Geoenvironmental Engineering (Environmental Geotechnology): Landfills, Slurry Ponds & Contaminated Sites

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Lecture – 34
Geotechnical Properties of Coal Ash and Mine Tailings – Part 2

Good day and welcome to this class where we continue our discussion on geo technical properties of coal ash and mine tailings. Last time we introduced you to the concept of identifying what does coal ash mean in soil mechanics terms. And we said it is silty sand sandy silt it is non plastic it has low specify gravity, and the finer particles are spherical in shape. So, that is what we got to understand last time. So, let us carry on from there let us complete our discussion on coal ash, and then after that let us look at the geo technical properties of mine tailings.

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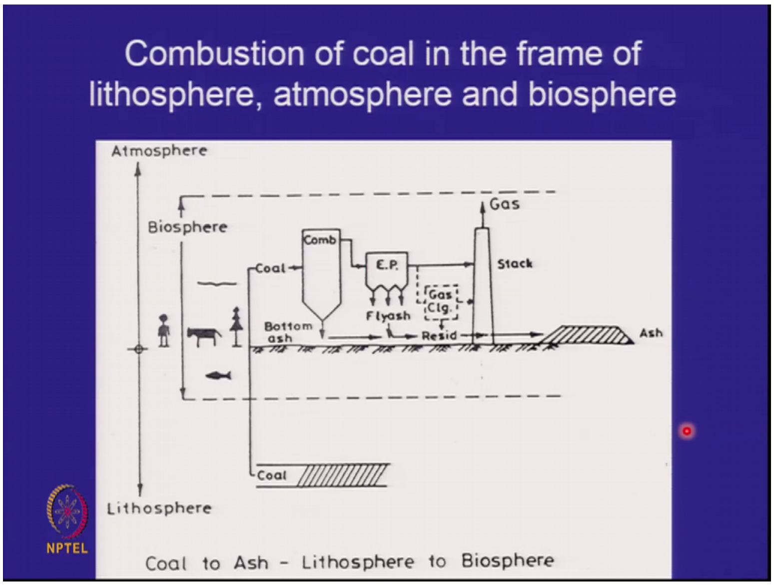

So, just to recall we done this last time coal is coming out from deep below the ground is going to a thermal power station and the ash is being deposited, the ash is being deposited near the thermal power station.

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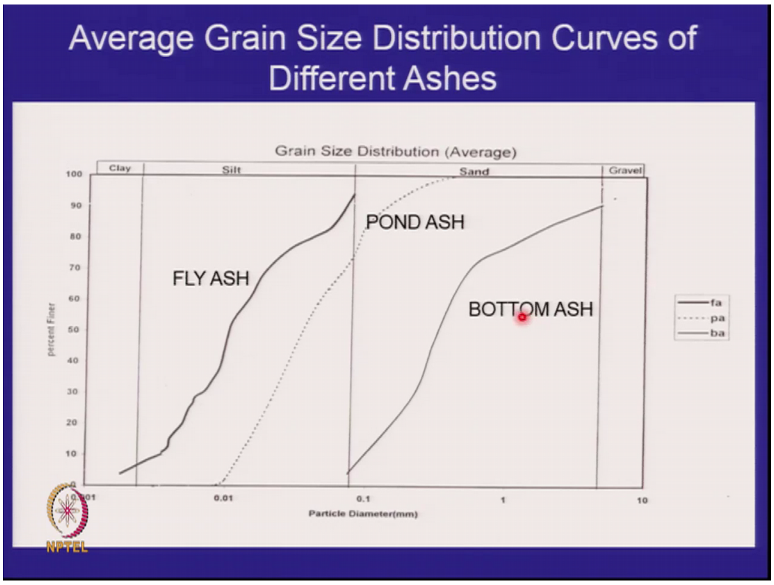

And we said bottom ash is sand sized fly ash is predominantly silt sized, and pond ash which is the mixture of the 2 is partly sand and partly silt.

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Specific Gravity of Ashes at Different Locations

Location	Specific Gravity			
	Bottom Ash	Flyash	Pond Ash (Inflow Point)	Pond Ash (Outflow Point)
Indraprastha	-	-	2.30-2.50	1.84-2.0
Korba	1.84	1.85	1.73	1.75
Ramagundam	2.28	1.85	2.22	2.13
Vijaywada	-	2.03	-	-
Badarpur	2.22	2.24	2.22	
CESC	2.09	2.16	-	-

The specific gravity values that you find from different thermal power stations typically in India specific gravity varies from about 1.7 to about 2.2 ash is non plastic in nature.

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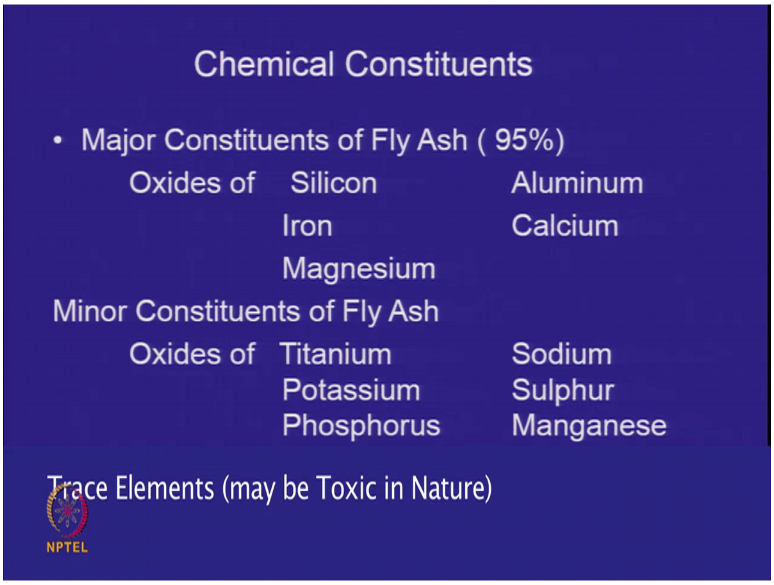

And now let us look at the chemical constituents of this ash. I told you last time that it basically comprises of oxides of silicon and aluminum and iron. There are other minor constituents of fly ash which are oxides of titanium potassium, phosphorus, sodium, sulphur and manganese. But ah you will also see some trace elements, but remember bulk of the ash corresponds to this.

The trace elements like heavy metals may be toxic in nature, but their concentrations may or may not be above the minimum acceptable limits.

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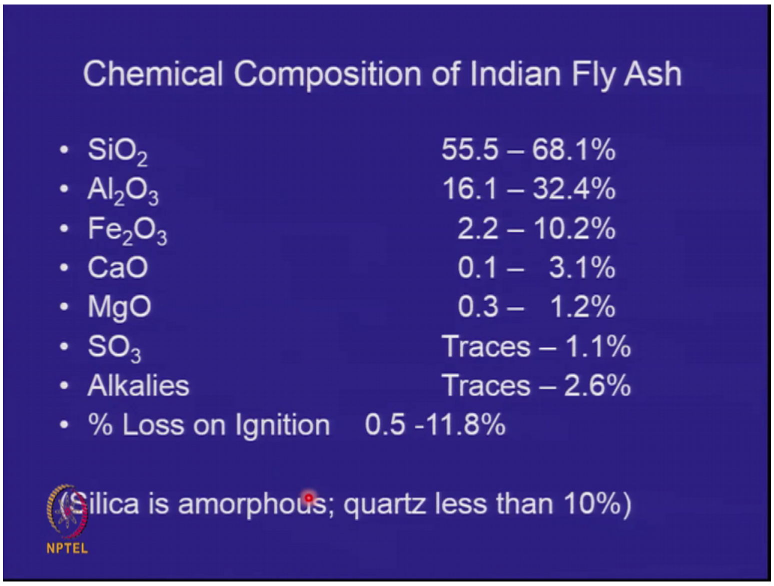

So, how much of ash is made up of silica if you see silicon dioxide 50 5 to 68 or 70 percent is the amount of silicon dioxide. The important thing is that the silica is amorphous. So, it is not in the form of crystals, out of this silica less than 10 percent is quartz. The balance is not in a structured arrangement. So, in a sense it is reactive. Then typically you will find 16 to 30 percent aluminum oxide a little bit of iron oxide and then small amount is small amounts of calcium and magnesium oxide. And there are other trace elements as we settle sometimes the coal will have sulphur in it.

