Geoenvironmental Engineering (Environmental Geotechnology):
Landfills, Slurry Ponds & Contaminated Sites
Prof. Manoj Datta
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture – 40
Geotechnical Reuse of Waste Materials - Part 1

Welcome to the class and good day to all of you. Today we will look at the geotechnical reuse of waste materials. In fact, this lecture as well as the next lecture 2 lectures will be on this topic. So, just if we recall where is all the waste coming from we pick up the raw materials from mother earth, we putting some energy do some processing and get some products. And after the products the useful part of the products have been used the end waste is the material which is not of use to anybody is waste.

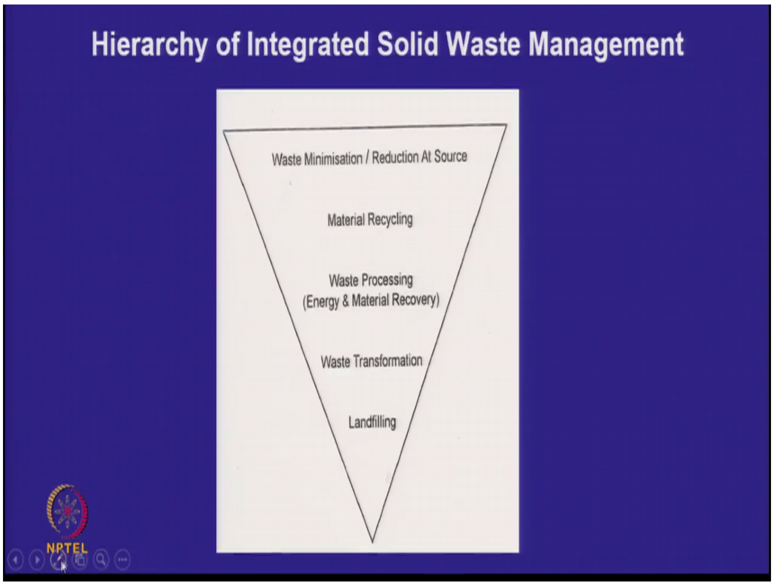
So, if I had a magical methodology that all the waste I could break it down into it is individual components which were mixed. Let me say that if I have an old car right, I have used it and used it and now it is not of use to anybody. I can take out certain parts and recycle them, but the painted door I (Refer Time: 01:37) have a problem why the paint is on the door and I cannot take off the paint. So, if I had a methodology where I could actually breakdown all my waste into it is original components of the raw material from which it was made.

Then I would have a wonderful solution, I would take any component take it to that processing plant and all the raw materials which were in the component would come back again and those raw materials would again go into the manufacturing process and therefore, I would have a very healthy sustainable society. So, as long as you cannot get back the original raw materials from the mixed products because they are So intimately mixed chemically thermally electrically what whatever have you therefore, I will end up with this waste.

Now if I have to use waste which is not of any use in any other process, which is the application in which there is maximum potential for consuming it. And if you look at again look at mother earth from a faraway distance from the top your trees are growing, your plants are growing, your animals are multiplying, your human beings are multiplying, but one of the non biotic elements which are growing as it is. So, I have these huge concrete buildings sky scrapers buildings. So, they are all raising above the ground and; obviously, since they are raising above the ground the raw materials have come from some place and they are making this raise. Similarly all the embankments on earth works are causing materials to be at a higher elevation then what they originally were.

So, consequently one of the potential area of the application is can I use all my waste materials in infrastructure development, because in infrastructure development I am using millions of tons of materials. So, how wonderful it would be that I am producing millions of tons of waste which could be used in infrastructure development of a millions of tons. Now it is quite clear that you can not use biodegradable material necessarily for making these buildings which are raising high up above the ground, but is there a component of the waste which is non biodegradable which can be used? So, one of the segments of reuse in infrastructure sector is in the building material segment cement concrete bricks and blocks, we are not touching that. The other k segment is using the waste in geotechnical applications. Earth works filling low lying areas making embankments whether lakes or roads back fill behind retraining structures all these flyovers that you see there got retaining walls can I use my waste as backfill material. So, there also we are using millions of tons of earth every year. So, that is what we will look at today how can we use waste materials in geotechnical applications.

(Refer Slide Time: 05:13)



So, let us just quickly recall the hierarchy of integrated solid waste material was minimize the waste recycle it process it transformat and then only you send little bit for ladndfilling. So, recycling is again sending back the material recovering the material to become a raw material for some other industry or for reuse in waste processing.

And waste transformation as I said If I could magically convert my waste in to raw materials from which the waste was produced I would be able to consume all the way, but really we are not able to do that we are able to do some secondary processes by which I can recover energy or material from waste or we may be able to transform the waste transforming a waste in to a brick is I have a powdery material which I could make a brick out that is a waste transformation process.

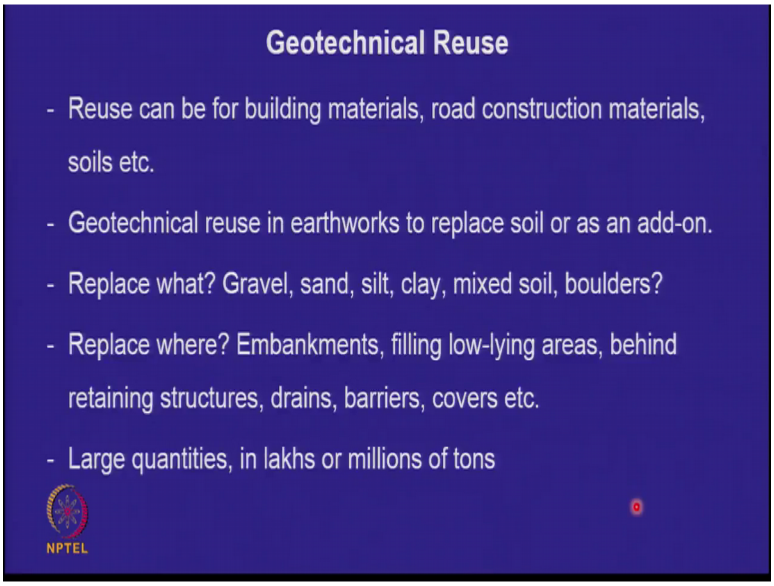
Again to the call high biodegradable fraction as in the case of minuscule solid base we need to do biological treatment to decomposition get composed out of it, high combustible fraction if your waste has got cloth and the plastics it has got wood it has got combustible material to thermal treatment take out energy burning it, if you have high inert content like a structural indument waste all the silt which are picking up from the drains all the sediments which you are picking up from the bottom of canals which may Sometimes be contaminated but anyways if you have high inert content you go towards the direction of physical treatment.

(Refer Slide Time: 06:42)

That means, we will use it either by fractionating them or you will be putting them in some inert metrics.

So, separately stored wastes can be used for material and energy recovery, but if you mix everything all this are very intimately mixed then to break it up in to it is individual fraction is very expensive when currently it does not work.

(Refer Slide Time: 07:05).



