Environmental Geotechnics
Prof. D. N. Singh
Department of Civil Engineering
Indian Institute of Technology, Bombay

Lecture – 11
Soil Improvement and wastes

(Refer Slide Time: 00:15)

The second issue is Soil Improvement. The concepts of soil improvement are well established, what is the main idea of doing soil improvement? Should be good compaction, less drainage more cementation and so on. Where do you use them? For creating pathways, roads, huts and homes and sometimes other structures also which are of strategic importance. So, what is the challenge in soil improvement? To avoid?

(Refer Time: 01:05).

Ok.

(Refer Time: 01:07).

That is right, more strength; anything else? Yes, we are creating imperviable system. So, if you create a imperviable system what happens to the pore water pressures?

Increases.

Increases. So, the biggest challenge with non improvement techniques is believe me people do not bother about this issue, but the whole challenge is when you are creating a system by improving the soil which is going to be less pervious impervious, what about the pore water pressures? So, this is where you have to have a different model which has to be applied for soil improvement schemes. Do you agree with this? That's it.

You do not agree? It's a challenge. So, any idea how would you reduce pore water pressures from the soil which have been modified or improved?

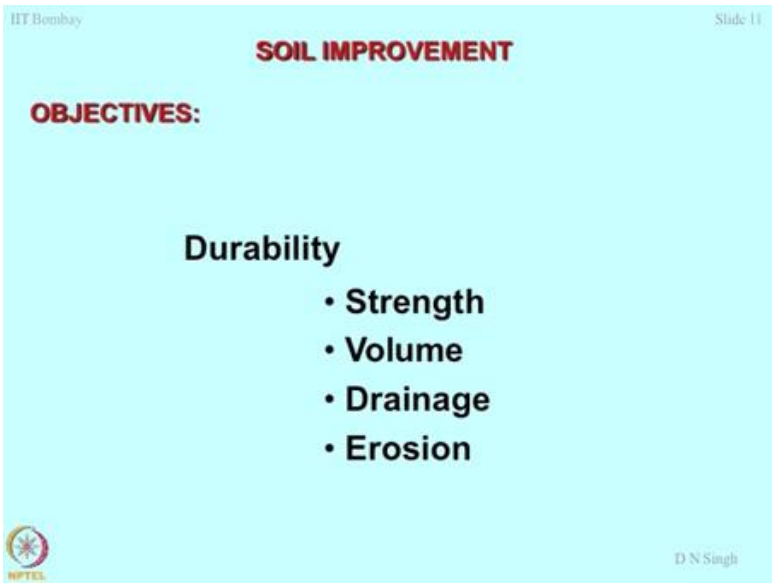
(Refer Time: 02:38).

Did you ever wonder that why pre loading is done by putting the band drains inside? What pre loading is doing without putting band drains?

(Refer Time: 02:50).

Exactly. So, the answer is you always do pre loading by installing PVD band drains or sand drains clear? Simply pre-loading the structure will not improve the strength, it will keep on building up pore pressures. So, one way is to remove pore pressures which are developing because of preloading would be to insert PVDs. So, you have pore pressure release and settlements and system becomes stabilized, it's logical.

(Refer Slide Time: 03:22)



So, what are the major objectives of soil improvement? Vinil, you are talking about durability.

So, we have discussed what are what is meant by durability, what are the attributes of durability. When you say some system is very durable, rock is more durable than concrete or concrete is more durable than rock.

Sorry?

Rock is more durable.

Then why did you discover concrete? You should have been you are still living in stone age; you should have been happy with stones. Is it not? Why you discovered rock oh sorry concrete?

Workable.

Workable, yes you have to say something.

My question is simple.

Yes, sir.

Sorry?

(Refer Time: 04:25).

My question is very simple. Which one is more durable, rock or concrete? You are saying rock.

Rock.

Anybody who are concrete in the class? No one? Then write off the concrete technology. The first parameter is strength when you talk about durability. Rocks may not be so durable why? Because they may not show you so much required strength. So, when you say concrete of certain strength you are sure that this system is going to give you at least 95 percent of the designated strength, clear. So, durability the first parameter is strength, there should be a target strength F_{CK} versus crushing strength, all right characteristic strength and crushing strength.