So, when you burn it you will get sulphates, and sometimes there will be unburnt carbon in the coal. So, even after you get the ash, if you burn that ash; that means, all the coal has not burnt and sometimes you will have as much as 10 to 11 percent a loss on ignition. This is not a this is not a good quality ash we would like loss on ignition to be as low as possible as for as the ash is concerned.

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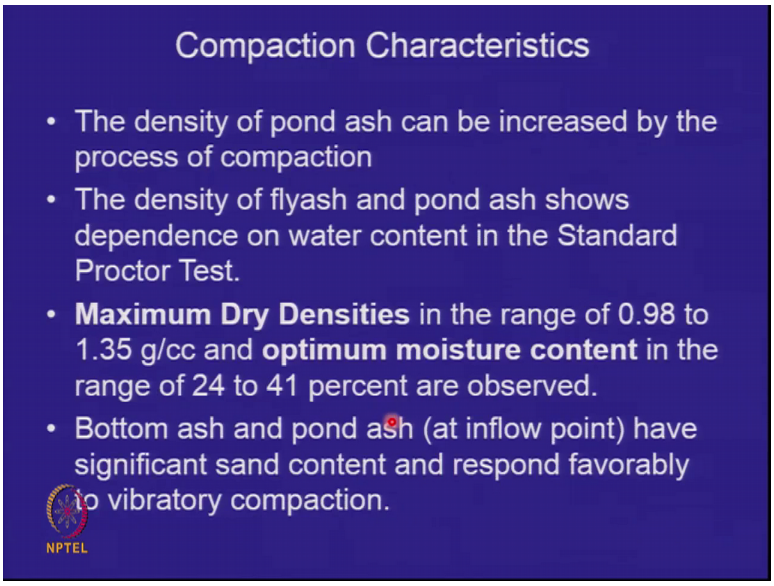

Can we densify the ash like soil that is the next question. So, yes you can densify pond ash by the process of compaction. And just like if you perform a standard proctor test the density of fly ash and pond ash does show dependence on water content right.

So, just too quickly recollect if I have fine grain soil.

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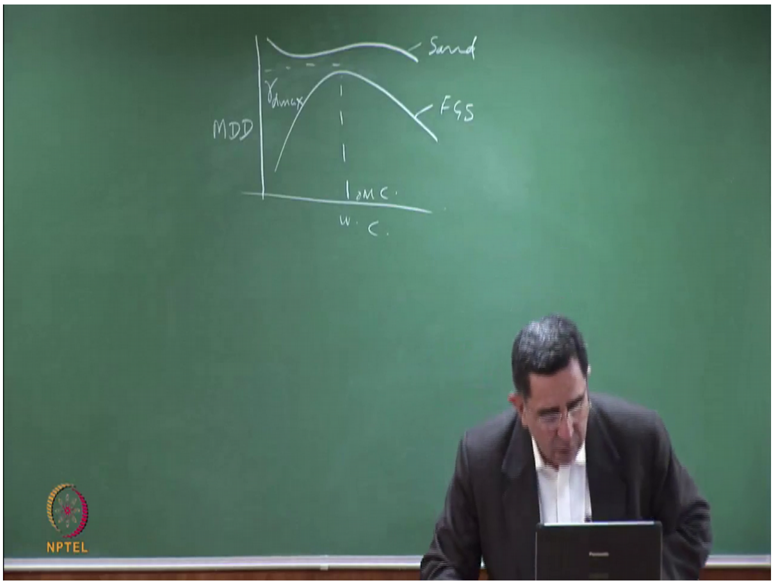

And I compact it in the standard proper test and I plot maximum dry density with water content, I get this behavior right. And I will get OMC and gamma d max. And this is what we use for compaction of soil in the field. But this is true for fine grains soils if I take sand and if I perform standard proctor test on sand what will happen? Will I get an inverted v if I take sandy soil I do not get an inverted v I get some kind of a shape which may look like that. Not too much dependence on water content not too much dependence on water content and no mc. Sand responds better to sand responds better to vibratory compaction and to get the densest state of sand we should use vibratory rollers. Whereas, fine grain soil respond better to sheeps foot rollers and pneumatic tyred roller.

So, that is the difference. Now the question is how does ash behave. If it behaves like a fine grain soil you will get a curve like this, if it behaves like a coast grain soil you will get a curve like this. Even in sand when there is 15 to 20 percent of fines, the sand begins to show dependence on water content. So, what we are saying here is, that the density of ash and pond ash shows Dependence on water content.

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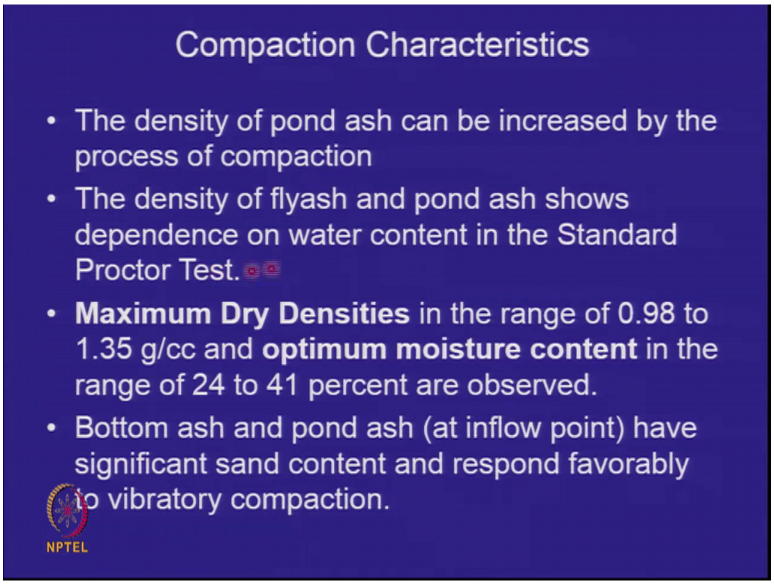

And maximum dry densities are in the range of 0.98 to 1.35 grams per Cc and optimum moisture contents are pretty high, 24 to 41 percent. And we look at the graphs in the next slide, bottom ash which is sand like and pond ash at inflow point which is also sand like, respond favorably to vibratory compaction.