So, when can we and how can we reuse the material for geotechnical applications? As I said in the infrastructure and in the construction sector reuse the reuse can be for building materials, it can be on roads because several kilometers of roads are been constructed. Or it can be that you are using some other material as a soil. When you construct a road there is of course, the pavement section at the top, but do remember that beneath the road there may be a long embankment which may be a few meters high and run for several kilometers. So, there is a huge potential if waste can be used as a soil.

So, geotechnical use is geotechnical reuse is the use of waste material earthworks to replace soil becomes the original material raw material which you are using for making embankments. So, if you can reduce the amount of soil because you have to dig up soil from somewhere from borrower are and bring it to your point of application you either making a hole in the ground or your you know taking a small rise in the ground and excavating it. So, you would like to replace the soil or you can use waste as an extra layer. So, what do we want to replace? When you deal with soil you deal with gravels and silt clay mixed oil and boulders.

So, in boulders and gravel sometimes we may use reprap can we replace it. Sand is used as drainage materials it can be used as sand drain chimney drain blanket drains can be replaced at waste. Silt and clay are like normal top soil or earth or on which plants in (Refer Time: 08:44) row. So, can we use waste for this purpose. So, this is what we would like to replace with waste. By where would you like to replace it what elements I said embankments on roads embankments on lakes embankments on resoviors. Filling low line areas many areas are flood prone you may be buying plots for your house and you might find it is lying at a level below the road level and you are worried that the rain comes all the water from the road will come in to your plots. So, you will raise the level of ground above the road level to make your house. So, filling low line areas you might want to fill earth fill behind retaining structures we might want to replace drains we might want to replace play barriers covers etc. If you can get geotechnical reuse then the advantage is that it is used in large quantities, you may in one project millions of tons the waste.

(Refer Slide Time: 09:49)

So, when I consider a material for replacement of soil what is it that I should be hundred percent sure about. I am tempted, but I should be sure that it is not classified, as a hazardous material as it is do not touch it. I should be sure that it does not have significant biodegradable content you see all design life of any civil engineering structures fifty to hundred years. So, if I have high biodegradable content the material will go volume reduction with time because your organic pattern will eventually biodegradable matter will eventually decomposed. So, typically for all for soils a 3 percent is what we have been traditionally dealing with less than 3 percent organic material is fine this can be extended to 5 percent.

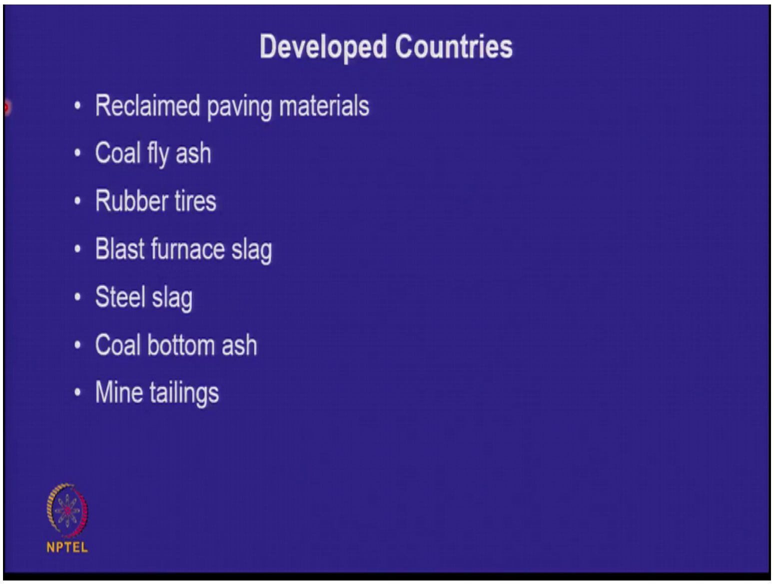
But if you have got 10, 15 percent of biodegradable material we will prepare that it will settle with time and it is not due to consolidation it will be secondary or creep kind of behavior. I should be clear that the particles will remain physically and chemically stable in the long run. And basically you should have silica matrix. So, can you have a calcium carbonate lime matrix lime stone matrix well, lime stone has solubility in acidified medium caco 3 plus 2 hcl will use cacl 2 plus co 2 where as sio 2 plus hcl does not do that.

So, there is an issue if you have lime stone if it is in a protected environment it will work, but on a long term basis where they are going to be spills of acids or they may be acidified environment you may have issue. So, even in natural limestone formation geologically you find some seepage channels or channels which are dissolved over a geological time frame over a particle should remain physically and chemically stable. Should not contain deleterious material it may not be classified as a hazardous as I said suppose your waste has got common salt in it there is no standard that soil should have less that 1 percent nacl or 2 percent it may not get classified under the TCLP procedure it may not have any problem, but if any sulphate or any chlorides or any total dissolved salt are coming out of the material that is not very good because it can harm other things.

So, should not contain deleterious material. Particle size should be such that standard earth moving equipment can be used I do not want a waste which is you know having on meter by one meter by one meter blocks by neither my doses nor my compartal will work on it then I have to first crush it bring it in to a soil size range will our earth will equipment will move. Typically earth moving equipment works well with gravels sand silt and clay. So, we need that particle size range. And it should not harm ground water quality whatever other constituent you must be hundred percent sure that the result of putting soil on ground it should not harm the it should not harm the quality.

And it should be fairly homogeneous you design an embankment the wastes coming in today it is coming in is the in the silt to clay range tomorrow it is coming in the silt to sand range; that means, as you are building the embankment your soil is changing. You do want fair homogeneity; that means, lack to heterogeneity in your material it may gradually change, but if you are digging up from some place and suddenly you are finding you know material is changing drastically and in the same length of the embankment and one place it is a fine grained soil and other place is a (Refer Time: 13:21) soil it can just you can design for it, but then you have to have you know your embankment section changes this you are making a lake embankment a fine grained soil was fine suddenly you find a lot of (Refer Time: 13:30) content cheep in the start to be excessive through that part. So, then you have you make that design measures. So, it should be failure homogeneous and have low variability. If you can do all this you got good material.

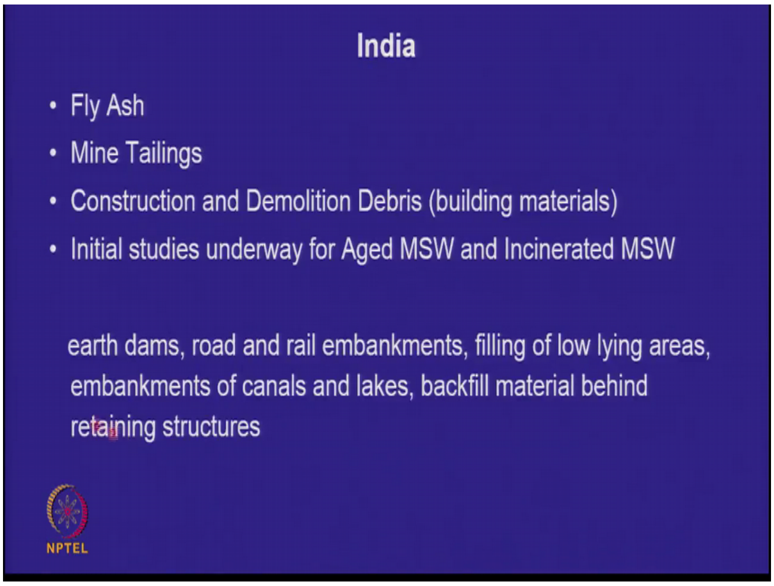
(Refer Slide Time: 13:45)



