Ground Improvement
Prof. G. L. Sivakumar Babu
Department of Civil Engineering
Indian Institute of Science, Bangalore

Module No. # 01
Lecture No. # 03
Emerging trends in ground improvement

In the last class**,** we had some discussion on the need for the ground improvement, classification of ground modification techniques.

(Refer Slide Time: 02:23)

And today, we will try to see some of this points much more like, how do we classify and what are their advantages and all that, and also emerging trends in ground improvement.

You may recall that, we are able to cover the classification of ground improvement techniques in terms of mechanical modification, then chemical modification and physical modification, modification by inclusions or reinforcement and also some techniques that we just mentioned. And what are the factors that influence the selection of techniques, like the type of soil, the seepage conditions, the cause, economics, there are so many issues there.

(Refer Slide Time: 01:03)

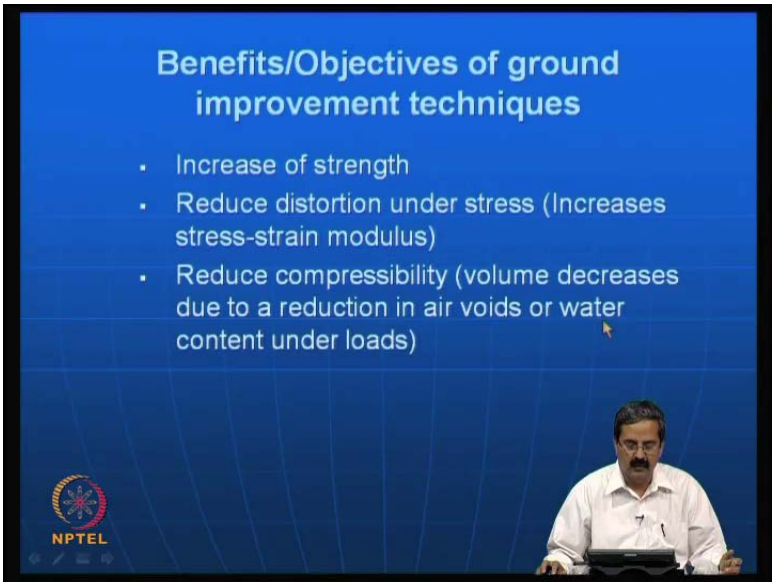
Of course, we do not need to daily stress on this need for soil improvement, because as we see that the sides have become scarce for construction. And at the same time, you need to really improve the bearing capacity of the soils and come out with the good performance from the foundation systems. This a classical example of a leaning tower of Pisa that we know, and the type of soil that exist here is a soft soil, this is so which means that, this is a classical case of a bearing capacity problem in which the differential settlement has exceeded the permissible limits. But I think still, like the leaning tower of Pisa authorities wanted this acceptable tilt, so that it remains as an attraction to tourist, if it becomes vertical nobody would go there.

So, even that acceptable tilt is an engineering design there, soil mechanics foundations lot of work has been done. This particular thing is in fact liquefaction phenomenon in which, because of the liquefaction, which means that the effective stress is 0 when the earthquake occurs in the foundation soil. So, the total foundations - I mean - they just get sunked in and you have a tilting of - I mean - total collapse of the buildings here.

Then, this is another type of area called sinkhole formation in which, say for example, what you have some carbonate soils or something like that, because of the leaching, there is a possibility that the soil gets removed and you have a formation of the holes, which is something very risky.

Fortunately, it does not happen in some of this, it happens only in a few rare places like in US, in some places and in Germany where I visited, and it was a very risky situation.

(Refer Slide Time: 03:02)



So, as I just mentioned the ground improvement techniques can be many, right from stone columns, soil nails, micropiles, jet grouting, ground anchors, geosynthetics, fibers lime columns, vibro-concrete columns, mechanically stabilized earth's, biotechnical methods. Then, surface compaction, drainage surcharge, electro-osmosis, compaction grouting, blasting, dynamic compaction, soil cement, lime admixtures, flyash, dewatering, heating and vitrification.

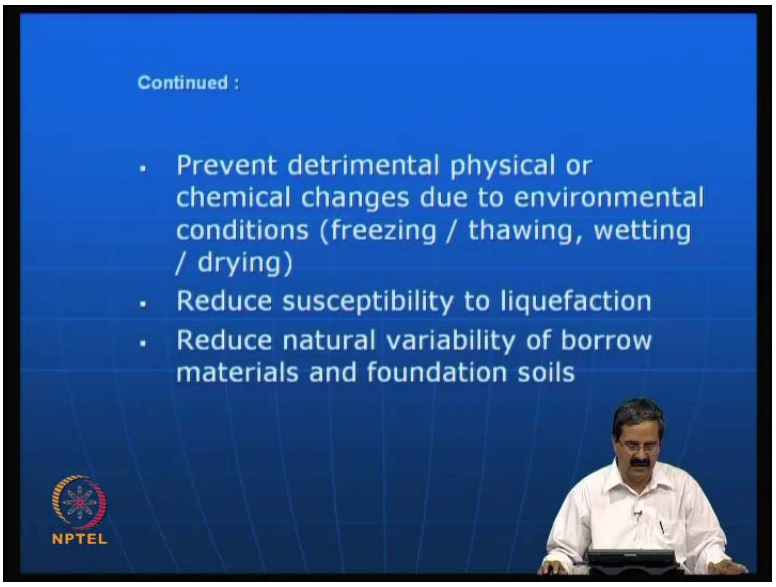
So, there are many methods that one can think of, but then, you must find out what exactly is a usual given situation. So, we should see, what are these benefits of a ground improvement techniques, increase of strength. So, you would like to see that for example, the bearing capacity of soft soil is very low, like it could be… you measure using an undrained shear strength, it could be about 5 ton per meter square and you want to make it to 25 ton per meter square.

So, what is the order of improvement? Is about 25 to 5, it is about you need 5 times increase that is required. So, one can do that using ground improvement techniques. Then, reduce distortion under stress like, the tilt, or the tilt of the building is called distortion.

So, the increase of shear strength and then, the reduction and distortion, some of this things they come from the stress-strain modulus of the improved soil, like so you need to really conduct some tests on improved soil, and measure its stress-strain modulus. And also one can do, say for example, a plate load test; one can do a plate load test on a soil that is not improved and also you can do another plate load test on soil that is improved or one can do CPT test - Cone Penetration Test - in which you can penetrate the soil into the ground in the cone into the ground and then get the signature of the ground, like variation of undrained shear strength with time, you can get it and then, compare both of them.

So, this also leads to some sort of you will get very good idea of what is the order of improvement, so this is one. Reduce compressibility is nothing but changes in the performance - improved performance - because of the ground improvement, wherein divide ratio decreases. And this is again, like one can do preloading or you can fill up the air voids with some materials, so that the compressibility is less, the material does not undergo lot of compression.

(Refer Slide Time: 05:53)



Then, there could be some problems like prevent detrimental or physical or chemical changes. What is detrimental? It is damaging, like physical change means like, if you try to excavate a building - excavate some area next to the building - then, there is a physical movement of the building like you have a distortion there, that is one problem.

Then, chemical… you know there could be some of sort of leachates in a particular area, you would like to see that the whole leachate is removed or contained within the system such that the leachate does not really contaminate the nearby areas.

Just I mentioned one example yesterday, where you have some, say for example, the factory which has lot of battery waste and may leave have for if the water gets contaminated with that type of material. Then, the possibility is that you have lot of metal ions into the system which could be very risky. So, you may try to contain them by using sort of ground improvement techniques, this is one issue.