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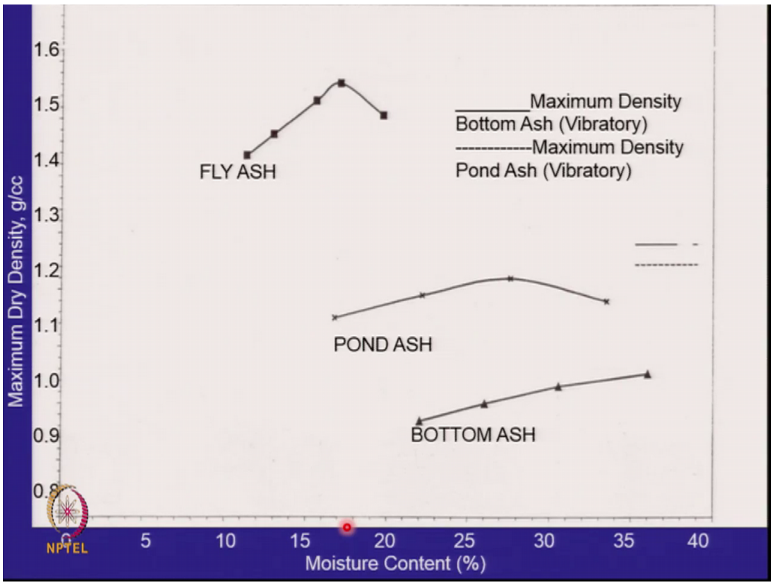

So, if I look at 3 samples from the same thermal power station, this is my fly ash I have got an inverted v curve, this is my pond ash I have got a inverted v, but a pretty flattish curve that is why I put all of them on the same graph. And this is bottom ash does not seem to have any peak and remember this is about 40 percent water content you add more water, water starts to drip out of the sand. In fact, water is already dripping out of the sand in this drain.

So, you have some dependence on water content in pond ash and great dependence on water content in fly ash which is the finer material.

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Compaction Characteristics from Standard Proctor Test

Location	Ash	Max. dry density (g/cc)	Optimum moisture content (%)
Indraprastha	Pond Ash (Outflow Point)	1.15	32.4
Korba	Pond Ash (Inflow point)	1.08	36.0
	Pond Ash (Outflow Point)	1.02	39.5
Ramagundam	Pond Ash (Inflow point)	1.33	23.0
	Pond Ash (Outflow Point)	1.26	26.2
	Fly Ash	1.36	23.0

If I try to see the maximum dry density values, I see they all lie between about 1 to 2 1.36. In fact, they are sometimes 0.98, 0.95. What is the maximum dry density for soils? Typically if you would like to recall the 1.5 in terms of the grams per Cc 1.5, 1.6, 1.7 if you have compacting very well and you got a good well graded material.

So, soil show higher maximum dry densities then ash, and that is the reason is that ash has got lower specific gravity and therefore, it is a light weight material. Also please see optimum moisture content is pretty high. Optimum moisture content in the case of soils is high in the case of clays, when plasticity index is high. So, this is the another aspect that you have to see. And I would like to ask you if the maximum dry density is 0.94, does it mean that this material will float on water. What is the density of water? 1 and this is 0.94, is this lighter then water? No, this is the dry density. The specific gravity of the solids is 2. So, it is definitely heavier than water when you saturate the sample the density of this will be 1.4 1.3. So, do not think that 0.94 means it is lighter than water.

So, compacted ash can be any way having a maximum dry density in the range of about 0.98 to about 1.36 or 1.4. And optimum moisture contents are pretty high. But it behaves like soil, bottom ash and pond ash at the inflow point will respond well to vibratory rollers whereas, in the other case you can use rollers which are non vibratory such as pneumatic tyred rollers and sheeps foot rollers.

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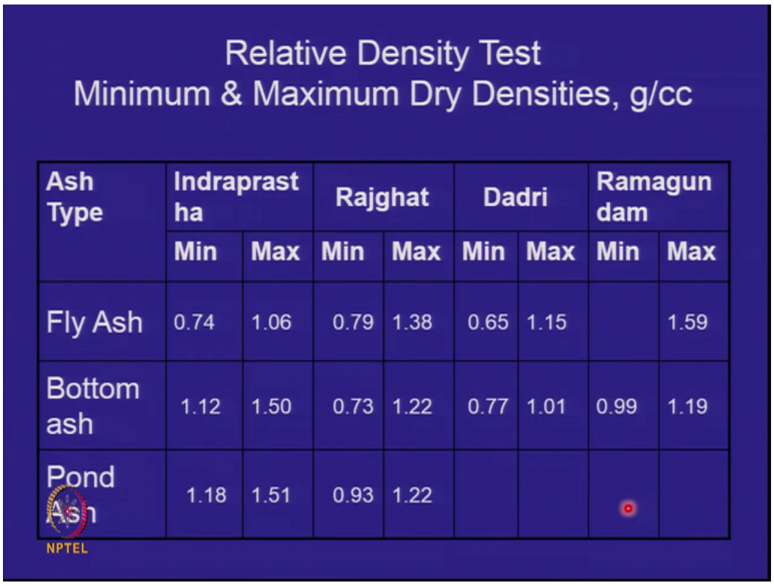
Relative Density Test
Minimum & Maximum Dry Densities, g/cc

Ash Type	Indraprastha		Rajghat		Dadri		Ramagundam	
	Min	Max	Min	Max	Min	Max	Min	Max
Fly Ash	0.74	1.06	0.79	1.38	0.65	1.15		1.59
Bottom ash	1.12	1.50	0.73	1.22	0.77	1.01	0.99	1.19
Pond Ash	1.18	1.51	0.93	1.22				

If I do the vibratory test in the laboratory, what kind of maximum densities do I get? 1.06 for bottom ash I am getting 1.5 for pond ash I am getting 1.5, but basically from the vibratory test for different these are different locations Indraprastha, Rajghat Dadri, Ramagundam this different power plants. Still I am in the range of 1.06 for fly ash, and I may go as high as 1.59 and similarly here 1.5 1.22 1.01 so, typically one to 1.5 with vibratory compaction. Do remember that bottom ash will respond the best to vibratory compaction because it has no fines. Also given in this table is if you place the material at it is loosest density what kind of minimum densities do you get and you can see the as low as 0.6 grams per cc.

So, hydraulically deposited ash which is going to be deposited from the slurry is going to settle down in it is loose condition. So, inside the ash pond the ash may be in a loose condition, but when you take it out and compact it with rollers it will be in the dense condition.

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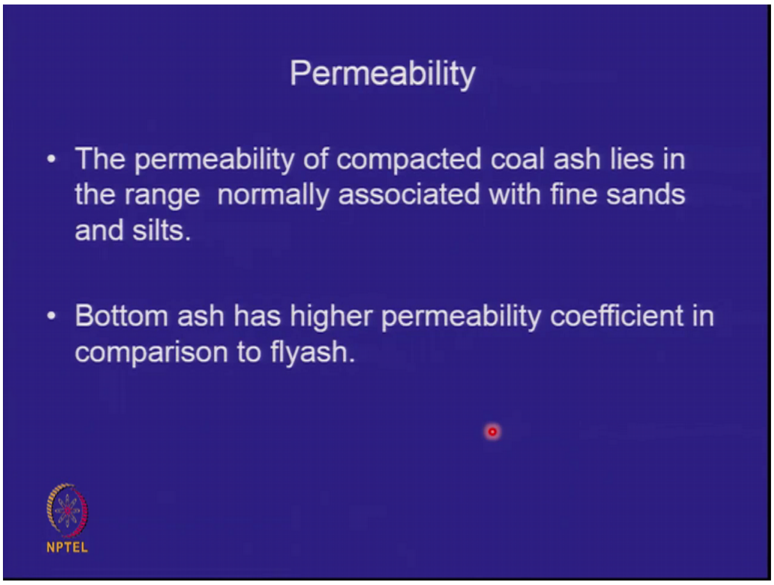

Permeability of ash, ash is non plastic it means that it has no net negative charge like clay particles. And therefore, the permeability would typically be in the range of silts and in the range of sands. So, permeability of compacted coal ash lies in the range normally associated with fine sand and silts.