So, let us see what is what are the materials which are traditionally used. If you go to the developed countries what is being used reclaiming paving materials in the developed world typically you do not put over lace on your equipments you dig up your pavement in India you put overlays the road has gone bad what will happen next day somebody will put another layer of pavement material in the developed world you dig up remix more bitumal and ash fault and relay the road. So, reclaimed paving materials if there are rejections that that can be used as soil. Coal ash fly ash and pond ash is used rubber tires are used rubber tires are difficult to dispose. Blast furnace slag is a term what is the word what is the word slag mean to you chemistry or tenth class twelfth class what is slag slag is an impurity. So, you are wanting to take out steal you want to take out iron.

So, you will have iron ore, ore will have how much iron 99 percent iron and one percent no it is the other way around. So, over we took all reach over may not have more than a few percentage of the main material. So, you will crush it and grind it and you will get tailings, but beyond that you will want to further refine the material then you will go into a chemical process or froth flotation process you know gravimetric process air separation. Whatever eventually you will get something called impurities those impurities are slag. And what will the impurities mainly comprise of the original rock; however, in the processing you may added a lot of things. So, beware all slags may not be good material, but if a slag does not have a hazardous component you can use it if a slag does not have hazardous component you can use it. So, you can have blast furnace slag steel slag all kinds of slags coal bottom ash can be used separately mine tailings can be used.

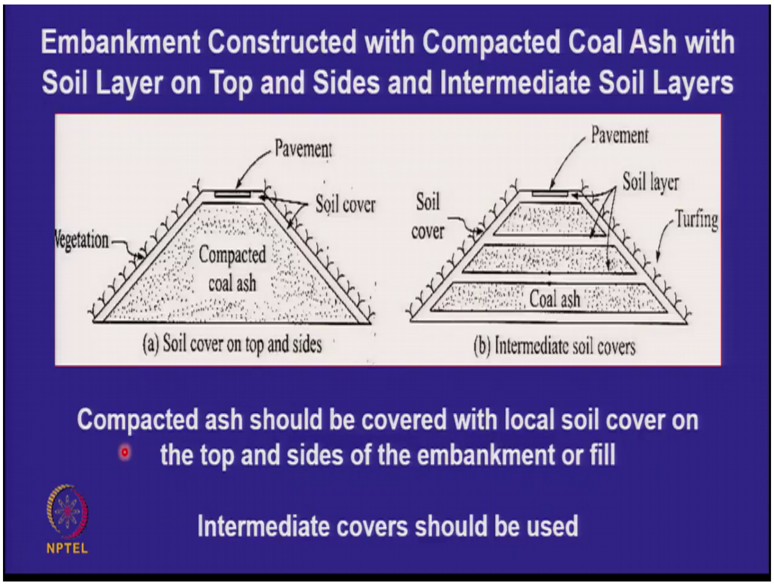
(Refer Slide Time: 15:59)



So, this is what is being used in developed world in India, what are we using? You are we are using fly ash when I use the terms fly ash here it basically means pond ash, because fly ash is not available individually that much and whatever an individual fly ash is available it is going to the cement plants, because of it is possononic activity.

So, what is available to us is ash which is lying in the ponds which the cement plants do not want, because the fines have actually got washed away. So, we can use pond ash we can use mine tailings if they are not classified as hazardous important. We can use construction and demolition debris. But we have to process it we have to crush it and bring to workable size and initial studies are underway can be used old municipal solid wastes or incinerated municipal solid waste for geotechnical reuse. And we are talking of earth dams road and rail embankments filling of low lying areas embankments of canals and lakes back fill materials behind retaining structures.

(Refer Slide Time: 16:59)



So, we have all done properties of ash and properties of mine tailings do you recall them we did these 2 materials these are slurry deposited materials right. Was there anything which was bother some for you when we did ash we talked about pond ash we talked about fly ash we talked about bottom ash. And basically (Refer Time: 17:18) silica matrix they were they had no biodegradable components. There was some issues of he environmental concerns mostly relating to erosion erode ability, but some thoughts about heavy metals and other issues; however, if your ash does not have leachable heavy metals.

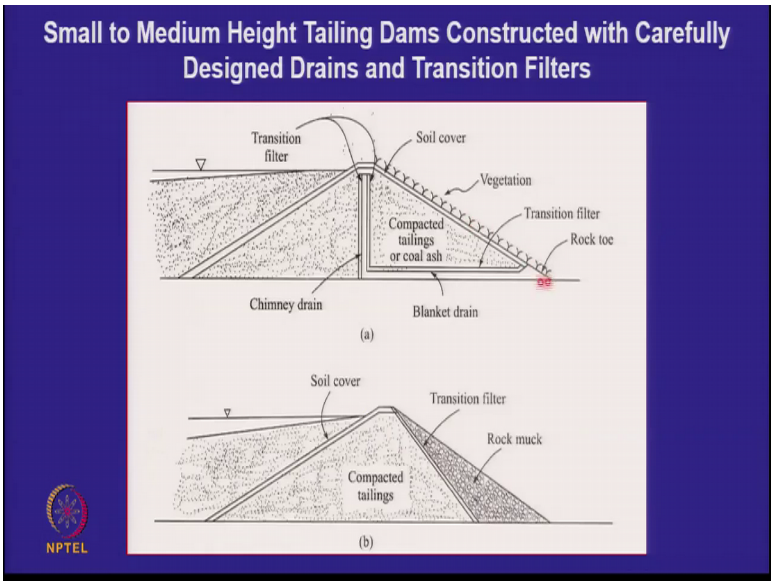
It is basically a material which is in the silt and the sand size range you can definitely use it for the purpose of earth works; however, it should not remain exposed. So, any design is designed like a normal soil we will determine the properties of pond ash fine seed ash (Refer Time: 17:55) ash cc permeability do the stability analysis and make the embankment. So, here it just showing road embankment there is no drain in it, because this not designed like a water retaining structure.

So, the entire soil can be replaced by compacted pond ash. An important design aspect is to cover the ash in an envelop of soil and vegetation to prevent any dust or rain water erosion. So, if you have pond ash available nearby say easy to transport distance local soil will be much more expensive than ash will be available to you free, why? Because the thermal power plant will want to create capacity in it is pond to put more ash. So, they will offer it to you free you may even sometimes negotiate can you do the half the transportation cost or can you deliver it to me. And that is for the thermal power station to see if the thermal power stations ponds are full. What will they do? They will say ok we will how far your site you will say in 12 kilometers ok. We will deliver it to your site because they want the capacity very urgently; however, if they have a capacity for the next 20 years they may not want to give you ash transportation cost free, but they will say send your trucks you can take it.