Volume; the volume the system should remain as it is, it should not change, no disintegration is allowed. Rocks would disintegrate or not? There are some rocks which may disintegrate. How about the concrete? Yes, or no?

No.

We are living in stone age. If concrete is going to disintegrate then why you are designing it? Of course, the idea is that you are designing a system which is durable which is not going to disintegrate. So, volume is remains is going to remain constant, all right. So, this is how you define the durability. So, in my opinion concrete is more durable than rock and that is why mankind has invented concrete and they are not depending upon rock much. Drainage: all right, drainage should be less or more for making a system durable?

Less.

Less there could be rocks which are highly?

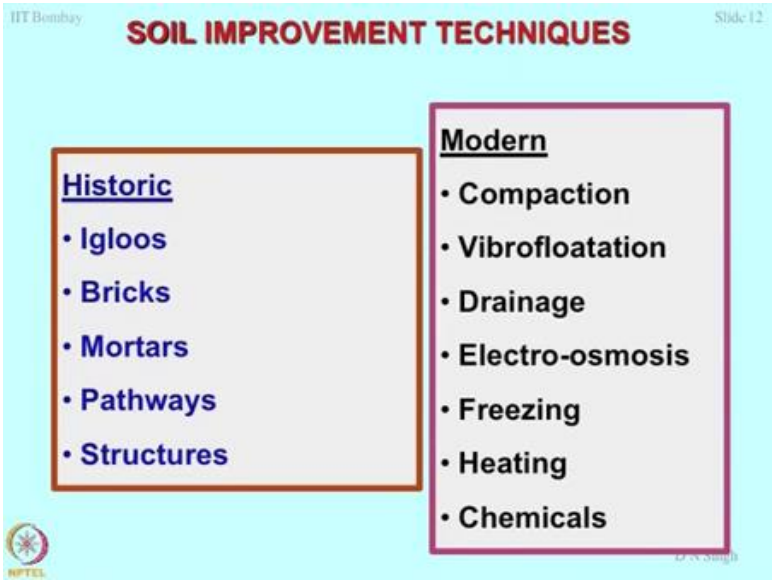
Fissured.

Fissured, fractured, disintegrated and hence the hydraulic conductivity or drainage would be maximum. So, a durable system should not allow transport of any flux through it, agreed? That means water should also not flow through this. So, drainage should be as less as possible if you are designing a durable system. Erosion: how much so soils are formed? Erosion of rocks, ok. So, these are the attributes of you know durability. Unfortunately, only structures guys they talk about durability of concrete.

We do not talk about stability of soils and we do not talk about durability of soils also, but those who are involved with soil improvement work, they should have these four parameters in their mind. What is the meaning of this? The whole idea of improving the soil is, it should be more strengthful, the volume should remain constant clear the drainage should be less and erosion should be extremely less. So, these are the aims of or the objectives of adopting any soil improvement program.

So, we are trying to convert soil in a sort of a very durable structure or a system which is less susceptible to environmental changes or effects.

(Refer Slide Time: 07:57)



I am sure you are aware of the techniques which are normally adopt for soil improvement ok, historically people designed igloos what are igloos?

Ice.

Ice, clear? So, in south pole, north pole people will definitely make igloos. Bricks is the simplest possible example of soil improvement. You take the soil mass shape it up break it, add some chemicals break it. So, what has happened the soil has become more stabilized, volume remains constant, drainage has reduced, more strength clear and less erosion. So, all those four parameters are in built in this system; mortars when you make mortars pathways different type of structures. So, these are all historic treatment or schemes which people have followed. What is happening in the present day world? You compact the soil, to attain all those four parameters more strength less drainage less change in volume and what was the last one less erosion vibro flotation then drainage schemes, flooding with water all right.

Electro osmosis apply some current and what happens water simply goes out of the system drainage gets enhanced, water goes out the resulting mass is of control volume and gives you more strength. Ground freezing have you heard of this type of technique ground modification freezing,

Yes, sir

where do we use it?

(Refer Time: 09:53).

Mostly in tunneling operations they go for freezing; that to in cold climates you know where you have fractured rock mass and there is no way to do tunneling because of too much of drainage from the rocks. So, that is where you can go for some local anesthesia sort of a thing. You can inject some anesthesia and what it does? It makes your hand or that part of the body numb and then you can adopt surgery; the same thing you can do in structures. So, you inject Freon gas or circulating brain solution and what it does? It lowers down the temperature freezes the soil mass. So, all the water which is remaining in the pores gets frozen, clear?