Bottom ash of course, has higher permeability because of larger grain size distribution.

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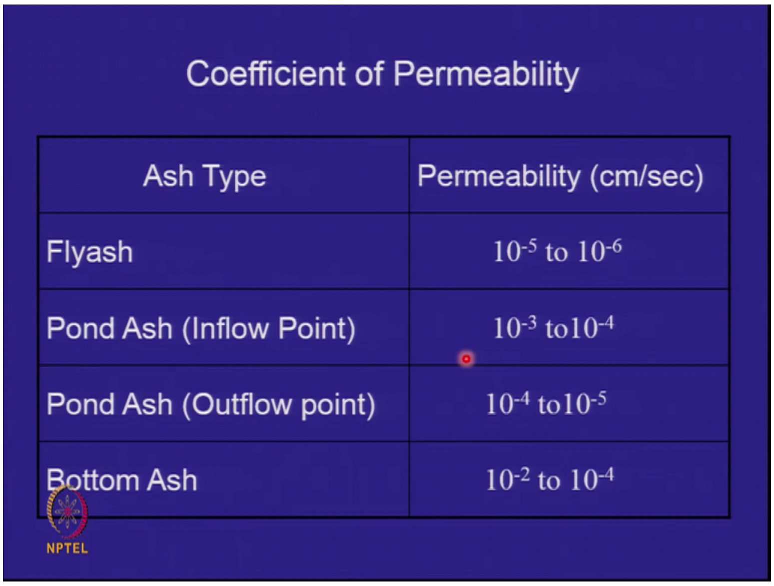

Coefficient of Permeability

Ash Type	Permeability (cm/sec)
Flyash	10^{-5} to 10^{-6}
Pond Ash (Inflow Point)	10^{-3} to10^{-4}
Pond Ash (Outflow point)	10^{-4} to10^{-5}
Bottom Ash	10^{-2} to 10^{-4}

And if you look at the permeability in centimeters per second, and you go down to bottom ash this is for sand, typical range for sands fine sands this is pond ash at outflow point this is pond ash at inflow point and this is fly ash. So, fly ash being the finest do remember 10 to the power of minus 7 centimeters per second says you have clay. So, we are in the range of silt the permeability. Important to note that in an ash pond when the material settles it sort of gets layered in it is coarse and fine fractions, and the horizontal permeability is always much more than the vertical permeability. Because in the layers if water has to travel horizontally it will travel through the sand sized where as if it has to travel vertically it has to go through sand sized then silt sized then sand size then silt size.

So, the composite effect is vertical permeability is lower than the horizontal permeability. Which is the case for most alluvial deposits; if you look at Yamuna sand deposited by the river Yamuna there also you will find that the permeability in the horizontal direction will be more than the permeability in the vertical direction.

We are also interested to know what about the compressibility, does this material show compressibility, yes and what kind of coefficient of compressibility do you get. So, compacted ash exhibit is low compressibility.

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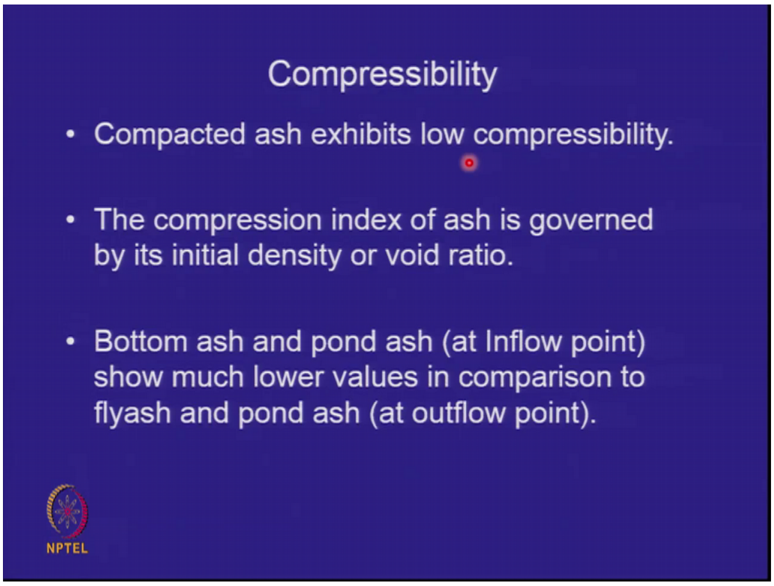

And the compression index is governed by the initial density or void ratio and of course, bottom ash and pond ash show lower values than fly ash.

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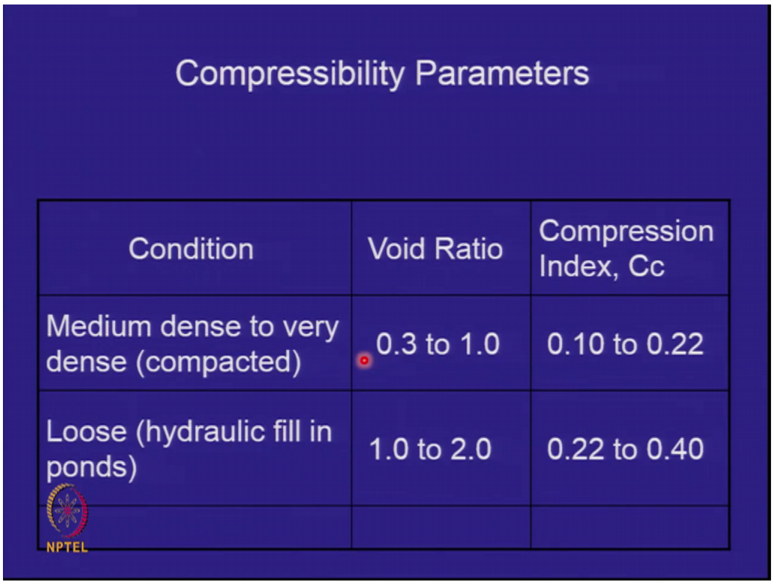

And if you want to look at the values of cc. So, if it is loose and hydraulically deposited it varies from 0.22 to 0.40 and if it is medium to dense compacted then Cc varies from point one to 0.22 and this is the normal range that you would associate with silts or sandy silts or silty sands. So, ash behaves like typically like soil.

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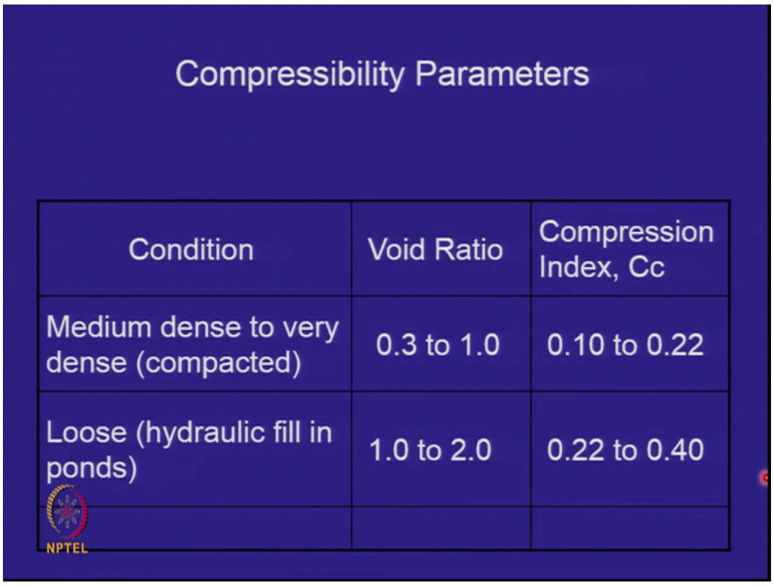

Finally we come to check that we have light weight material, does it mean it has low strength? We also have spherical particles which we saw with smooth surfaces. So, one tends to think my be light weight spherical particles may be the shear strength will be low.