So, I can use it, but I am showing an alternate design here also, see while the embankment is being constructed it is constructed in layers. And I cannot construct from bottom to top in one day right. So, what happens when you have layers you will finish construction let us say here, for the end of the shift or 2 shifts or whatever. Then you will come in the next day ow in the dry months this will start to fly over the night or you know it is dry. And if you are close to populated area people are going to object. So, a good design is to put intermediate soil covers right, even if the soil flies it is not fly ash.

So, the local population is used to the local soil flying around. They are not use to a grey fine ash flying around. So, intermediate covers are a good idea, but they are rarely used, because getting local soil is more expensive once you are get where once you get use to the fact that your borrow area material is free then you tell somebody no now you have design please put local soil and if you are a private contractor you will say this cost be much more. So, I would like to minimize this. So, they extend possible people will tell you I can use sprinkling to do environmental control of ash, but believe me I have not seen a sprinkling system in my past 20 years of working in geoenvironmental engineering looking which is a sprinkler system which works all the time and does not allow ash to fly and I am not seen one the sprinkling system is put on whenever the visitor comes to the site or may be an are for you comes. And are after it goes away it is also used if it is very dusty for some peak critical times when you are working on it, but is not used 24 into 7, it is not a luxury which costs which is built into projects.

(Refer Slide Time: 21:07)



Not only can we built road embankments, We can also build small dams and water retaining and embankments for retaining tailings and coal ash. So, we have extensively designed in this country if I am off will be 50 of such structures which has reason either by the upstream incremental method or the downstream incremental to 50 meters and above and they performed very well.

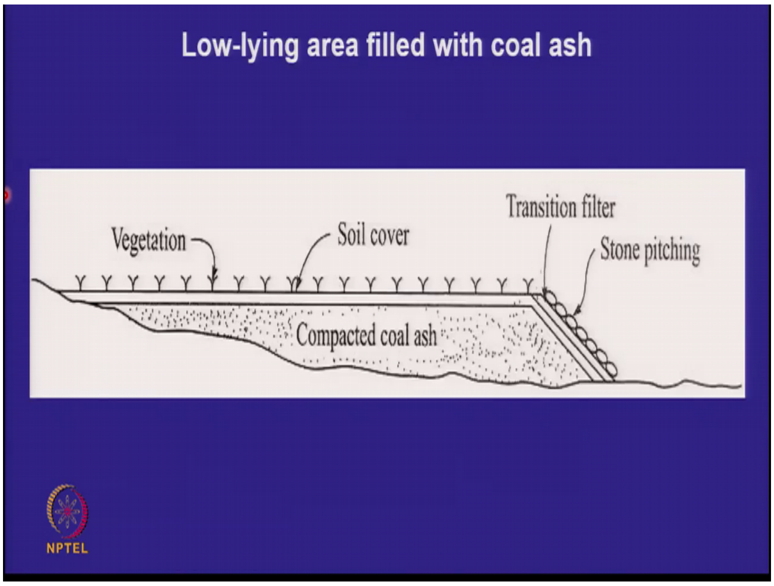
So, you can use again in the middle of the embankment either compacted tailings or coal ash, but very important are these drains, if you do not make proper drains it is not going to work and most important is if you do not make the transition filters between the drain and the ash or the mine tailings. So, transition filter design as per the criteria is extremely important having a rock toe is extremely important and having a soil cover to in case and vegetation on it putting the soil cover by itself is not sufficient. Because eventually when the soil cover erodes. So, if you have use the thin soil cover and you have a few rain cuts or rain water gullies which are formed then the ash gets exposed again. So, the important thing is to have vegetation on it and maintaining vegetation in aired climate is difficult maintaining vegetation in humid climate is fine. So, you have to get local vegetation. So, then the thickness of the cover is the item of debate one would like the cover to be as thin as possible how thin should be your cover?

Let me say I am putting the cover at the top of ash what is the thinnest cover that I can lay am putting the cover of local soil how thin? Some idea how thin can I lay one millimeter? No what about 10 millimeters 10 millimeter is one centimeter how you will going to lay one centimeter? Whose going to measure it? Whose going to make the payment? Because first you have to clay you know after all you are going to get a earth you are going to multiply it with that thickness and pay the contractor will say sir I have layded, but you are you have an undulating surface which may or may not be, so precisely paved. So, typically minimum thickness are in the order of tens of centimeters typical 6 inch I mean typically 6 inch thick is the minimum thickness which you can lay with the earth moving equipment and 8 to 9 inches are the norm. And one foot is good very good and from the point of view of root zone penetration also one foot is a good thumb rule, but if you want to put shrubs whose roots are going to be deeper then you will have to put thicker covers.

So, this playoffs between the thickness of the cover as a as erosion control measure verses the additional cost of the local soil is something you have a have a tradeoff I am showing here in a very interesting example which we did for a hindustan zinc limited you know they were taking out ore. But before the reach the tailings they had to dig up the soil and the rock and then reach the tailing ore in doing. So, they were producing something called rock muck. Now rock muck was nothing but rock fill blasted material or drilled blasted material, it would have a range from cobble sized down to sand sized. And instead of having drain, instead of having soil cover because you know once you have this was in Rajastan site Rajastan dry most of the time maintaining vegetation is a big challenge. So, we said we will design this like an earth come rock fill dam. So, this is a clay core type of situation compacted tailings, there would be transition filters in between and then this will be rock muck. This was available to us free because I we could take it from the deposited material this was available to us free because they were just stock piling it after excavating it.

So, this design has been wonderful and it has worked very well. So, small to medium height dams or dams of ash can be constructed with carefully designed drains transition filters rock toes and covers. For a iocl project they had several hundred acres of land, but the land had to be raised by 3 meters.

(Refer Slide Time: 25:22)



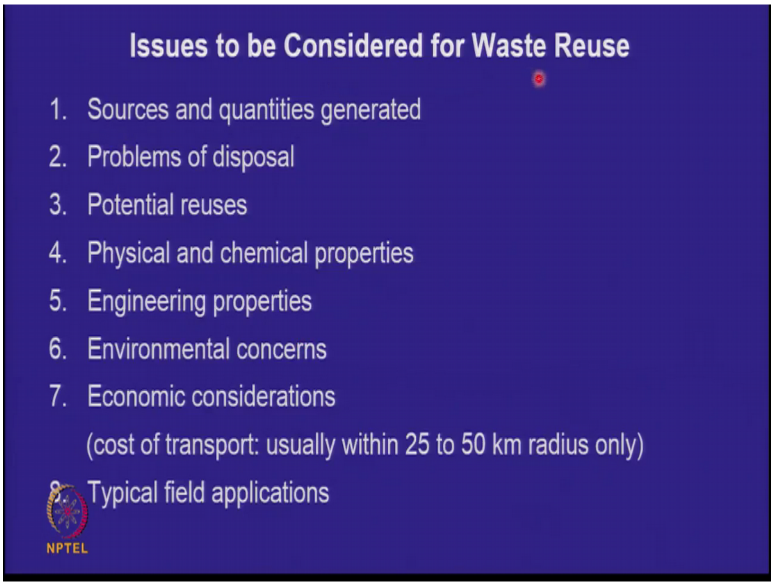
So, just take several hundred acres of land multiplied by 3 meters and see how much earth work in involved. And just multiply the earth work by cost like 500 rupees per cubic meter and you will see how many crores of rupees were are involved in raising the height of that plot. So, they came to us suppose an ash pond nearby and we did extensive testing before we allowed this to be adopted, and we looked at heavy medals we looked at every possible contaminant which would come and we have used ash for raising low lying area there are no issues of settlement the engineering behaviors fine permeabilities are fine the only issue erodability when you dig it up to put a telephone cable or you put dig it up to put a electricity cable if you dig into ash you have to be very very careful.