Then, like wetting and drying, some materials they have lot of problems because of wetting and drying, say for example, the classic case of expensive soil, when it gets wet it swells a lot; when it dries, it dries a lot go to a minimum volume. So, we do not want that, so you add them some additive what happens? The range of water contents, like as I just mentioned from liquid limit is 100 and then, shrinkage limit is 10, so 90 percent is the water content change.

That can be reduced to maybe about 30 or 40, if you add some lime or a fly ash or any of them, so this is one classic example. As I just mentioned, this can be done with physical changes or physical additives like fly ash or a chemical additives like a lime and all that. Then, the one of the improved important aspects of the ground improvement techniques is to reduce susceptible to liquefaction, you do not want all the soils to get liquefied when earthquake comes.

Say for example, the Bhuj earthquake created so many problems, say for example, many dams, many dams collapsed because of the liquefaction, in fact, we have lot of information on this. And this is a challenging problem worldwide and people have been trying to work on liquefaction and it is control. Like, how do you avoid liquefaction and is density is ok, or is that reinforcement technique is ok, or stone column is ok, any improvement in soils will always leads to some improved liquefaction resistance.

Then, another important point is a reduce natural variability of borrow pit materials and foundation soils. What happens is that in a construction area you bring out, say for example, soils from different areas like, the for example, you may need some 1000 million cubic meters of soil in a particular area.

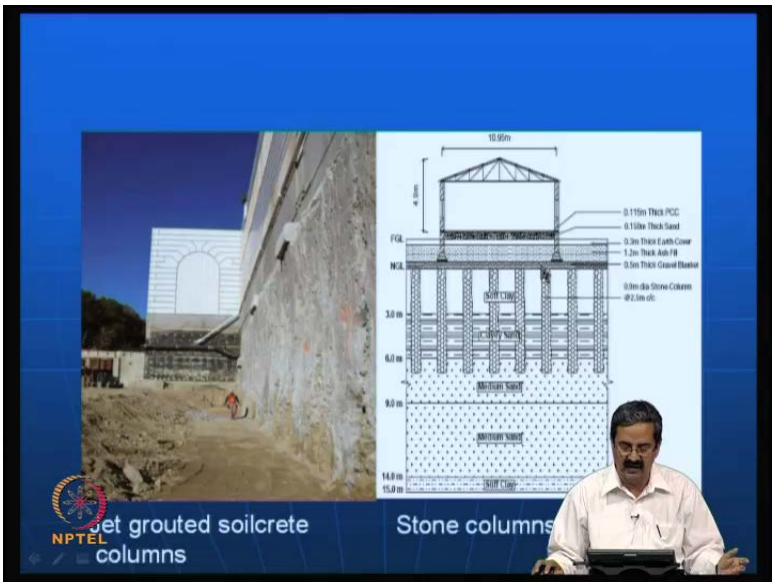
So, you do not get in one location, so you get from different locations and even if you get from different locations you need to really stack them and compact them in a proper way and see that the variability is something that is between two... If you try to use different soils in a different localities, one should able to understand that it may leads to lot of problems.

So, there should be a compatibility like in a sense that, you have the degree of compaction is what you call, when you are trying to compare different types of soils - degree of compaction. So, degree of compunction is another term that we would be using, and actually the borrow pit materials should be compacted to their maximum possible densities.

And see that the variability like if you take number of samples there, you take some say 5 for example 5 to 10 samples for example in a some area, the variability means, the dry density variations like gamma d maximum should not be too much varying, like it should be within 5 percent. Like, if I say, 18 kilo unit per meter cube, it should be may be 19, it should not be too much in a same soil, may be, next area you should be able to see you should be really, say for example, there is another borrow pit material in the next side.

And then the foundation of the a big structure is lying on this soil and then that soil, the way that it should done is that, it should really calculate the stress-stain response of both materials and try to compare whether the material has the same stiffness, these two materials now. There are 2 foundation soils one is here, the other is here, whether the soils have same stiffness and same densities and all that. One should be able to have some understanding, otherwise that could lead to some sort of difficulties.

(Refer Slide Time: 10:58)



So, this is some classical example I just want to show you, where you have a building which is just very tall building here, but then you can see that, you are able to vertically cut down. In the normal circumstances, you cannot do this, because few loop lines develop and the whole building collapses, so what we do is that, we do what is called jet grouted soilcrete columns.

Infact, in Bangalore we have couple of constructions like this, where you just put some columns like this, which is with soilcreteings of concrete, we call it soilcrete. So, we have a columns here, which are made like this, and then this is truly vertical - I mean - in the sense that, this will not really influence this building in anyway like, that is a very useful technique here.

So, this is another example for a containment yard in which you have stone columns here. Stone columns are nothing but, say for example, the area here is soft soil, here the soil is clay sand, this is a medium here - medium and stiff clay here - so this is a floor level and it is not resting on soft soil. So, we try to put this basement of this foundation slab of this particular material, it is called a gravel blanket we are putting here, and then we come out some design in the form of a stone columns here.

So, previously there is a soft soil here, where the bearing capacity is very low, for example, may be 5 ton per meter square or something a very low value, but if you put

here you can see that, what you are doing is that, you have already stone columns here, you have some of sort of a gravel blanket here, you may put even geotextiles or geogrids anything here, then you can put it structured, otherwise it becomes very difficult.

(Refer Slide Time: 13:09)

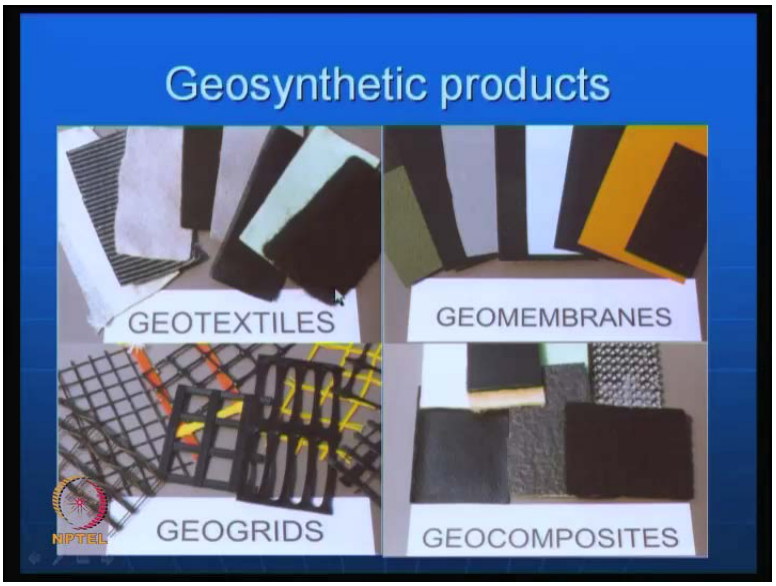
So, stone columns are very convenient in many structures, this is another important thing here, it is called the nailing and reinforced soil. In fact, this is a hilly area and you would like to construct a retaining wall here. Normally, what is that you do is, you have a gravity retaining wall and counter foot retaining wall, but then it is not required here, what we do is that we put some nails here into this system, so that the expression is not developed and put a thin a short crete and nice finish you can get.