So, second issue does pond ash have pozzolonic properties, very often what we hear is that ash will have self hardening properties; that means, if you leave ash for some time it will set like cement, but very weakly, but still there is a self hardening property. Some calcium silicate hydrates are fallen forming how, I showed you in the composition there is some CO line right and I showed you that there is some SiO 2, and this SiO 2 I told you is amorphous; that means, it is reactive it is not crystalline.

So, CO will not react will sands suppose I take a SiO 2 in the form of quartz grains, and if I put lime on top of it they are not going to react, but if I reactive silica and lime I will get a c s h gel, but nominal amount. So, ash does show self hardening properties which is of interest to structural engineers, but then we have to store ash as produced. Please note number one, bottom ash behaves like granular material like sand, it does not show self hardening properties, but the fly ash will show you self hardening properties. Once you send the flash in water in the form of a slurry to a pond, will the self hardening properties increase or decrease? See much of the self hardening properties comes from the finest fraction, why? Because the surface area of reaction available is more, much more than the weight of the particle.

So, when you are verifying particles of fly ash they will be the one which will contribute to the self hardening properties. You take fly ash you mixed it with bottom ash, you mixed it with 10 times of water, you send it to a pond in the pond ash the fines the finest of the fines get washed away you know. So, what happens? The self hardening property goes. So, pond ash per save will not exhibit self hardening properties, if it does it is very, very minimal.

So, if you keep fly ash in the dry form, then you can say that the pozzolonic properties are retained, but if you store it in the form of a slurry, and then put it in a pond where some of the fines get washed away we are not going to get much of self hardening a pozzolonic properties. To so to us if I go into a an ash pond I can take my hand and I can scoop out the ash with my hand. If it had self hardening properties I would not be able to scoop it out. Sometimes at the very top you will find a very, very thin layer of fine ash right. Trying to have some self hardening properties, but you can just take it in your fingers and sort of crushed it.

So, pond ash pond ash rarely exhibits significant self hardening properties.

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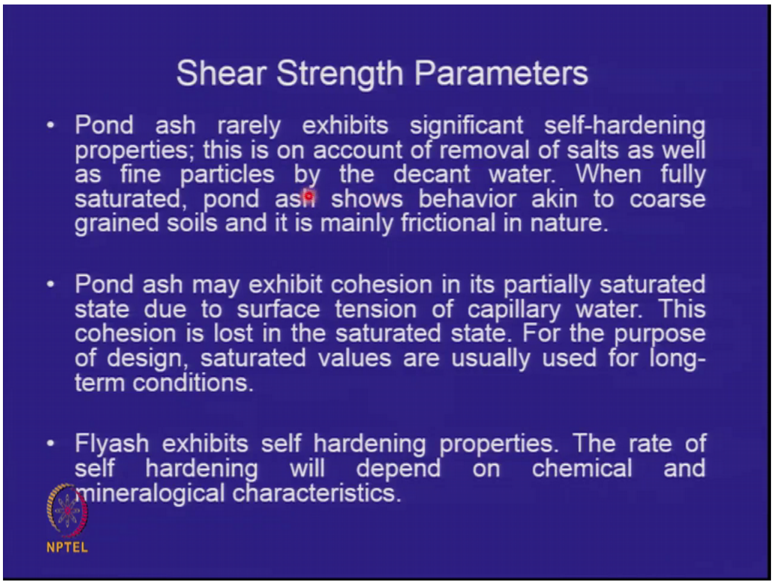

You may be able to make a sample of pond ash in the partially saturated state. But that is due to the negative pore water pressure at the surface tension effect in the voids of the little bit of water. This is not due to any cementation which takes place at the grains. For a soil sample to show cementation when you submerge it in water the cementation should not go away. If you submerge it in water at the sample crumbles it means it has no cementation it has some kind of a electrical charge issue or it has some kind of a negative pore water pressure due to the partially saturated state of the soil.

So, sometimes people say that pond ash exhibit is cohesion, but that is not a reflection of a self hardening properties. Fly ash will exhibit self hardening properties, but it will depend on whether you have collected it in the dry state or not. And this is the most valuable thing from the perspective of people wanting to use the ash in cement. So, you will always find cement companies will be very interested in your fine portion of the fly ash. And not so interested in the coarse portion of the fly ash. So, if I take a direct shear box and perform the tests, the behavior is similar.

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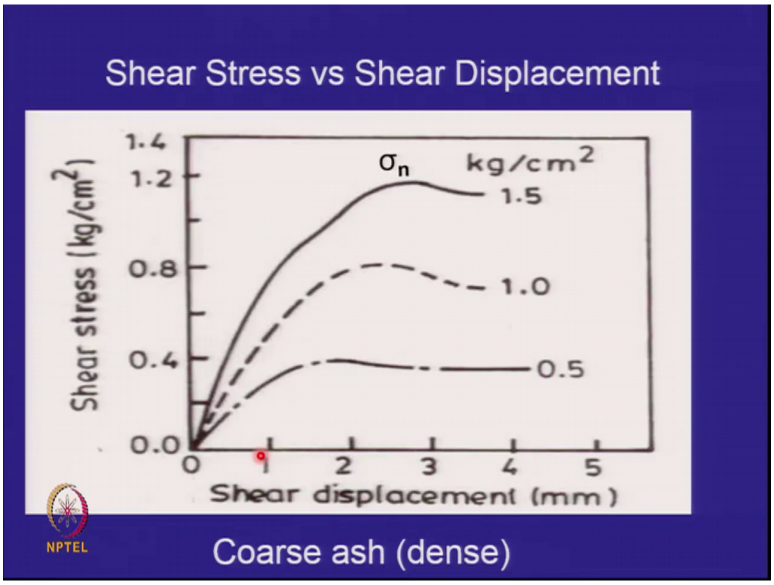

This stress and curve at 3 normal stresses. This is dense, coarse ash from the inflow point. And this is the dilatant behavior. So, ash behaves very much like a dense material. This is the result for loose ash, no peaks, no peak, and this as you can see is it didn't go up, it did not go up.

So, ash seems to behave very similar to coarse grain soil right.