Even more if you have utilities water pipe lines seevage pipe lines passing through this you have to be careful, but otherwise this material is fine. Why do you have to be careful?

If a water pipe line leaks even in soil some soil will come in through the cracks, but if it is in ash more will come because erodability of ash is high right. And similarly in the flyovers now at a lot of places coal ash is being used as a back fill material for the purpose of design of for the purpose of retaining structures. Of course, a big change is occurring which is slightly tricky earlier all pond ash is used to be a mixture of bottom ash and fly ash. Now what is happening? Bottom ash being consumed by the industry as a replacement for sand.

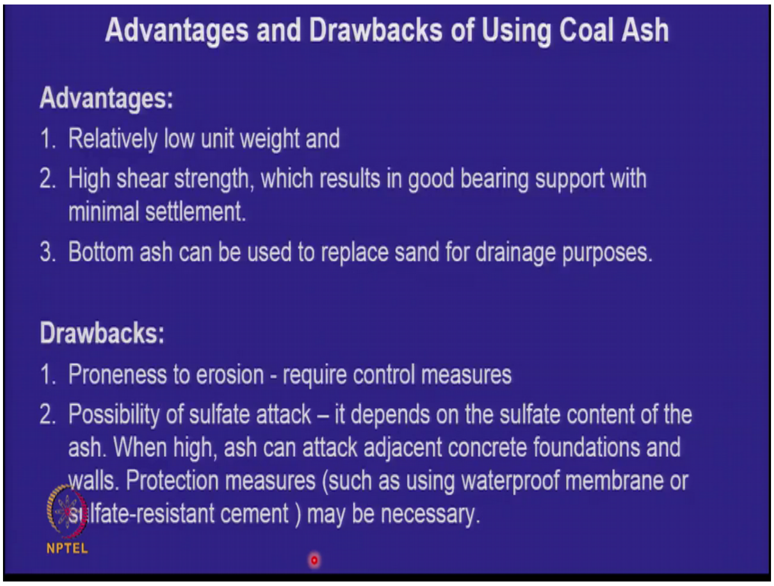
So, more and more pond ash is becoming fly ash when it becomes fly ash the it actually does not need the requirements of back fill for reinforce earth walls. If you look at the European standards and other standards it does not need those requirements. It is becoming finer than that. Indian roads congress has allowed use of pond ash without realizing the shuttle change which is occur occurring. So, one of a phd student is working on this that if the bottom ash is removed from pond ash, over a period of time how is it going to affect the behavior of reinforced earth walls. Because mostly back fill for reinforced earth has to be granular it has to have a significantly high flied ash and it has to be free trading. So, as the coarse component goes out it behaves more and more like silt and that is a grey area about how it functions in terms of the pull out capacities of the reinforcing elements which are put in the ash; however, this is been used in several places. Already I have told you about this issues, when you are going to consider waste re use you are going to look at the sources and quantities being generated in a city.

(Refer Slide Time: 28:14)



You are going to look at what are the problems for disposal as the capacity is become full the desire of the waste generated to give it out comes more as long they have capacity the person says the next person will take care of it when the capacity is full. We look at what are the potential reuses in geo technical activities we have to go through intensive physical and chemical testing you have to look at the engineering properties you have to address the environmental concerns of putting that material on soil the we have to look at economic considerations typically up to fifty kilometers away now you can bring in all these waste materials if they have been given to you free of cost. And the material will be cheaper than the local soil and then you have to see which applications they are useful for.

(Refer Slide Time: 29:05).



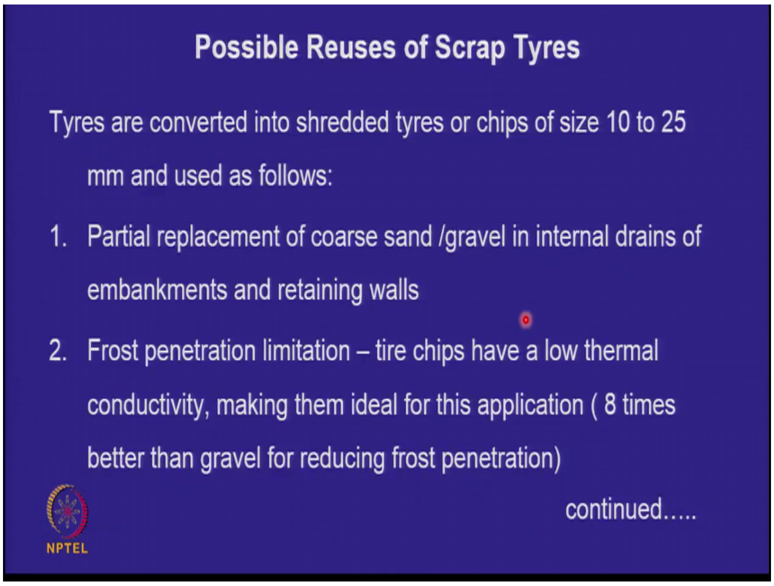
So, let us say let us look at coal ash. The advantage of coal ash it has relative low unit weight it has high shear strength like granular material, which results in good bearing capacity as well as other minimal support minimal settlements. And other performance reasonable slope stability good behavior of reinforce earth wall n such materials. And bottom ash can be used to replace sand for drainage purposes with all these interventions of the coats on mining from river beds and crushing of rock availability of sand for drin is for drains for drainage purposes very very low. So, lot of pressures to use bottom ash to replace sands.

Drawbacks I have already said one is the proneness to erosion to requires the erosion control measures. And sometimes ash will contain sulphates which your coal has sulphur. If your coal have sulphur which is not unusual then the sulphur gets converted to SO3 SO4. So, you will have sulphates now you know that if you put concrete elements in soil with high sulphates the sulphates attack the concrete and the csi gel and the products of reaction disrupt the cementation. So, if the sulphate content is high then you have to take protection measurements measures such as using water proofing membrane or sulphate resistant cement.

(Refer Slide Time: 30:43)

Those are required for the purpose of for design purposes. Critical to ash and mine tailings performing well over the long term is properly designed transition filters. None of the material should the fine should not get washed out to start piping. And another important point is that If you are burying pipe lines in ash or tailings you may like to put soil blankets around then that even if there is a little bit of crack or a fracture then the material coming into the pipe line is soil, and you do not want ash to run into the pipe lines.