So, suppose if you are working in a c5 soil or a sandy soil which is saturated and if I freeze that soil what will happen? The properties get transformed from friction to cohesion. Is this okay or not? If frozen system will act like a cohesive material rather than a friction material is this concept clear or not? So, we have transformed the properties from friction material to a pure cohesive material which is nothing, but ice. So, this type of transformation lot of people have tried, heating. Earlier days or sometimes in military operation they can create air strips just by heating the top two feet or three feet of the ground mass. So, what happens? It becomes desiccated.

Nature also does the same thing for you. In coastal regions the water table fluctuates, soil mass becomes wet and then again during the dry period what happens to this water? It evaporates. When this water evaporates ultimately what you notice is desiccation cracks on the soil mass. So, this heating is nothing, but it is a natural heating or a synthetic heating also can be created to remove water from the soils and to make it very strong. So, temporary air strips can be created out of simple heating of the layers of soils and of course, you can add chemicals which we have discussed earlier as well.

Terracotta is nothing, but an example of heating of the soil terracotta. So, you take clay and break it at elevated temperature. So, ultimately what happens? What type of transformation is this? It is a permanent transformation of minerals or temporary? If temperatures are very high, I can amalgamate the minerals. So, whenever the amalgamation comes in picture, this becomes very igneous type of material. So, the nature has created temperatures of few 100°C which you can create very easily in the laboratory clear?

So, you can convert this clay mass into a sort of a magma and then let it freeze, the same thing you do for creating tiles refractory systems and so, on which will be anti heat anti chemicals and whatever anti magnetic anti electricity and all. So, ultimately it boils down to too much of materials modeling. You must be observing this you are altering the state of the material it is a physical effect, vibro floatation is also a physical effect, drainage is also a physical effect what is electro osmosis?

It is a electro physical effect. So, water contained in the pore is being taken out by applying some electrical current. Now this type of analysis or studies when people are doing they have to talk about electrical properties of the soil that how easily the current can be passed through the soil systems and all earlier geo-physicists use to do this type of studies. But now a day's lot of geotechnical engineers are also adopting this.

(Refer Slide Time: 14:12)

One of the industrial wastes which everybody is talking about these days is fly ash. So, I do not use the word waste, I say that this is a manmade resource it's a manmade soil. So, truly speaking the way we have soil mechanics a day should come where you should talk about fly ash mechanics. It's a natural resource which is manmade and the more and more industrial activity which a country takes you are producing more and more ash. However, the challenges are how to transport this material from one location to another location and so, on why transportation is so, difficult?

It's very light.

So, that means, handling and storage also a big problem. So, because of the physical attributes the material is very light lighter than air it flies off causes lot of environmental problems and then the question is how to utilize this material. So, days have gone when people used to talk about fly ash utilization only for making bricks, now a days the focus is not on making bricks only that was about 20 years back when I was a student, 15 years back what should be the focus in today's scenario where people should like to use fly ash.

Student: Bricks (Refer Time: 15:36).

That is right.

(Refer Time: 15:40).

I will show you some of the recent developments by using fly ash and what researches have tried to work on?

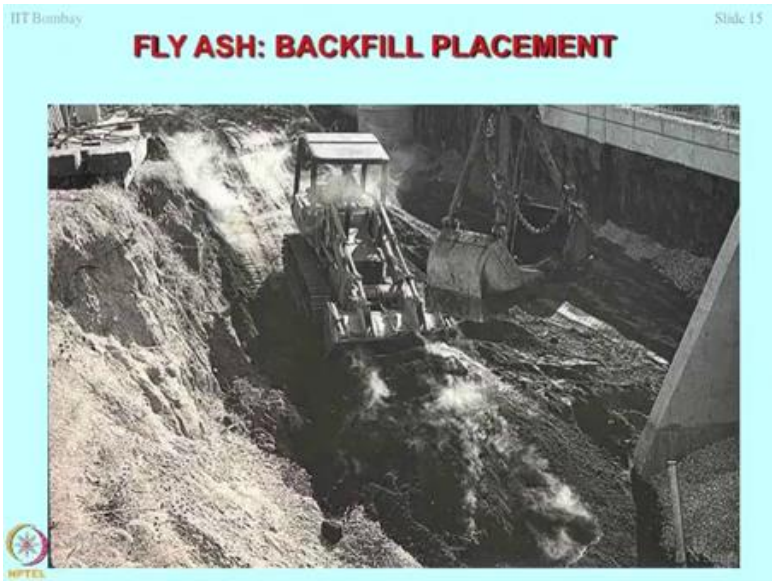
(Refer Slide Time: 15:47)