It is a very interesting thing in fact, our own underpass construction at I I S C which you see in coffee board is an example of this technique, like where we did not disturb any of the trees at the top. So, this is a very classical example of how do use native soil and then, make it stronger. There is no point in trying to disturb the soil and then replace the soil, whatever is an existing soil try to understand the soil behavior properly, you try to find out the soil properties properly. If this, it is not strong enough like, it has a tendency to collapse, calculate how much of reinforcement is required to make it stable that is all, so this is what we did here, what we can do in many cases.

And so, this is actually technique called reinforced technique, it is one of the classical cases of earth reinforcement. And you must have seen this type of structures in many of the flyovers, where the great separators are constructed with the facing elements, then reinforcement and a backfill.

So, you have metallic strips and a granular backfill, which can be very effective, in fact, this is from 20 to 30 percent cheaper than the conventional retaining walls and the economy increases, this is the increase in height of the structure.

(Refer Slide Time: 15:00)



Then, these materials called geotextiles or geosynthetics, you have many types of products here, you have a geotextile here, you have a geomembrane here, you have a geogrid here, you have a geocomposite here.

Actually, civil engineers have been trying to only deal with soil concrete and water and some of these things like that. But then, if there is a problem with or if the materials you would like to conserve or the soil mechanics there is a problem, so like in a bearing capacity of soil is less, so you would like to improve the bearing capacity. One can use a geogrid at the bottom of the foundations and improve the bearing capacity, so geogrids are some they are all plastic materials like there made of high density polyethylene and PVC and polyamides and all that.

So, geogrids are very good for increase in bearing capacity, deduction of settlements, liquefaction resistance and all that. Geotextiles are very good for drainage separation and where the protection layers, say for example, there two types of soil layers. And if you put one of the soil layers as a separator, it really separates both of them, it does not allow them to mix together and this is a very important application payment, particularly, you do not want all the different layers to get mixed up and if they get mixed up what happens is that the whole performance is useless.

So, you try to provide separation and see that the materials, whether it is a payment or anywhere, the filtration function is properly satisfied, then drainage function is also properly satisfied, it is also a very good protection layer and all that. So, you can use in many of the payments, many places there are so many applications here, that as we go long we will see. And geogrids can be used in many applications from bearing capacity to retaining walls to slopes and many applications.

Then, geomembranes, for example, you do not want the permeability of the soil to give trouble to you would like to seepage you would like to avoid. So, when you have geomembranes which are nothing but plastic membranes, you can use geomembranes, the permeabilities in the range of 10 to the power minus 14 mm per second compared to the soil which is 10 power of minus 7 mm per second, which is something very good, like more than 10 power of 7 times higher which is a very useful in many of the applications particularly in dams structures, where there is lot of seepage or even in a wherever there is a problem of even reinforcement, then landfills, these are very excellent material for many of the applications.

Then, geocomposites like two functions we combine here, like reinforcement and drainage one can combine, because the soil is poor in drainage and also on reinforcement. So, put a geocomposite and then see that the geocomposite can help in both drainage and reinforcement, so you have the geosynthetic product that can be very useful in ground improvement.

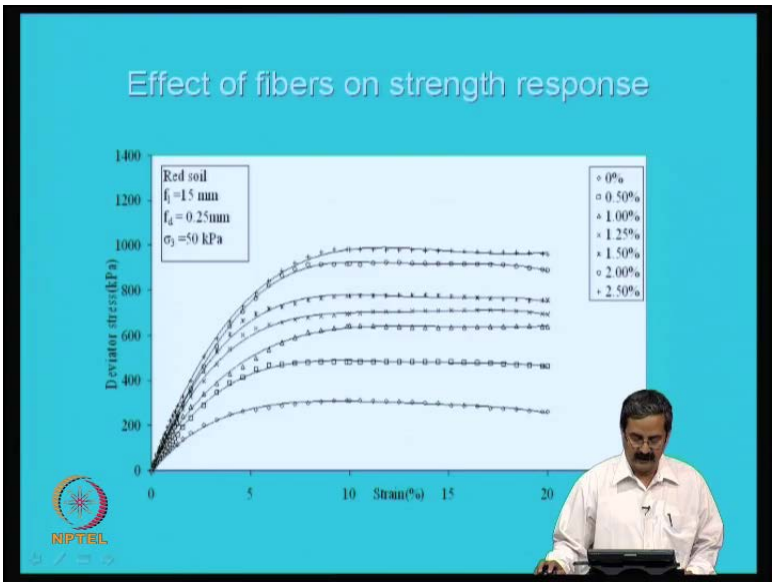
(Refer Slide Time: 18:26)

Another classic case is like fibers, fibers is another one that you can just use many of the fibers that is available like, people are used to fiber reinforced concrete, you can have fiber reinforced soil this is what actually the slope made of fiber reinforce soil. And fibers can be, they can be right from coir fibers, jute fibers then they can be even natural like the steel fibers, it depends on the application.

Say for example, you are looking at a function like this; people go for natural fibers like coir and jute, where people have been using extensive applications in many places. Then, if you are trying to use it in some other like, say, where a bearing capacity needs to be improved you do not need to go for natural fibers, you can go for synthetic fibers, like plastic fibers or even you can go for plastic waste.

In fact, we have been working on the use of plastic waste, I will show you some results, and plastic wastes can be - then even geogrid wastes many things can be - used like this. So, this another case of a reinforced earth wall like, what you saw previously was simple reinforced earth wall, this is actually two tier retaining wall here, where depending on the profile requirements whatever profile you want one can construct nice slopes here.

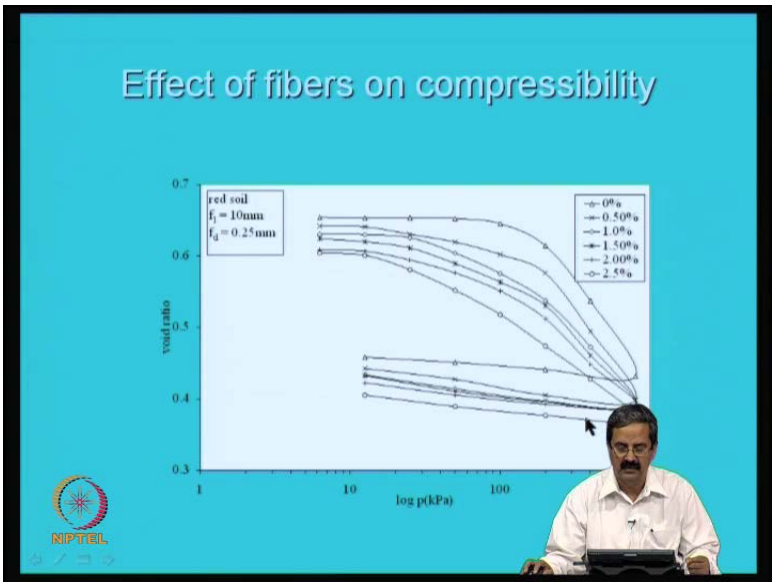
(Refer Slide Time: 20:02)



This is the Actually, the facing elements are what is called modular blocks, then this soil will be native soil will be behind this. So, I just want to give some examples of ground improvement, because as I just said, the objectives of the ground improvement are to increase the strength and stiffness. Like you can see that if you add in the case of a red soil, this is a stressing curve of the red soil and if you add some fibers say for example, from white 0.5 to 0.1 or 1 percent or 2.4 percent, you can see that there is a stress and which is original like this got improved like this.