(Refer Slide Time: 31:20)

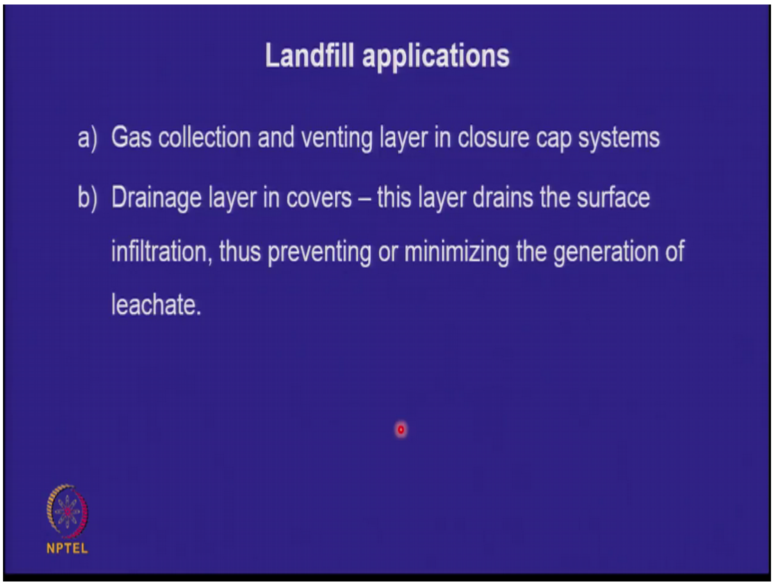


Let us also look at something which is happening as far as tyres are concerned. Tyres as we know we can re trade them we can reuse them and we can reuse them eventually you cannot reuse them. So, what happens is in america this tyres started getting coming to the landfills and if a tyre catches fire then it starts to give out this thick fumes and all ind of gases which are injurious to health. So, one of the ways to tackle this problem was to break up these tyres into small, small a particles right. And these particles typically one centimeter cubes. And we have some (Refer Time: 32:02) and tyre chip making devices very economical. So, all the tyres can be converted to small chips in the gravel size range.

So, now you have a rubbery gravel a gravel which is spongy right. Because the rubber itself is not a solid stiff matrix like silica particles, but it is a spongy or got some movements which takes place, does not matter. Where it is done have a load bearing load then you can use this material, when radial tyres started to come around or reinforced tyres started to come along hen there were wires in the tyre. So, the process of making chips became a little more expensive because first you have to remove the wires. So, none other chips come with wires. So, wires have to be taken out during the shredding cooperation and you get these chips which are typically one to 2 centimeters in size. So, they can be used in replacement of coarse sand gravel for internal drains. Definitely they can be used they have more settlements, but the thickness of the drain are sufficient for them to continue to perform alright. In cold countries one of the problems is that when you have snow then the tendency is for the freezing to be above the ground also and bellow the ground. When there is freezing below the ground what happens if there is water it will turn into ice and as a consequence it will expand. If water will expand during cold months the building will heave. So, you want a protection called the frost penetration protection, and that a can be done by putting a layer of tire chips.

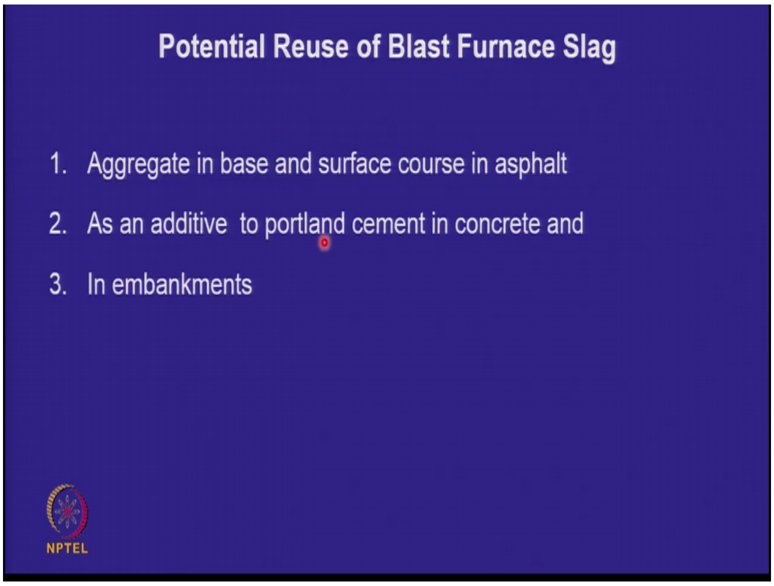
Because they have low thermal conductivity and they reduce the frost penetration; that means, frost will start from the top and start to solidify downwards fine your footing let us say that one meter depth. If you have done a good design you will find the frost penetration depth and keep your footing bellow it. So, may be your frost penetration depth is 1.5 meters and you have kept your footing at 1.75 meters. Now if instead of a soil I can put a layer of tire chips the frost penetration depth gets reduced, because this is a thermally better material in terms of preventing frost penetration.

(Refer Slide Time: 34:37)



So, they are used in the developed countries for reducing frost penetration. They are also used in gas collection layers in land fills. And they have also used in drainage layers of covers just beneath the top soil, you can use these for the purpose of you can not use them in the leachate collection layer, because the rubber may react with one of one or 2 of the constituents of the leachate which may cause a problem.

(Refer Slide Time: 34:57)



Let us look at blast furnace slag, can I use slag for the purpose of earth works? So, it has been used as an aggregate in base and surface courses in asphalt payments. The slag is also been used as an additives to portland cement in concrete and slag is also been used in embankments. So, let us try an underline what is slag and this is the data which it picked up.

(Refer Slide Time: 35:26).