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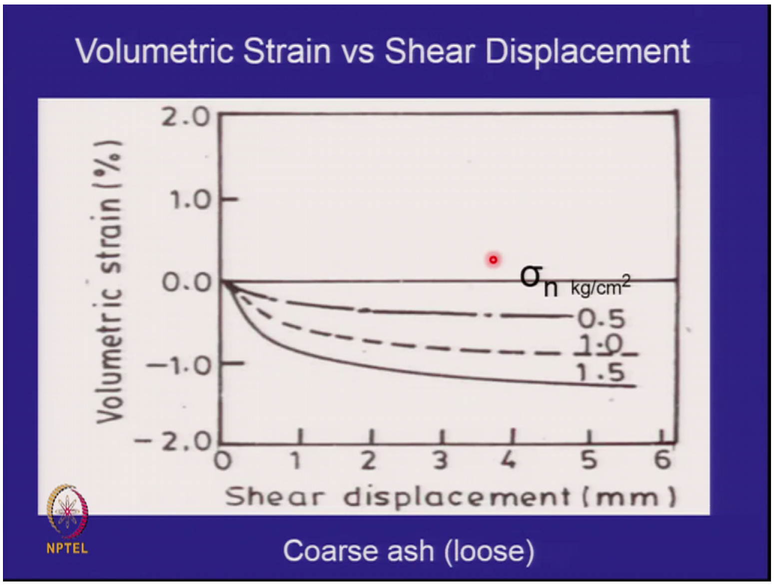

If I take dine ash this is the dense fine ash behavior. The dense fine ash did not show di latency in this test. This is the loose fine ash behavior, and the loose fine ash did not show any dilating behavior.

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Shear Strength Parameters of Saturated Ash

Ash Type	c' (kg/cm^2)	φ'(degrees)
Pond Ash (Outflow Point)	0	25 to 35
Pond Ash (Inflow Point)	0	32 to 40
Bottom Ash	0	38 to 42

I can summarize the properties if you plot the tau versus sigma plot in the direct shear test and what kind of phi dash values do you find. Pond ash at the outflow point will exhibit. Firstly, all ashes exhibit c dash equal to 0, do you remember that. All ashes exhibit is c dash equal to 0. Fine ash at the outflow point will give you c dash phi dash of 25 to 35 degrees this is for the loosely deposited state hydraulically deposited and this is for the compacted this is the range of values. Pond ash at the inflow point which is coarser will show this range.

Bottom ash which is nothing but coarse material which is angular in shape, or sub angular in shape. That shows very significant high phi dash values. So, more and more can I say that ash is like soil? Can I say that ash is like soil? Now that we are talking about it, before I discuss field studies after all the data that we have put across in front of you it is non plastic. It is light weight, low specific gravity, it is compactible, it has permeability similar to soils confessibility similar to soils and the phi dash values are similar to soils.

So, you all ready to use it as a material, are there some concerns that you have about this material? Using in place of soil or as a replacement of soil, and any concerns that you have? No concerns? You haven't asked me is it hazardous, you haven't asked me does not affect human health, you haven't asked me does not it erode more than soil. So, these are the questions which you have to answer before you use ash as soil. Question one does it erode more than soil, what does it mean? It shouldn’t be that you have made an embankment and whether rain comes you get a erosion gullies and all the ash starts to follow away. Second question is it?

Student: Hazardous.

Hazardous, does it have any chemicals which may cause bad health. And the third question is, we call it fly ash is it going to give us a lot of dust. So, all these 3 things are addressed when we use ash in earth works, all these 3 things have to be addressed when we use ash in earth works. And when we are going to use geo technical reuse of material we will address this. But briefly to classify whether a material is hazardous or not from the toxic point of view we have to be the TCLP test

So, if you look at lot of data on leachability studies on ash and the heavy metals which come out from it, the data is not clear. Many study show that the leachable heavy metals are below the prescribed limits, so the material is fine. But there are some studies which show that these may be elevated slightly above the permissible limits. So, this debate is on for a long time is does ash leach toxic materials to the ground. There is no conclusive evidence that it does.

So, that first issue remains open for discussion and remains open for debate. And that debate is most important where you are creating very high ash ponds, because then there is a whole column of ash through which water travels and then it can go into the ground water. And if the ash has got something which is coming out of it then you will have to put a liner at the base of the at the base of the ash pond or the ash storage facility. America in 2016 has just come up with that regulation.

So, they have looked at a lot of ah ash ponds in the country, and first they appear to be the view that nothing harmful was coming out from the ash pond. But now taking a holistic view including the elevation of the water table level, because once you make an ash pond you are creating a big lake that lake may you know lift the level of the water table. Now there are they have started to prescribe liners for ash ponds as well. And we will address that in the design of ponds and as for as erodibility is concerned dust or water erosion we will look at it when we design embankments using ash.

Very quickly I would like to take you through a study this is an old Ash pond in Delhi.

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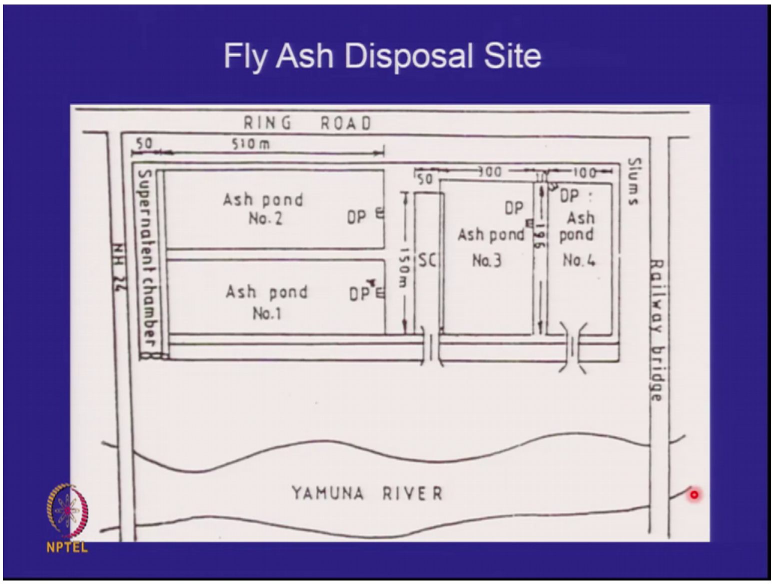

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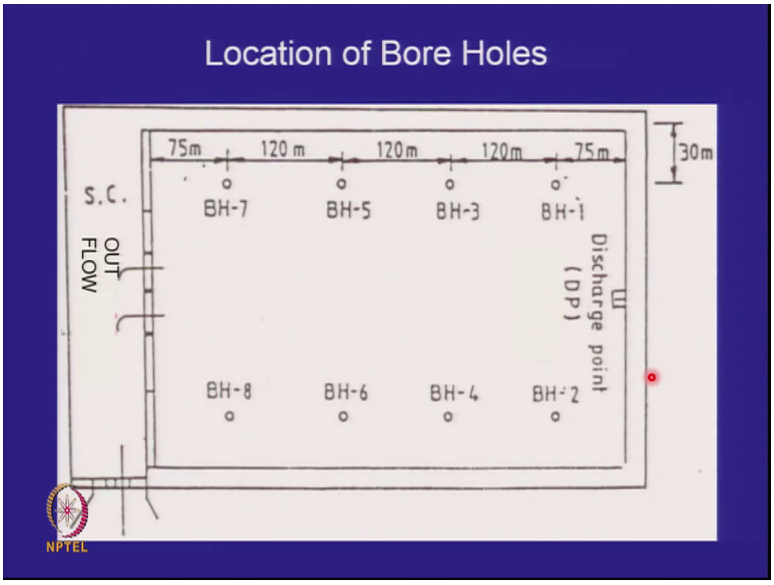

But we had the we had the opportunity to work on this several years ago, this is the ash pond this is the inflow point, and that is the outflow point. What we could do was we could pick up samples as we went from the inflow point to the outflow point, and we just wanted to see how the grain size changes how the water content changes.