This is the way you can transport the ash do you find any difference between the two modes of transportation? Why it is being done open and closed; what is the intention why you should adopt this type of disposal system or transportation system, why you should adopt this type of a transportation system? If you want to protect the pozzolanicity of the material, you do not want to allow this material to interact with water rains you have to cut it off from the environment so, that the calcium which is present in the system should not interact with water.

So, this type of a unit is in high demand by which type of industries? Those who are producing cement clear. So, these are clear cut demarcation the type of ash which you produce, how would you transport it and where its utility would be. However, when you talk about the second situation where you are going to use this type of ash. See if the direction of movement of the train is this, you reverse the direction in which direction what commodity will be coming like this. The coal is coming from the mines in this direction to an industrial unit and if train is moving away from it, this fly ash is going for filling purpose of the mines.

So, this is a very good deal with a most of the coal manufacturers, Government of India has done. We will buy the coal from a manufacture only when he is ready to use the fly ash for filling purpose clear; otherwise what is going to happen? This type of material keeps on a stacking near the power plants. So, ideally when you go for open disposal system or transportation system this material is not good for pozzolanic activity this will work as a good fill material filling of mines filling of ditches and so, on.

(Refer Slide Time: 17:57)

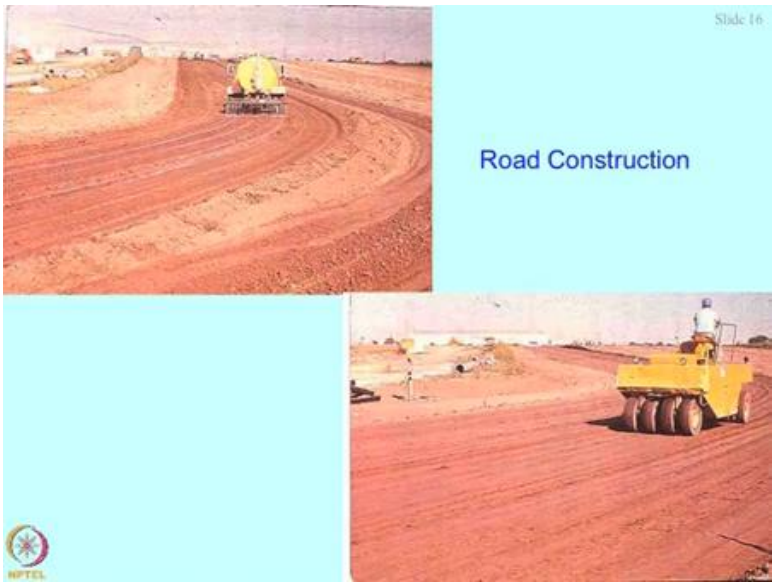


This is for making the embankments as a backfill material, you can compact it along with the soil and what is the beauty of fly ash? Why it should be classified as a good backfill material? That's right so its specific gravity is very less; that means, the earth pressures with this system will induce on the walls are going to be quite less.

(Refer Time: 18:24).