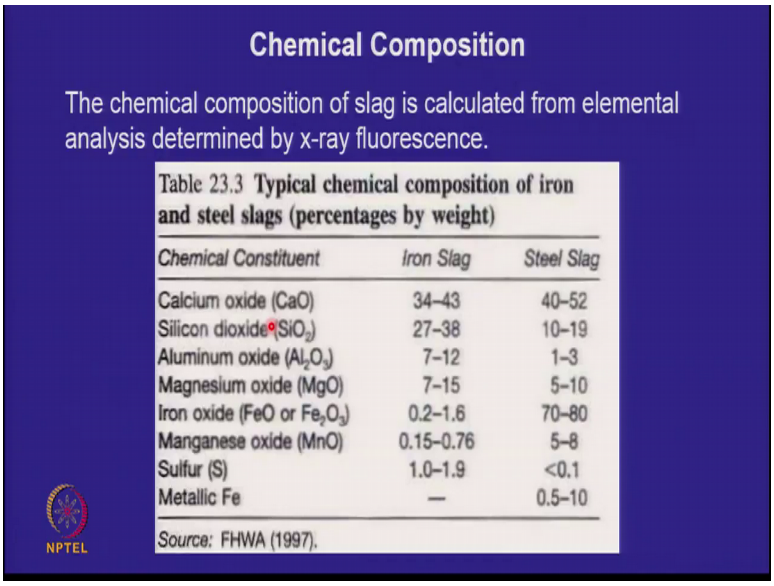


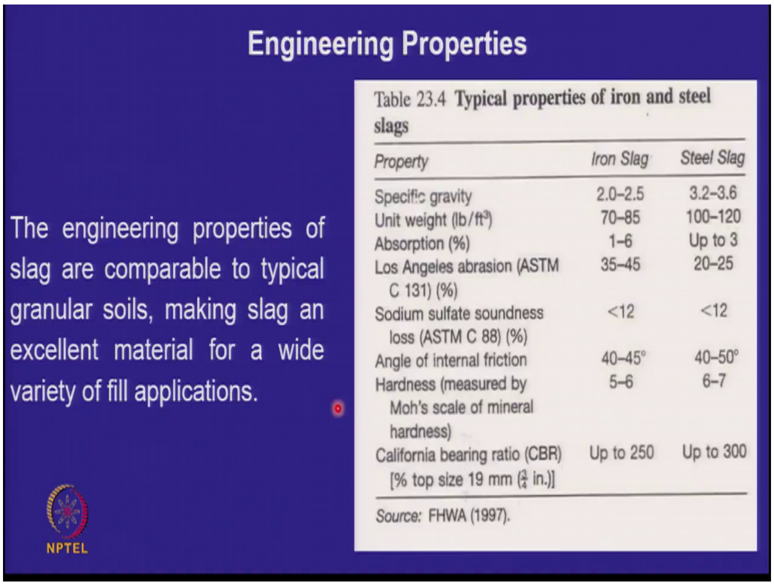
Table 23.3 **Typical chemical composition of iron and steel slags (percentages by weight)**

Chemical Constituent	*Iron Slag*	*Steel Slag*
Calcium oxide (CaO)	34–43	40–52
Silicon dioxide (SiO_2)	27–38	10–19
Aluminum oxide (Al_2O_3)	7–12	1–3
Magnesium oxide (MgO)	7–15	5–10
Iron oxide (FeO or Fe_2O_3)	0.2–1.6	70–80
Manganese oxide (MnO)	0.15–0.76	5–8
Sulfur (S)	1.0–1.9	<0.1
Metallic Fe	—	0.5–10

Source: FHWA (1997).

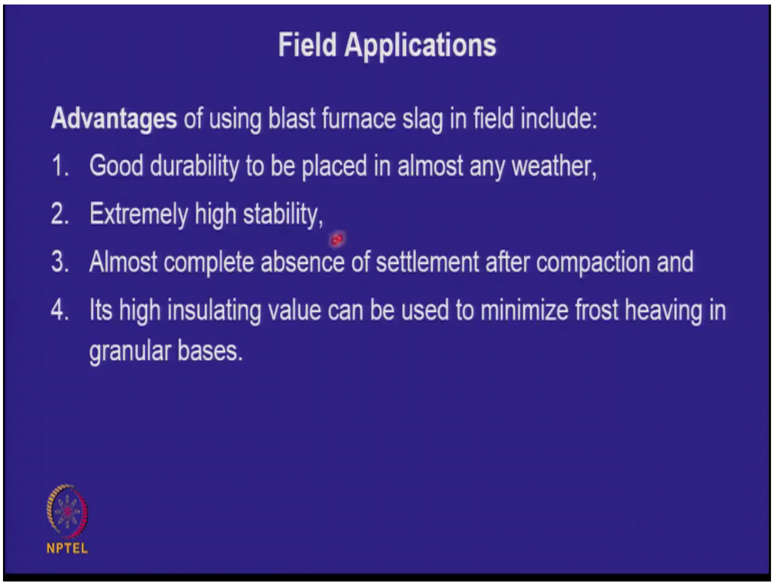
So, if you do chemical composition we would like to know what slag is it silica is it what. So, you see is basically silica and calcium, but calcium is in large quantities. Why is that So? It may be an additive you know in this processes during your during your processing of the ore lime may be an additive for some purpose. So, here you are getting calcium oxides silicon dioxide that is the main matrix plus other materials. So, you have iron slag you have steel slag.

(Refer Slide Time: 36:05)



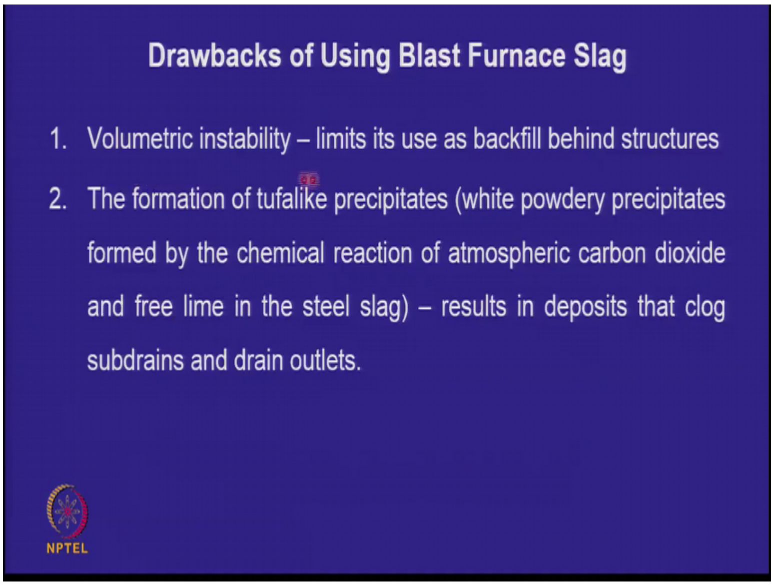
And if you look at the engineering properties 2 to 2.5 3.5 to 3.6 specific gravity unit weight is in pounds per foot let us get about it, but absorption is there abrasion values sulphate soundness tests. Angle of internal friction just look at the angle of internal friction what you call angle of shearing resistance is pretty high, Mohr's scale of hardness california bearing ratio. So, it is been used in embankments in the developed countries as a replacement for soil is a good material. What you do not get from both these tables is what is the grain size distribution when you look at something as a soil I cannot sort of adjust to it until I see the grain size distribution (Refer Time; 37:03) remember it is a mixture of the various grain sizes sand silt gravel grain sizes. And the advantage is it is found is it can be placed in any weather hat means it is not like clay where you cannot put it in with this becomes slushy like in wet weather cannot put clay. But if you compacting sand in wet weather no problem rain comes go and work after 15 minutes the water would have gone away your equipment can move, if you have clay rain come please wait for a day till the site dries up before you can your equipment can.

(Refer Slide Time: 37:38)



So, you can work in any weather it is got extremely high stability and almost complete absence of settlement after compaction and as I said it is high insulating value can be used as a protection against (Refer Time: 37:56), but there is a drawback because it is got calcium oxide what is calcium oxide quick lime, quick lime is reactive. And what will it become either it will become calcium hydroxide, cao plus h 2 becomes, caoh 2 or cao will react with carbon dioxide to become cao plus co 2 equals to caco 3. Now when you have a material which is going to adsorb something from the atmosphere or get react with it, then it is creating a new compound. Now as long as the new compound does not cause any volumetric changes then it is fine, but if is going to have a new texture new volumetric changes then it can be a issue.