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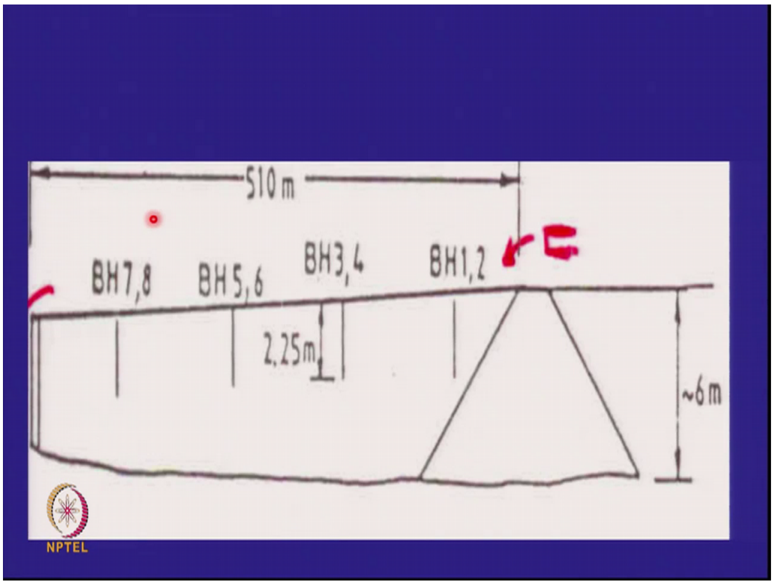

So, this was the inflow point, bore holes 1 and 2 were very close to the inflow point and bore holes 7 and 8 are very close to the over flow vier. And unfortunately this figure is a mirror image.

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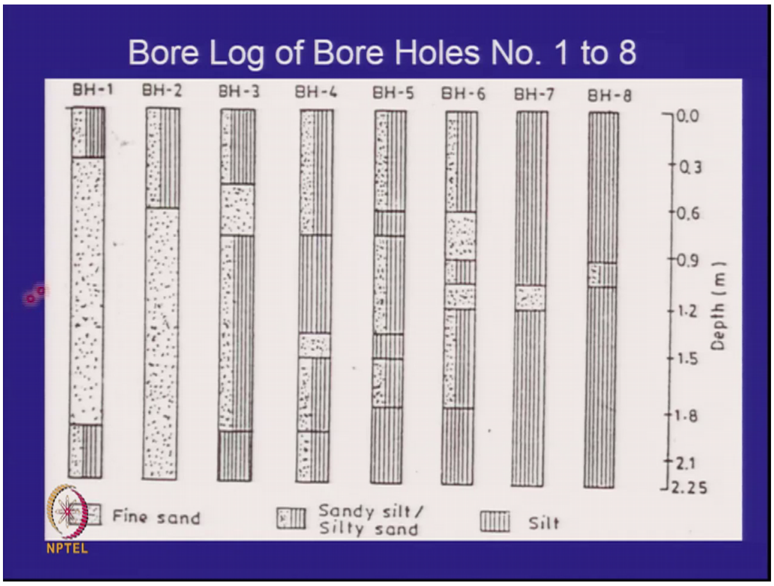

So, this is the inflow point 1 and 2 and this is 7 and 8.

So, using the standard dotted representation for sand, and vertical lines as a representation for silt please see what is happening. When I take the samples from the first 2 meters or 2 and half meters from the top, bulk of the samples at the inflow points are sand sized with some silt. But as I travel to the outflow point bulk of the samples have predominantly silt sized material very little sand. So, all this tells you and if I look at the water content when we have sand then the holding capacity of the field capacity is lower than when you have silt. So, if you look at bore hole one you find that water content is of this value.

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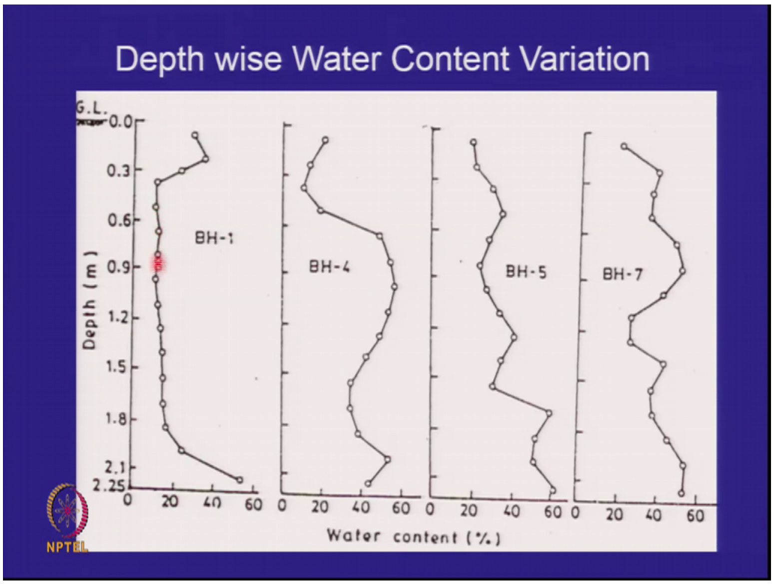

Look at bore holes 7 water content is about 40 percent. So, what do you get? When you are predominantly sand you hold less water, in the inflow point when you are predominantly silt you hold more water.

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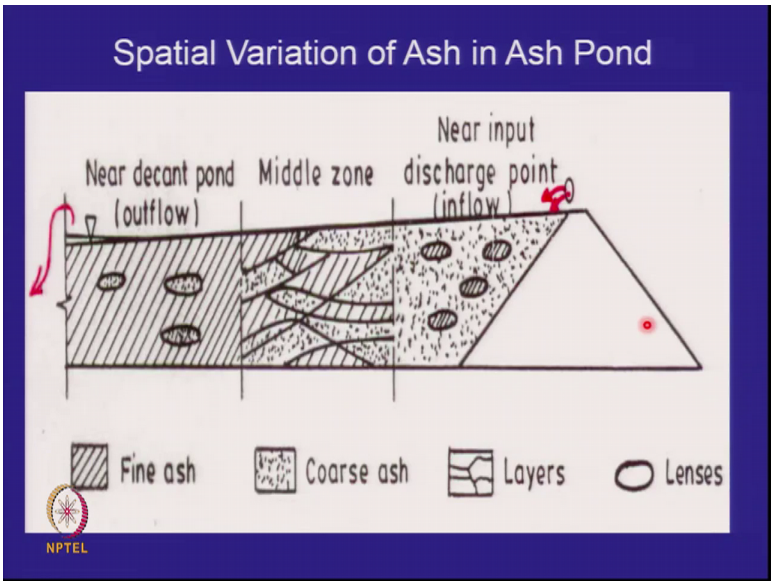

And a diagrammatic representation of what we saw was you we would like to say that in ash ponds near the inflow point predominantly coarse ash with lenses of fine ash, near the outflow point predominantly fine ash or silt with lenses of sands sized ash and in between of course, there is a lot of layering which occurs.

So, I want you to get that feeling about what is happening in an ash pond.

