. It will increase the forces that are resisting the disturbing forces and it will also act to the it will reduce the disturbing forces. So, it has two long components, it will reduce disturbing forces, it will add to stabilizing forces.

The other one is a confinement, it affects it gives a pseudo confinement in the sense that actually we have seen that if you increase a load on the soil, there is a confinement effect is there, but then that confinement can be brought out brought about by putting the soil in some confined manner. So, one can increase the strength of the soil in proper manner and get the improvement.

So, one can get the benefit of all of these properties by combining mechanical modification like, compaction, using reinforced earth, then consolidating say they for example, the reinforced soil is a very classical example, where you have to use road rollers for compaction of the backfill and also put the reinforcement and also confine the soil. Actually the thing is that, because of the confinement like particularly, you must have seen in the many of the R u walls, there is a phasing. The phasing is required to provide the confinement effect of course, reinforcement is there, but then between the two reinforcements, the soil has a tendency to fall.

So, if you put a phasing which could be out of 200mm thick RCC panel, then one can say that the confinement effect is introduced and then physical modification also could be done particularly in the case of say for example, expansive soils which I tried in one of the cases, where you can add for the expansive soil, lime as well as flash.

So, lime makes a chemical modification where as a flash or sand can make the physical modification. One can make a chemical modification and one can also make a physical modification, with the result that the problem with the soil is not very severe. So, one can use many of these techniques in combination and see that you have a proper ground improvement techniques used and also see that you get maximum benefit out of them, thank you.