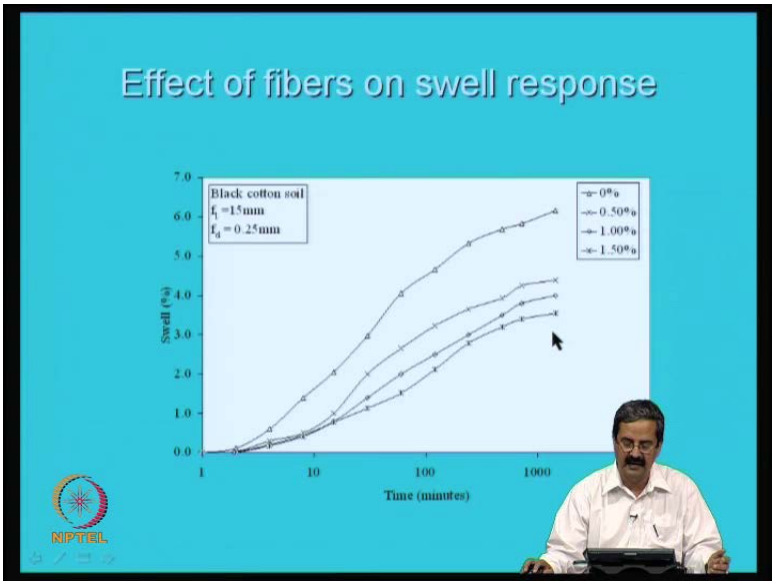
So, it is almost about right from about 220, it got increased to 1000, it is a very good improvement both… this is called strength, the ultimate value what you get and the tangent of this will give the stiffness. So, you can see that there is a good difference in both cases, this is what we need in many of the applications.

(Refer Slide Time: 20:56)



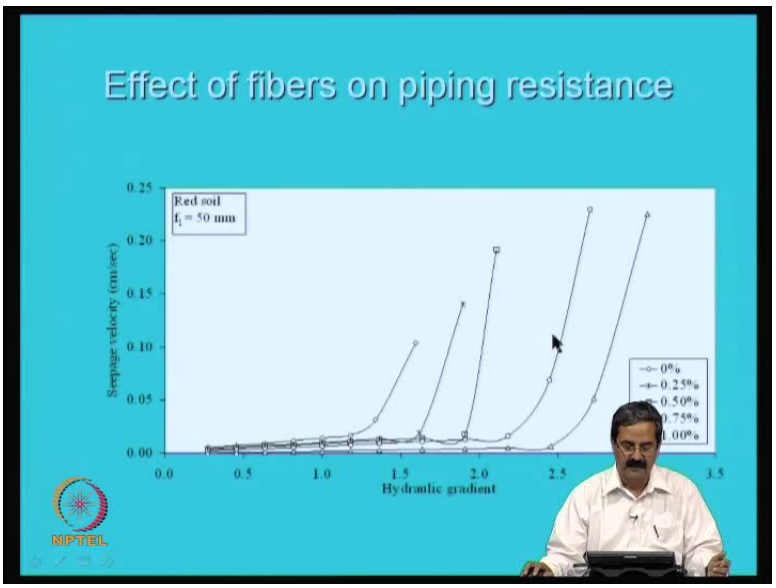
Then, you can see the effect of fibers and compressibility also, like why I am trying to cover just fibers is that they have been useful in all the applications. Like, you can see that originally the compressibility is quite high in the case of soil without fiber, but then, if we add fibers with increase in fiber content the compression index c c and the recompression index c r will come down, this is a very good advantage if you would like to reduce compressibility.

(Refer Slide Time: 21:32)



Then, in some cases, you would like to reduce this percent swell, particular in the case of expansive soil. So, when there is no fiber in the material the swell is about 6 percent - it just expands the soil - you take an expansive soil and then do a consolidation test and add water, then it swells by 6 percent. But then, if you add different percentage of fiber you can see that it came down to 50 percent. So, what I want to say is, that this ground improvement techniques in the form of many anything could be used. I am only trying to just illustrate with the example of fibers, because I have the results readily.

(Refer Slide Time: 22:15)

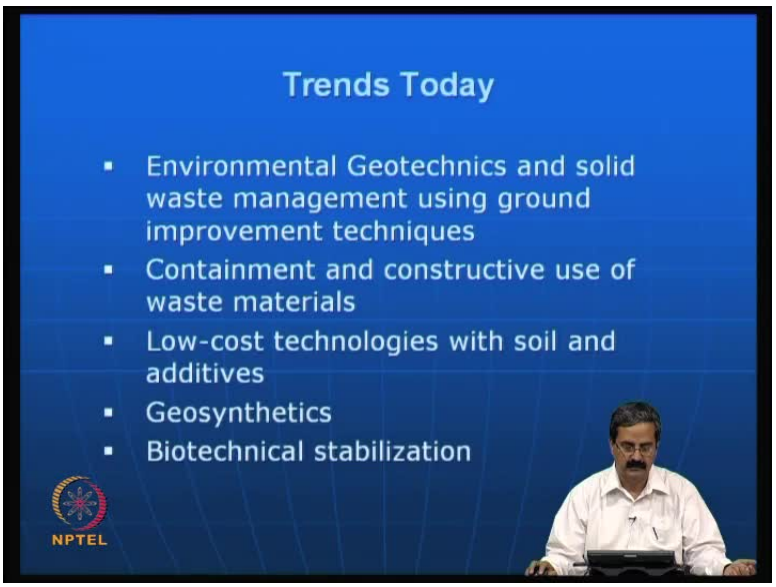


This is another important observation on piping resistance, the many sands many materials have quick sand condition like; you know, what is a critical hydraulic gradient? It is i c equal to g minus 1 by 1 plus c it comes close to about 1 and all that.

So, a materials will have a tendency to liquefy at low hydraulic gradients, but then if you add fibers, you can see that what happens is that, when you allow the water from bottom there is seepage and then, whole material got it failed. In the sense that, lot of seepage came out of the sample, initially the seepage was very low after that seepage suddenly increased because the piping resistance is over come. So, here the hydraulic gradient is hardly about 1, but if we add fibers what is happening is that with different percentages of fibers, the critical hydraulic gradient at which the liquefaction occurs can be improved right from about 1.1 or 15, we have increased it to 2.5.

This is a very valuable application in the case of embankments on the downstream site particularly, where the seepage water comes and then, there is a lot of uplift pressures created, so if you have some sort of fiber reinforce soil, it is going to help a lot.

(Refer Slide Time: 23:43)



So, what the trends that we have today are too many, like in the sense that, now ground improvement techniques are required in the areas of diffuse fills also, like you have a landfill. Nowadays, there is a shortage of spaces and people have been trying to even go for places where there are waste dumps.

So, in the case of waste dumps what should be done is that we should see, we should use the knowledge from Environmental Geo-technics, where the waste dumps; they will have lot of difficulties, because the waste dumps have biodegradable, they have a biodegradable composition. For example, some material may degrade with time, some material may not degrade, they have a highly variable composition. So, what we do is that, what you call municipal solid waste, we call it, and we try to understand the behavior of a municipal solid waste and leachate compositions and their effect on buildings and foundations.

Like, if you have a leachate of very high concentration and it affects the concrete and steel, you construct a foundation then it affects a concrete and steel, it is going to be risky, so you do not want that. So, the knowledge of Environmental Geo-technics is

required particularly in the understanding of compressibility, shear strength and some of the engineering properties and also the quantity and quality of leachate, its long term and short term effects, then the solid waste management using ground improvement. In the sense that, we are trying to use this ground improvement techniques to see the landfill is not going to be harmful for us.