(Refer Slide Time: 38:39)

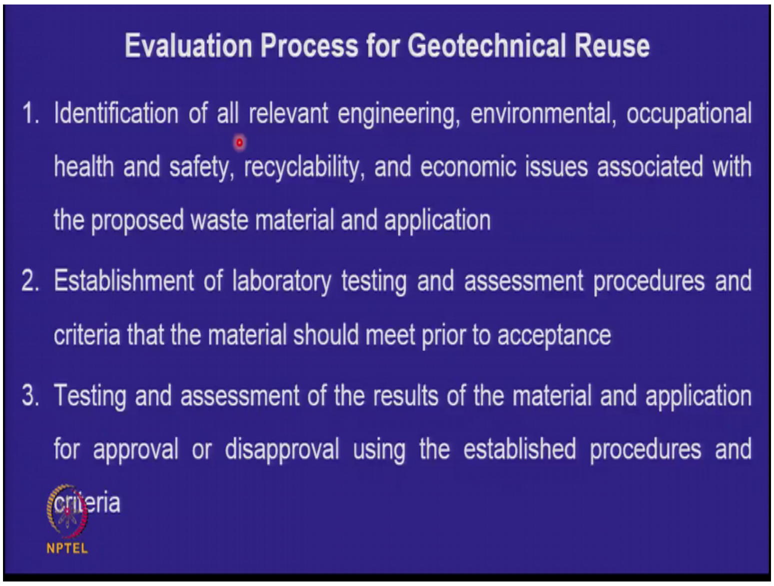


So, because it has volumetric instability you know it has gets some powdery precipitates, which are formed because of the chemical reaction of carbon dioxide and the free lime. So, that is a problem it can result in clogging of drains and other outlet us. So, it is not some material which will not undergo volume stability material may not biodegradable with time it is not something which will vanish or it will not something which will reduce it is volume, but because it reacts with carbon dioxide it is volume may.

So, if you have a flexible thing like a embankment it is fine, but if you want to be in a place where flexibility is not acceptable then slag cannot be used. So, finally, I would like to say that if you are doing geo technical reuse, we are going to look at all the relevant engineering for each waste, please remember the just with because person a used slag at one location then person b getting slag from another plant will use it is not possible. Similarly if person x used coal ash from a particular thermal power station which may I know sulphates, person y cannot use it from another thermal power station which may have sulphates. So, for every waste material you need to have the complete analysis about it is chemical physical characteristics which is not what you do with soil.

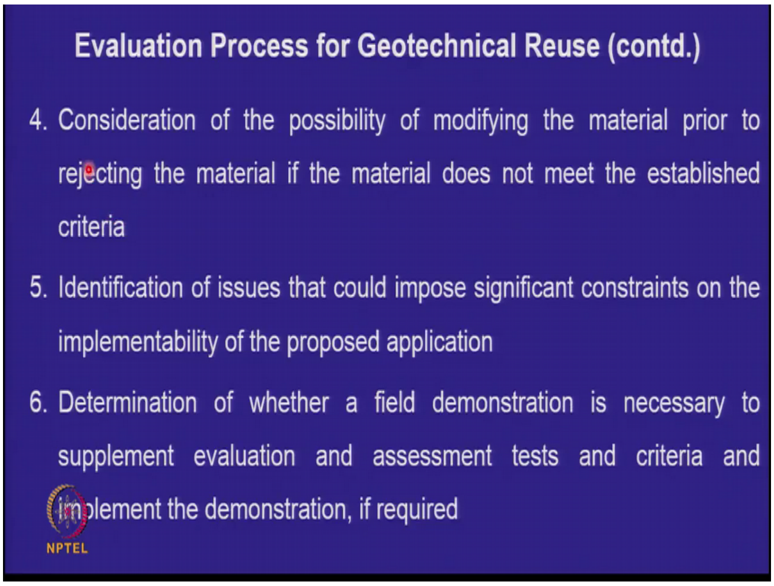
I will not pick up soil and start doing all kinds of chemical and leaching tests and TCLP test it is a natural material it is formed with millions of years we know that it has no harmful impact on the environment because people are living on it, but for wastes or at every location all engineering environmental occupational health and safety recyclability and economical issues are to be understood. You have to have a very high laboratory testing and assessment procedures for all the points that.

(Refer Slide Time: 40:27)



I gave you in the beginning and you have to be able to have a criteria for approval or disapproval using the procedures and if you have going to do the TCLP test you need all the values beyond which you cannot use it and bellow which you can use it. So, you need to have your criteria fixed and sometimes with the waste material you may not have a criteria. You may have to set up your own criteria. And if sometimes the material does not meet all the standards, you can also consider pre treatment.

(Refer Slide Time: 41:03)



Now what is the pre treatment I am not going to go into detail because pre treatments are expensive the moment you do pre treatment, you might find the local soil becomes much cheaper or a soil from 30 kilometers borrow area becomes much cheaper than the material that is being offered to you; however, in terms of economic considerations you have to comp compare the full economics about the land area which is being occupied by the waste at the mement and how much area will become free. So, if it is necessary you may reject the material, but possibility of pre treatment to modify the materials should always be considered. Even if it has got little bit extra organic matter.

Can we do something? Can we do soil washing? Can we do heating to remove the organics? And if so what is the cost and can we get rid of the material from where it is occupying hundreds of acres of lands? Also we should be very clear that before we start the process that if they are going to be constraints on account of this material if the material has bad smell, that is a constrain I mean your bad smell you start taking the material from an industrial area it is start laying a road in a village the villagers will be in a up and arms in the edge of the gases may be harmless, but poorly because the fact that it is producing bad smell it may be a constraint in implimentability. And also nice if you are dealing with something new to have a demonstration project.

Theoritically everybody everything they seem fine, but if you are making an embankment of a new material defforate do a 6 months demonstration project make the make the embankment make it go through this summer and the monsoon and then if it looks fine adopt it on a full scale basis. So, with this spectrum you can you can cautiously adopt a lot of materials for geo technical reuse, but some of the materials just get knocked off right in the very beginning. As I said significant organics significant salts significant heavy metals. You are out you have heavy metals you might consider making blocks out of that right, why? Because you will be then fixing the material in a cement matrix and you can not release the heavy metals as long, as the brick building is in place your heavy metals are interest in that brick which you made from that material. So, in the building industry you can, but in geotech the material is going to be always in it is original form. So, slowly those things can come out.

So, somethings will immediately say that this cannot be made use of other things, please be always ready for those special design measures erosion control measures should not enter into pipelines it is very simple for us to say oh the cn phi is very good cc is very low permeability is good. So, free draining coarse grain material does not matter it still may be blowing dust in the air. So, we have to take those peculiar measures specific design measures such that it does not cause any problem to the local people both during construction and after installation. Any questions or any thoughts which bother you? Then we will stop here today and in the next lecture we will take up can we use old waste or can we use incinerated wastes in geo technical applications. Have a good day.