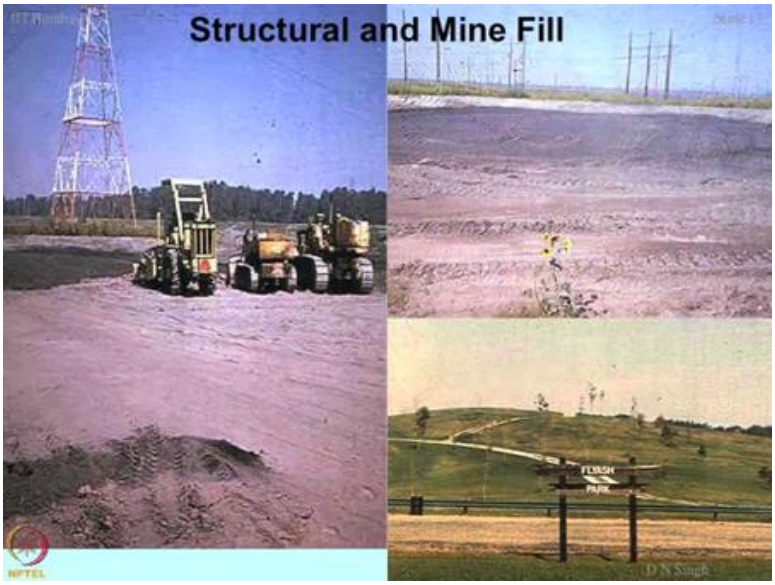
Unfortunately, fly ash cannot be compacted. It's very difficult to compact the grains of the fly ash you have to go into the microscopy and you will see that these grains are perfect spheres most of the time. So, achieving a density out of it is very difficult, I will show you some of the micrographs, but as a thumb rule compacting fly ash is very tough ok.

(Refer Slide Time: 19:01)



These are the examples from road construction, I am sure you must have heard of road construction using fly ash either by direct disposal on the ground compacting it putting some water and doing some pneumatic rolling all right these are all old techniques.

(Refer Slide Time: 19:23)



You can use this material for structural and mine fills. So, these are the open cast mines which are being filled with the help of the fly ash.

This is a open cast mine, where you are filling the open cast mine with the fly ash. In Canada there is a fly ash park now following this what they have done the entire dump has been converted into a park for amusement the name itself is fly ash park following this we have something like this in Ahmedabad, where the landfills have been used for they have been converted in public recreation centers ok. So, you can use this land in terms of recreation of people.

(Refer Slide Time: 20:16)

In-Situ soil improvement for which you can use fly ash slurry, mix with cement and lime and then you can inject it in the ground this forms a good gel and ultimately you can improve the soil.

You are talking about contaminant migration also. So, you can control contaminant migration by injecting fly ash lime slurry and making piles into the system or the curtain walls or the grouts these are known as thin walled slurry curtain of for waste isolation. So, dig up a certain portion of the ground and then inject in that slurry of fly ash, lime and cement. So, ultimately what you are doing you are cutting off the contaminated ground from the environment?

I hope you understand what are the limitations of these methods. Quality control is definitely very poor; injecting this slurry would be very tough in the ground if soil is a clay, it will not percolate into so, easily if it happens to be a fractured rock mass controlling grout will be very difficult.

You keep on pumping the grout and you never know where the grout is going. So, these are the difficulties associated with in -situ ground modification on improvement.

(Refer Slide Time: 22:02)

So, this is what I wanted to show you how you can achieve some value added products from the fly ash, this work was done by my second PhD scholar Dr. Prabir Kolay. So, what we did is we converted this ash by giving some hydro-thermal treatment and we converted this into a material which is known as a zeolite. I was telling you the other day that this type of a system has a tendency to absorb more and more water. Now this is a very interesting process which keeps on going in nature also most of the rocks get zeolite zeolitized because of hydroxides which are present in the system like sodium hydroxide or potassium hydroxide. So, they leach out of the material. Okay

Hello. So, this system shows a mineralogical alteration, it is a good example of how mineralogical alterations can be simulated in the laboratory or whatever happens in the lab. So, if you remember sometimes during first or second lecture I was talking about physical alteration, chemical alteration and physico-chemical alteration and physico-chemical-