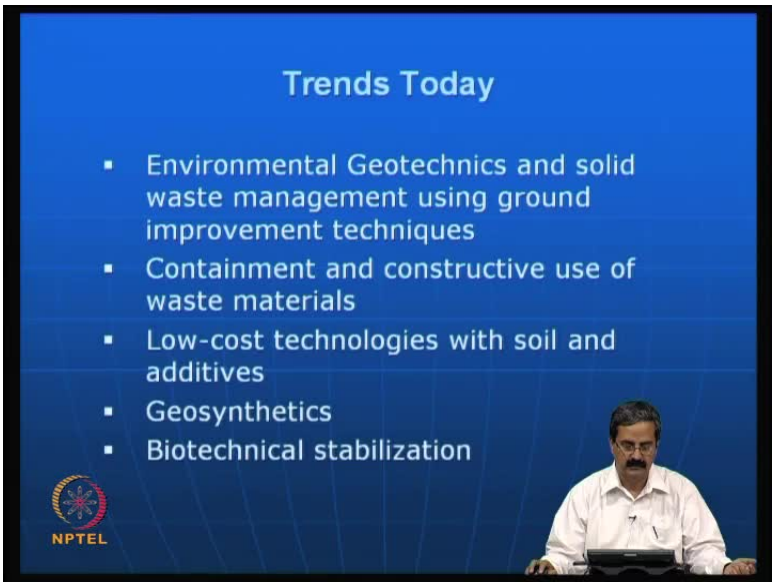
The area in which the dump is there, it should not really influence any of the nearby multi storied apartments; say for example, the multi storied apartment is resting on a landfill. The first thing is that the whole area should be stabilized, how do you stabilize? You need to use some sort of ground improvement techniques. We will see that some dynamic consolidation is very standard method used dynamic consolidation and then stone columns, many of the techniques are used to stabilize waste dumps.

Then, there are many problems, say for example, in leachate also that you have to monitor if any leachate is there, because you are trying to have your own water well there. If you are trying to have water well there into their landfill that what I do not want, we do not to use. So, even if you get somewhere else and you have a sump there, normally apartments need to have a sump; sump should not be affected by the landfill leachate.

So, essentially what you are looking for is that, you are looking for ground improvement, as it means to stabilize the whole area and construct a building. And also see that the water exist there should not be dangerous to the living there, it should not affect your living there. So, that is one thing, so containment and constructive use of waste materials.

Actually, as I just mentioned if you are trying to contain the waste material there itself using a geomembrane or some put some slurries. So, that the containments do not move at all that is very good thing. So, we need to see contain this material in such manner that there is no difficulty with some of the leachates. Then, another important point is a constructive use of waste materials like, what exactly we are trying to do is that waste material has been dumped. And then, now you are trying to stabilize the whole area and try using it for an apartment. That is one way of trying to reuse the waste material space, and the other one is, so much waste is generated, say for example, as I just mentioned about plastic waste, construction waste, then the like particularly roads making.

(Refer Slide Time: 23:43)



One can reuse some of these materials in some sense, you may not get very good 100 percent benefit out of it, but then say for example, applications you may not national highway road waste can be used in a village road, nearby village road. You have a big national highway and they thought that resurfacing is required or some more treatments are required or it should be totally relayed.

In such cases, what should be done, you can remove the total material and there are so many techniques to recycle the waste, actually because recycling is itself an art. So, there is a lot of work has been done in the use of construction of a structures using waste materials. Then, low cost technologies with soil and additives, like as I just mentioned in fact, soils in terms of science we have application of science and technology for rural areas where we have, instead of the concrete blocks for houses you can go for soil cement blocks, which are quiet efficient. And burning needs to be avoided, burning of bricks, what is happening is that in burning of bricks you are spending energy, you do not need to burn, because why you are burning the brick is you want to get some strength of the brick.

Essentially, you are trying to dry out this moisture and press it in some form. So, you will get some strength, the same strength if you get from compaction, it is fine, is it not. So, that is an actual basis behind some of the technologies - low cost technologies - one

can use flash, one can use many waste like you know, there are so many mining wastes that are there different types of wastes are there.

And one can use an aluminum waste and zinc waste, all of them could be used to come out with good technologies for road construction particularly, because road construction is one thing that can consume lot of material. You may not like to do in a building, definitely you do not want that in waste materials, you do not want use in a building, but definitely you are happy to use in a public funded project, because again you have to make sure that the effects are minimum.

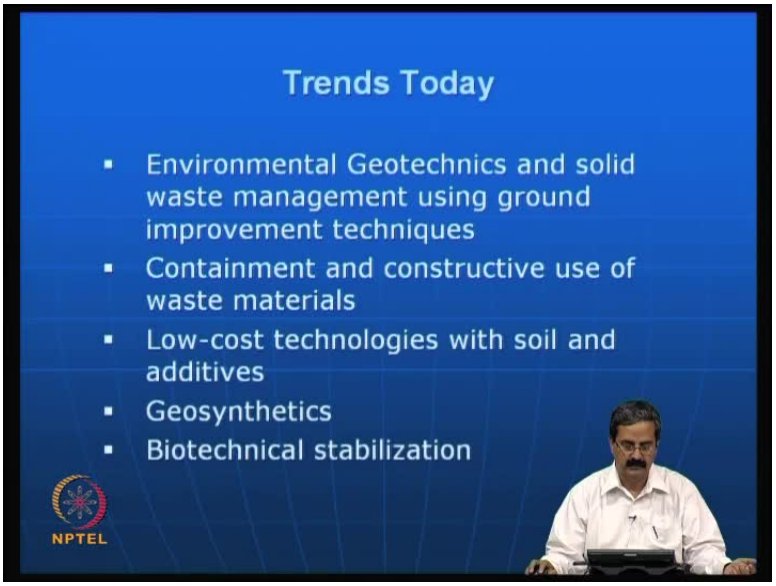
Then, as I just mentioned about geosynthetics, this is actually as I just mentioned geosynthetics have really been a big impact, they have made a very big impact and in civil engineering profession. And in fact, in all applications right from hydraulics applications to geotechnical to transportation, environmental, everywhere you have applications in of geosynthetics even structural engineering, because somebody you know, the thickness of the deck slab in the bridge could be reduced, because it can serve both as sealant as well as reinforcement in some applications and this has been quite useful.

Then, biotechnical stabilization, so the biotechnical stabilization is something that is again a very unique technique where people have been using the basis the biological concepts or using living matter, say for example, bio enzymes. Actually what you need in soil, you would talk about cohesion friction, if cohesion is if you can bring in cohesion because of some bonding, which gives some bonding like, the two particles should bind together. So, that is the principle here, if some biological processes using some bio enzymes or even biotechnical in the sense is people have been using grass to increase the slope stability in many applications. So, some people use grass, use of even bamboo sticks as a reinforcement one can use. They can be considered as biotechnical use of enzymes could be a biotechnical stabilization.

So, with the some of this techniques are of a great help in the increasing the stability of the ground. So, the trends today would be that there could be many in the sense that the environmental geotechnics, in the sense that the proper knowledge of waste mechanics. I should say, actually it is a big branch in soil. Nowadays they call it… soil mechanics is

one thing, but even waste mechanics is another thing, like how the waste behaves under load.

(Refer Slide Time: 23:43)



Essentially, you are looking at how the behavior of waste is there when load is applied, when the water is passed on. So, this is a very big area in particularly in abroad like, if you tend to go abroad you are only asked to solve problems like this. And the containment and constructive is another important aspect, where waste materials could be properly reused and also in some cases contained. I was giving you one example the other day, where there is an arsenic waste and you do not want that some of the metal ions to go out and then come in contact with water or any other thing.

So, that whole thing was immobilized, the whole area in which that material was present was immobilized totally and now it became very hard. So, that can be powdered and actually now, within that particular substance the concentration of the arsenic was much low, actually you have immobilized the whole thing.

So, there were trying to use it for road payment purposes in a particular road and some of the in one of the case studies in USA. So, you can see that arsenic which is supposed to be actually about Bangladesh; Bangladesh has a serious problem of arsenic contamination it seriously affects the health of the village in wherever it is present and there are some things like that.

So, people have been able to do good work in this areas and of course, low cost technologies with soil is something like, as I just mentioned in the case of soil cement block then any soil with additives. Say for example, it can be lime, it can be flash, it can be any material and in fact, rural technologies. For example, the villages; they do not you know it is difficult to make construct approach roads in villages, their cost is very expensive.

For example, even know the thing is the first thing is, you will have transportation cost to construct roads. In villages from the national highway you have to go to a village, say for example, 5 meters, but then the best way would be that use a local material available and then construct some road which can be approach road using local materials, local soils and local knowledge whatever. So, make that approach roads that can be used as a starting point to construct better roads later.

So, with low cost technologies and local soil conditions and additives in fact, I was suggesting the use of a bamboo reinforcement for many of the rural roads, because bamboos are widely available, bamboo wood and then they are all available. And the soil and sand, if you can really combine in some form or any of the materials they can be used. So, one can really come out with some simple technologies for rural roads also.

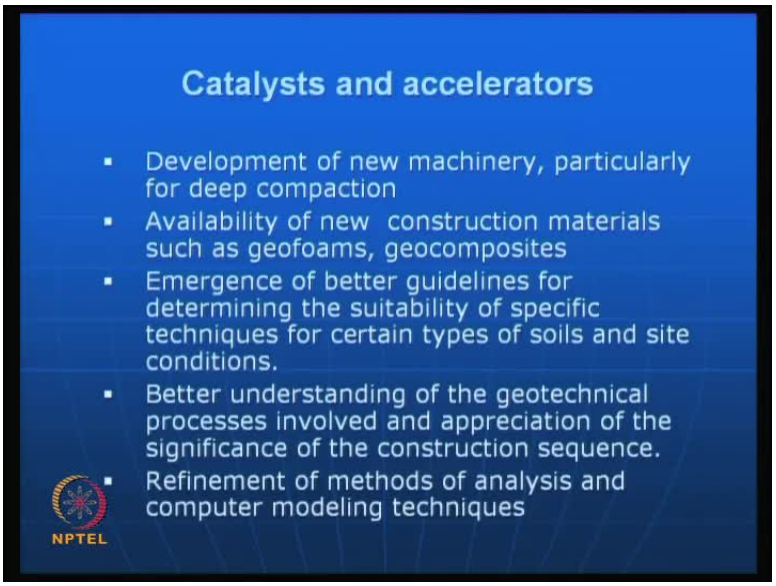
Just this of course, it has a very wide applications and biotechnical stabilization another big area. So, in this there are many things that are happening, actually what is important is that people have been talking about infrastructure growth in India. In 20 years back it was not so much but, then people want to construct and come out, you the thing is now a days the thing is that you; however, how fast we construct, you will get the there is some incentive also. Like, there is a one year project, if can finish in 11 months there is an incentive we are getting. If you go to some national highway projects, if you can finish you will get some incentive.

So, that way, there is so much advantage, nowadays in construction that people have been trying to come out with new methods of construction or they do not mind going say for example, I have seen many people they go to Singapore they go to USA, try to bring a new technologies.

And then say for example, in a metro project let me use it, you can see in a metro project. Say for example, pile driving, we know about olden technique of pile driving; one can say, but that could be very labor incentive, but we do not want labor, we do not want support. The thing is labor maybe happy, but we should finish, the cost of the project should not be expensive that is main thing.

So, you can keep the labor in some other form, but you would like to accelerate the cost of the speed of construction. So, you need to come out with new techniques and then new machines. So, like people have been working with new machines nowadays even for mixing and monitoring and anything.

(Refer Slide Time: 37:55)



So, this has been a development of new machinery in fact, is a big area, then particularly for deep compaction, you will see that shallow compaction has some equipment like a road rollers and all that. You know about shallow compaction, you have seen soil compactors, but for deep compaction where you know if the soil has to be compacted to about 15 to 20 meters you need to have some more machinery, where you make a borehole, then put some system into the soil and then try to see that, say for example, I was talking about stone column.

Stone column, we have to make a bore then put the sand the stone inside and then slowly withdraw that. So, it is equipment, it is costly equipment, it is not just like it is not easy,

so people have to mobilize and then people can only mobilize if there is a big project also.

See, it is not like the construction, it is such a big scale one has to work, if that man gets only one equipment for one project, he is gone; he cannot really get the returns in the project. So, that fellow should have some at least 10 projects where he can recover the cost of machinery.

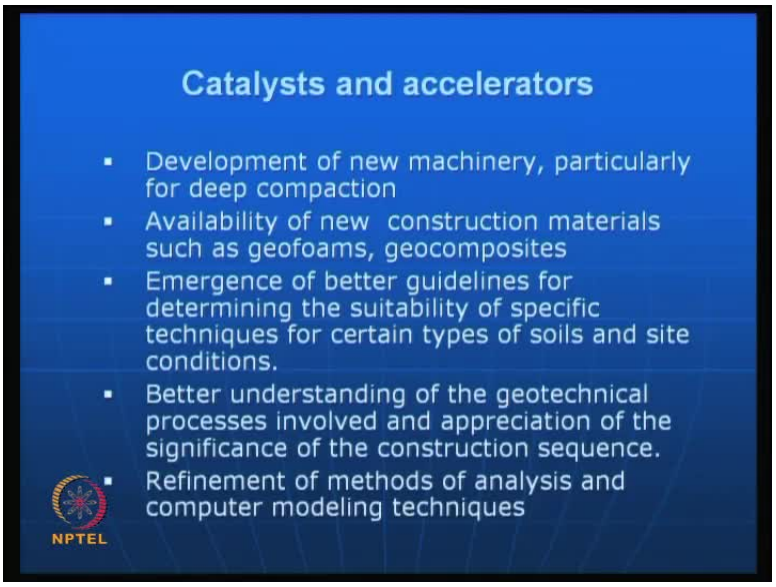
So, another one is the availability of new construction materials like, there are many actually, if you go to construct of roads and other places there are so many materials that is amazing. For example, I will tell you the case of geofoam, I will show you photos also in which see normally in the road construction, what you do and you make a sub grade, sub base, and then weighing cores.

It takes and then you see that half road is cut and then the half road is… you do not allow the traffic to go. It is always a standard scenario here, but the geofoam is one material we just bring it and place it, it has the all the properties that you want from the subgrade.

What is that subgrade, why you are constructing different layers? Essentially, we are constructing the road to see that the traffic load is taken care. Only thing is the existing load is some traffic loading and you are trying to provide some material which can take care of the load, nothing else. All these concept of a sub layers and all that is just older concept this is of course, the concept is important like, what the purpose there is to distribute the load gradually there. You have a subgrade, you have a sub base, you have a base and you have varying cores.