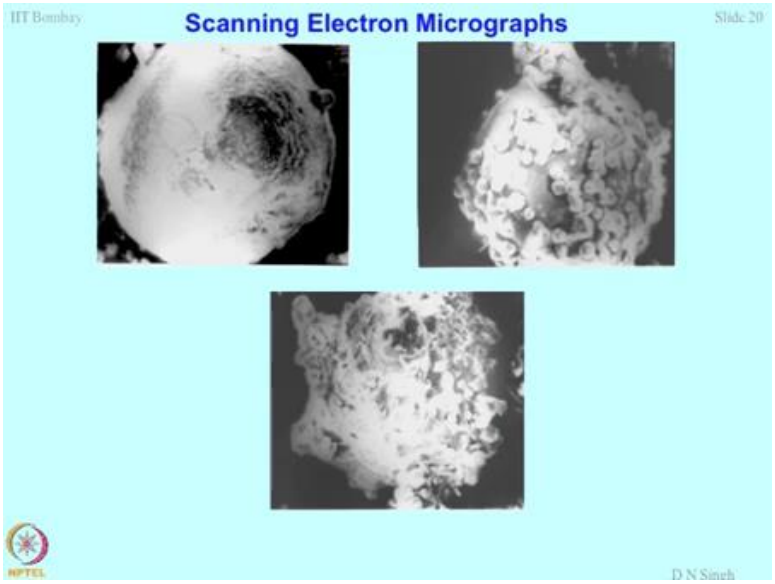
mineralogical alteration. So, this type of simulation we did in the laboratory and what we noticed is that, this system shows very high cation exchange capacity.

So, a material which was very high cation exchange capacity is chemically very active or mineralogically very active. So, most of the detergents they show you a very high CEC value the minerals which are used in that and a high surface area. So, the surface area of this system is much more than your original ash. Incidentally this also gives an idea to work on activated minerals, this is where one of my student Mr. Jha is working. So, formation of activated minerals and this is also known as Silica Reduction Technology (SRT). So, the best possible scenario would be if you can convert all the silica of the soil. So, what happens? If you talk about three phase system of silica alumina and iron. So, if you reduce silica, then iron and alumina will be maximum. So, this is the philosophy on which this type of studies have been taken up which is known as SRT. So, under certain typical conditions you know climatic condition nature does this.

So, when nature forms original ash into zeolite the silica which is passive is getting converted in to a mineral which is highly active. Another interesting application is extraction of tungsten or the minerals which are of high value where tungsten is used?

Lamp filament. That's right. So, these are the filament and right now India is importing tungsten you know if you develop a technology by which we can extract tungsten out of fly ash we will be self dependent requires lot of research.

(Refer Slide Time: 26:08)



Just to show you few micrographs of scanning electron micros graphs now this is the ash particle on which the minerals are being grown. It's like cabbage. So, you grow minerals slowly and slowly, this stage comes where the minerals or the protrusions on the surface become quite large.

This is what I have been showing you the other day, when you came to the lab different colors. So, what we are doing is we are altering this material into this state receding process. Now this system is a zeolite and a much more augmented form of zeolite is this. So, it depends upon the time of treatment which you have set in for a material, the type of chemicals which you are using and the type of environmental condition which you are using. A simple technology would be on which I think jha is working you take fly ash and boil it in pressure cooker.

Take a pressure cooker and just boil it, the way you cook your vegetables. So, what we notice is that this creates very good minerals and the same thing is happening in nature how diamond is formed?

It's a mineralogical alteration at very high temperature and pressure. So, same thing we are simulating in lab clear and the grates of zeolites which we get out of this activity have to be analyzed. So, we want to produce minerals or the zeolites which are highly active and which can be replaced by other commercially available zeolites which are very expensive.

So, this just to give you an idea about how physico-chemico-mineralogical alterations can be done in the laboratory. Now where these type of situation become important in our profession any loud thinking? If you are designing a foundation on let us say a rock mass. So, no theory takes care of these alterations which may go on in nature slowly and slowly in 20 years' time 50 years' time and so, on is it not? So, you just compute the bearing capacity based on Terzaghi's equation or whatever Dirac's equation, but nowhere in these equations they take into account the effect of environmental effects which are altering the material clear.

So, this component should get added that how much material deterioration is going to take place when a system is exposed to nature. A good example of this was when we were doing Bandra-worli sea link most of the samples and analysis we have done in our laboratory. We found that if you just go by the classical geo mechanics and the type of bearing capacity you will compute it will be highly misleading why? You are taking out samples which are from the sea and which have already gone in major mineralogical alteration in the form of zeolites.

So, you are just dealing with them as a SPT value which is not correct. Truly speaking they are zeolites which have already changed altered minerals and they will never show you the same bearing capacity after few years. So, this is where we point this concept of mineralogical alteration of the material and particularly how to map this information in your bearing capacity theory. This is one loud thinking which I am you know doing in front of you some of you should work in this direction whenever you get a time. I hope you will agree conceptually this is correct.