Whatever is the load that comes from the varying cores has to be distributed and then it should not it can reach the subgrade. And when you calculate that load coming on the subgrade that should be less than the bearing capacity of the subgrade that is the principle, that is why you have so many layers. You have so many layers why because, you would like to distribute the load to see that the subgrade is not affected to maximum extent. But when you have a material, I just bring it in a truck and then place it there and then put some varying cores and then, merge everything like a geofoam which is not the really compressible, it is fine for us, so you can construct roads very fast.

(Refer Slide Time: 37:55)



So, geofoams are one, there are many actually, like particularly in road construction there are many things that only contractor should be ready to absorb the techniques. Like, another classical example is the, you have seen pipe lying in the roads. You want to construct a pipe across the road, what happens in many villages you must have seen they make a cut and its takes lot of time for backfilling.

They first make a 2 meter opening, then pipe will come after 2 months, then the backfill take another 2 months, then the by the time lot of accidents would have happened, then we should have a detour, where somewhere accidents would have happened. This is a typical scenario in some places, but here actually the technology, I know, I have seen places where you make a cut and then put the pipe immediately, like pipes are available, like you have to really go for proper management there.

And then, the road should be constructed on a day, where there is not much traffic say for example, Sunday something like that. Somewhere or evening some like you know, you can just say for example, 1 meter pipe there are 2 paddy fields here on either side of the road and you would like to have drainage across them that is a point. So, for which you can use what is called trends less like, there are technologies where you can push a pipe without disturbing the traffic, you do not need to disturb the road and traffic at all. You can just push up what is called a pipe, it is called pipe jacking.

Actually, our own underpass it was done like that, without disturbing the traffic one can push the pipe small pipe. Other thing is, because I do not have a jack and it could be very expensive and all that. So, you simply dig it put the pipe and place the backfill which can settle in 4 hours. You know, settling of the See, what happens, if the backfill is… see if you put soil and start compacting actually our people will not compact at all people will be simply sleeping there.

So, but here we have you can use soil plus flash, you can make a mix and then pore that and then the setting time will be about 4 hours. Once its set and all that put it the whole road is ready, it can be used. Like, I have seen some field examples, where the road like this sort of connections is made in no time.

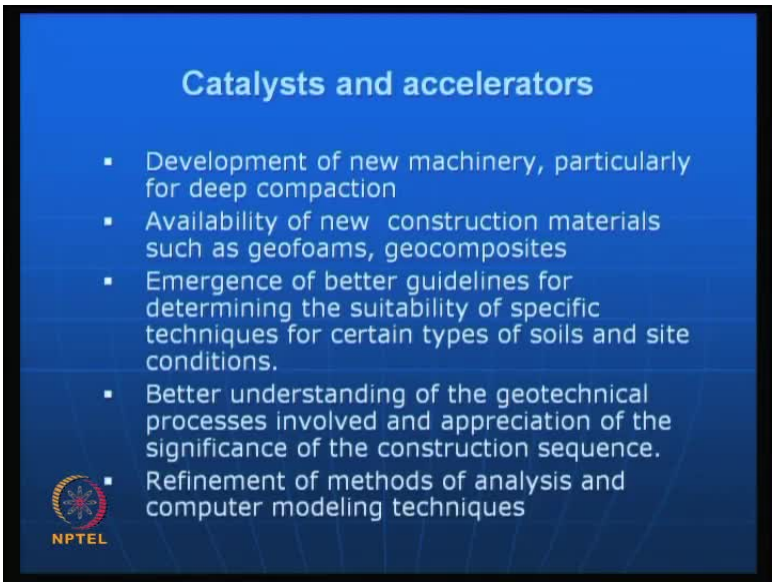
So, these are all what you call new construction materials of course, it is not a new construction material, flash is not a new construction material, it is not a new method, new technique, but how to use it, the material is not new, but the technique of using it in the application is very new. Of course, it is also not new in abroad it is being used, but I am sure that with the construction, if we have contractors understand the use of this, they will much more happy to use this materials.

Then, very important thing is emergence of better guidelines. Emergence of better guidelines for determining the suitability of specific techniques for certain types of soils and site conditions. For doing anything you need guidelines, without guidelines contractors will not be ready to come.

Even say, I may be, we are all faculty here, but if I just say to some chief engineer, sir, why do not you do this technique? He will immediately ask me, do you have guidelines from India, Indian roads congress or do you have I S code specifications? If I say, I do not have then he will say, I cannot use - that is it.

So, people have been trying to develop guidelines and if it not available in India go to some other nearby country, for example, if there is say contractor has experience in Malaysia bring him here and see if the technique is working properly. If the guidelines can be modified, is it not? Guidelines can be modified to suit our local conditions and types of soils.

(Refer Slide Time: 37:55)



So, like I just mentioned the one example of the Malaysian company who came to India and then, I think where they constructed road in a particular place, but then they did not understand the soil behavior, like it is soft soil area, they did not have lot of information and the soil gave lot of trouble there. So, the road itself was about 20 kilometers is at serious problems.

So, if you do not have proper guidelines or if you do not frame; actually before, we take up a particular project you should have guidelines first. Like, people prepare a feasibility study, you may have, say for example, I am trying to use a reinforced soil technique here, to what extent it is feasible, what is it is advantage, how it can be constructed, all this things will be coming in this guidelines.

Then, say site conditions are crucial of course, it depends on the depth say investigation should be very thoroughly done. Say for example, it needs a specific number of boreholes like, say 20 boreholes, 100 boreholes. It should be done systematically to see all that that can create problem to us later, it should not create problem, because the movement you construct the structure, then if the problem comes later it is very difficult to go back, it is a very risky.

Actually you will be very, it is a very pathetic situation, if things do not work particularly in ground improvement. Then what happened is that, in the recent years people have

been able to understand the geo-technics process involved like. Soil mechanics knowledge people are were much more serious like in the olden day's structural engineer, if you know c and phi, he will give you foundations.

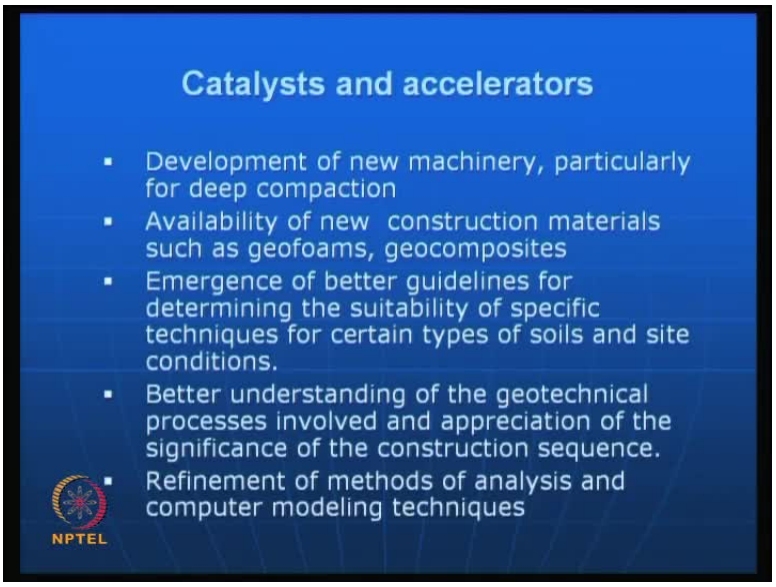
The structure engineering knows bearing capacity and raft foundation design everything. Now he says, sir, I will understand that you have some ground improvement techniques can you help me? He understands that the soil is much more; he cannot understand much. So, he consults a geotechnical engineer, Geotechnical engineer consults if he has good experience in ground improvement, he will do ground improvement techniques.

And the construction sequence is another important thing, because like see many of these civiling buildings and the system they have some construction sequence. Like, I will take the case of a nailing; nailing example, see nailing reinforced nailing can be used to construct a retaining wall, like what we have in underpass. So, the nailing in the conventional technique, you simply completely excavate about for example, 5 meter then put your concrete and put the gravity wall you construct. Here, in the case of nailing you just construct a bit then put some nailing, then excavate a bit put nails, excavate a bit and put nails, like this is a sequence of construction is followed. So, people should understand that, if we do not understand just simply excavate 5 meters it collapses, so one should avoid that. So, people have understood the construction sequence also in many of their projects.

Then, what happened is that the refinements of methods of analysis. See the thing is people have been having good analysis tools like, finite element software, finite difference software; you must be taking courses on finite elements like in many structural engineering or geotechnical engineering.

So, here the advantage is that the methods of analysis are quite useful like, you can say that the soil is elastic or the soil is plastic or the soil is elastoplastic and then, you can completely model the actual stress-strain response properly.

(Refer Slide Time: 37:55)



Like, as I just mentioned you are having, for if you want to have the bearing capacity, you know about c and phi. And then you get a bearing capacity and the factor of safety, three use and then you get some bearing capacity and compressibility like, you know compression index you calculate settlements that was helpful. But, if we want to really model a construction sequence that will not help you, knowing c and phi will not help. You need to use constitutive models to model at the sequence, because sequence is what is very important in geo-technics.

Like, say as I said even tunnels in the creation of tunnels also, you excavate something, then you short create, then you put some reinforcement, there are some issues in tunneling also, many of this geo-technics are more about construction sequence. Then, c and phi and some other engineering parameters will tell you about some information, but if you want to really understand what is happening to the deformation. Like, if there is a tall structure and if I want to excavate here, I should just seriously, say, I just excavate 1 meter then calculate factor of safety.

Then, deformation also I should be able to calculate, then go for next 1 meter, then calculate factor of safety and deformation. Like that sequential, like put reinforcement like this or put a sheet pile anything, you can do a sheet pile wall also many things could be done.

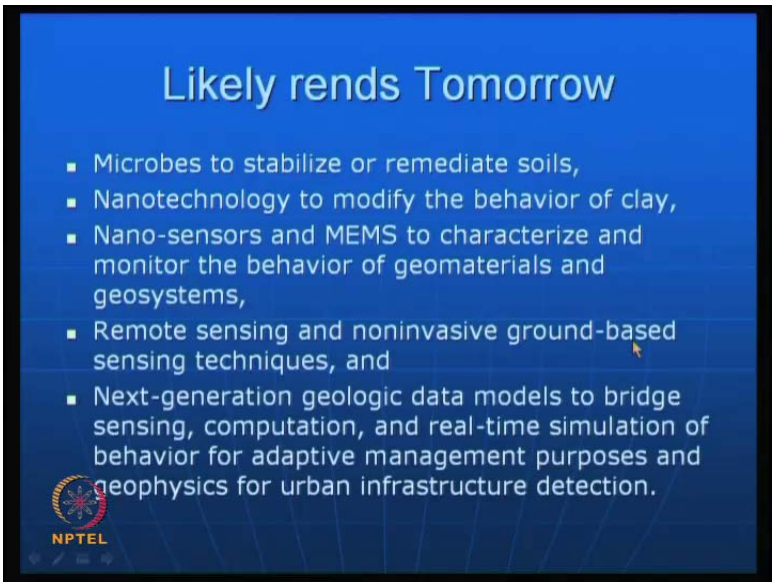
So, if you are doing a sheet pile wall first or some micropiling or something, first micro pile has to be put and then excavation should be done, there the sequence is different. Because our objective is that there is an apartment here, then put first a micro pile, then remove the soil, because micro pile will care of the load that comes because of the shear. Load, you know there is a component of load that comes from the foundation of the next building, which will cause shear on the micro piles or whatever. So, it should be taken care, so once you design it, you can remove here, so it is called what is called construction sequence is very important. So, for which you have very good methods of analysis now.

Then computer modeling, like you can just really see like the way construction is being done. In fact, people even update in abroad know on homepage as you know, say for example, I have seen there is a mall coming up, a mall is coming up and you are all going to have a nice theater there - underground theater.

So, underground theater construction is geotechnical issue, a 3D theater. So, the owner everybody has to be informed, because there is a lot of craze on seeing that movie in a theater. So, if that fellow will update it on the internet like, last week this is done like this, this much of depth of soil was excavated, this is a soil reinforcement everything is done. And then finally, within 20 days we are going to finish the structure, after 20 days it will be like this.

That is a level of sophistication people have been using, they have done it in some places. So, what I meant was that this some of this trends will continue, because I think there is a lot of scope here, but then we should understand what the likely trends tomorrow like, we should also think of tomorrow.

(Refer Slide Time: 52:35)



Like, as I just mentioned microbes stabilize or remediate soils like, because people are looking at natural means of stabilizing. Now, people have been talking about nanotechnologies everywhere in trying to measure and understand soil behavior. So, why not use nanotechnology to modify behavior of clay, because an electrical field in soils is a nanotechnology. It is a more of a nanotechnology related like, if you are trying to measure the electrical surface electrical charge of a clay particle you should go to angstrom level or much lower than that.

So, one can use a nanotechnology to modified the behavior of clay at basic level, people have been using. Then, to understand its response nano-sensors are being used, MEMS is another area that people have been trying to use to characterize in model behavior of geomaterials and geosystems.

Then, see remote sensing and remote sensing, like if you are looking at landslides in Himalayas you have to use remote sensed data, you can do the real time monitoring now, you have the GPS systems and all that. So, you can just see even after in the rainy season, how is a landslide? Is it going to come in the is it going to come within say people whether its rainy season or not people continue to move and live, in Himalayas and wherever they are there. So, you need to really, you can monitor from here, what is the condition of the slope there in a particular month.

So, that is a it comes from remote sensing knowledge and if you can calculate even strength parameters, you can even know its rainfall intensities there and calculate stability. Then, another important technique is non-invasive ground based sensing techniques like, nowadays GPR there many techniques that are coming up to find out how is the response of the ground.

So, one can use some of this nonresponsive non-invasive techniques to understand the response of the ground. Then, people have been looking at geological data models to bridge sensing; sensing means, just get a feel of it. Feeling alone is not sufficient, you must be able to compute things and then real time simulation of behavior like, say for example, if there is some load that comes on the foundation, how is a foundation going to behave, how is a whole structure going to behave? They do simulation techniques say, for example, nowadays people are talking about finite element model for the whole globe, the earth is there you divide into number of finite elements and create. See, now, we use a theory of plate tectonics for earthquake occurrences.

So, you just model also the plates and locate some source points, try to trigger energy there, see what is going to happen, zoom it to the place where you want and then see, what is its impact. There people have been trying to do this, that is what I said next generation geological data models to bridge sensing, computation, real-time simulation of behavior for adoptive management purposes.

In fact, what is adoptive? In fact, in Japan you have earthquake occurrence is maximum, so the buildings foundation they should be able to respond, they will have some active control and passive control systems in foundations. And like those systems should the movement they sense an earthquake they start working and see that they take all the load and building is intact. So, you have some of these techniques which are called in fact, for urban infrastructure, particularly because you spend lot of money there. So, with this likely, sorry, trend it is, thank you.