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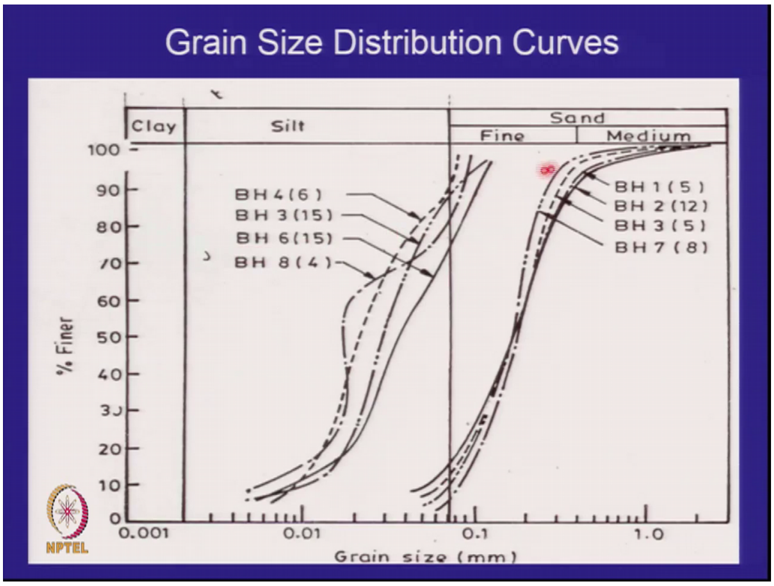

When I take the samples from bore holes 1 and 2 and you can see the bore holes which are So, I could get distinctly different types of materials. And in the bore holes also one could actually since you are done continuous sampling, one could pick out the coarse size fraction. And so, alright let us examine this coarse size fraction. So, if you see for I just go back 7 and 8 are here right, but in this grain size distribution curve 7 is here. That is because from the grain size distribution of 7 we took out the coarse material we wanted to see where does that fraction lie, and that is the inflow point fractions.

So, that is the coarse and that is the fine ash. So, in a sense you had fly ash in 6 feets. We mix them together, we send them to the ash pond, the ash pond again sorts them. The coarser comes here and the finer comes there even it is no sacro sand it depends on how your inflow point is changing. As I told you it is a garland arrangement. So, if the inflow point comes very close to the outflow point you are going to have coarse material there as well.

So, with this we end a discussion on ash. Ash came from the coal, we burnt the coal. If we had ash content of 6 percent, we would have very little ash. But in Indian coal as I said ash content is 40 percent plus or 35 to 45 percent. So, half the material which comes to a thermal power station is soil virtually. So, we are transporting a lot of waste with the coal, but since it is available locally and there is a were lot of this coal in the country. So, we are using it. Because we have a lot of ash in the coal we are then having to utilize this ash for various purposes.

Ash is being formed by a thermal transformation right. You have burnt the coal it was heated, somethings vaporized and again settle down. So, ash was basically a formulation from a thermal process. Mine tailings are a formulation not from a thermal process, as I said mine tailings are the remains of ores. So, in mines you take out the ore from great depth you crush it, and crush it, and crush it. So, that it becomes a fine powder then you do some processes like froth flotation magnetic separation whatever processes that you want in which the metal or the useful material that you want gets separated from the soil. So, your ore may only have 2 percent metal. And you may crush it and crush it and the 98 percent material will come out as mine tailings. And 2 percent material may be what you are getting for your production of aluminum or copper or zinc or iron whatever you are dealing with.

So, finally, this crushed material which has also undergone some chemical reactivity to remove the material from it is from outside. Actually it should be put back in to mine 98 percent material, but your mine is progressing. So, you do not want to be buried in your own waste. So, you keep on mining them ore sending it to the top it gets processed there and you know dump it on the top. It is exactly like coal coming out from deep below going to the top thermal power station ash does not come back. Otherwise the ash should come back and fill up 50 percent of the mine from where it was taken out similarly from mine tailings.

So, let us look at how mine tailings compare with ash. A mine tailings is basically crush rock. So, first let us look at the specific gravities, because that is what we looked at in the case of ash so what, so you see.

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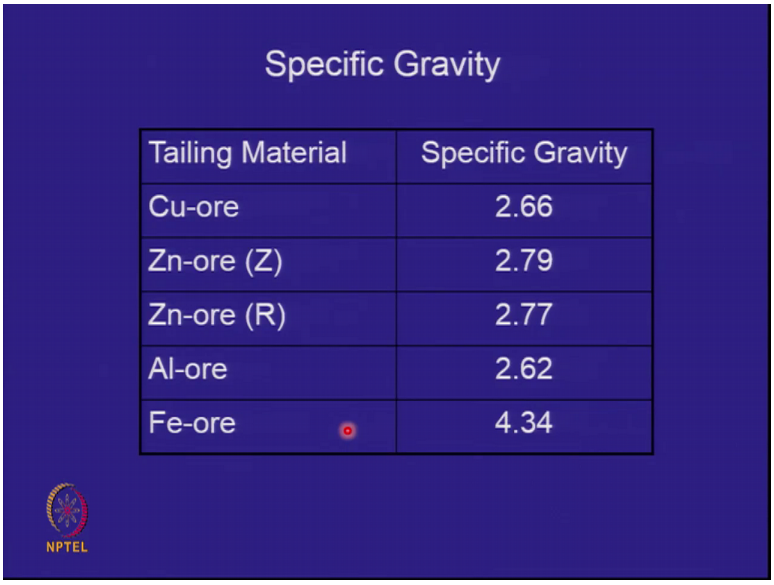
Specific Gravity

Tailing Material	Specific Gravity
Cu-ore	2.66
Zn-ore (Z)	2.79
Zn-ore (R)	2.77
Al-ore	2.62
Fe-ore	4.34

Specific gravity of soil is 2.65 specific gravity of ash is 1.7 to 2.2. Here we are getting specific gravities in the range of 2.65 to 4.34. So, 4.34 means that a lot of metal is going out in the tailings, 4.34 does not mean that the rock has got a specific gravity of 4. So, if you have not suppose your iron content of the ore was 8 or 10 percent, and from that you took out 7 percent, but you (Refer Time: 32:55) 1 to 3 percent going it is 2 expensive to extract the balance iron. So, you say [FL] we will send with the tailings. Tomorrow when you want to do even secondary mining or tertiary mining when iron becomes so expensive, then I can go and pick up that iron from, because that will tailings will still remain my ore on the surface.

So, here 4.34 means lots of metal coming through. This also shows to 0.8 is high 2.75. So, tailings have higher specific gravity or equal to the specific gravity of soil. That is number one difference. How much of the tailings are like ash in terms of grain size distribution? Well, here you see most of the tailings have more sand content. In the case of ash you would it would depend on where you picked it up from in the pond. It could have higher silt content if it was the outflow point or higher sand content if it is a inflow point. But by and large you are getting equibalance silt in sand. Here you are getting more sands.

So, normally tailings are coarser than ash they are heavier than ash they are coarser than ash. Because the specific gravity is a high, because the specific gravity is a high the densities will be high right. So, this is an attempt to see the minimum density, because you know in a in a slurry you are always interested in the minimum densities. Because these are all hydraulically deposited, but still if you see if you do dry poring you are densities are in the range of 1.36 to 2 1.63 in the case of iron it is higher. And if you deposit them under water and these are just solids content; that means, more and more solids lean slurry means 10 percent solids content then you will get lower values of dry density when you deposit the material under water.

If you do the standard proctor test on them, well you do get data which shows maximum versus optimum moisture content because you have significant silt content. So, just like pond ash show dependence. So, to do tailings show dependence on water content, inverted v.

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Maximum Density

Tailing material	Standard Proctor Test		Vibratory Test
	Maximum dry density g/cc	Optimum moisture content %	Maximum dry density g/cc
Cu-ore	1.97	6.8	1.99
Zn-ore (Zawar)	1.89	11.6	1.99
Zn-ore (Rajpura)	1.83	10.1	1.88
Al-ore	1.92	11.2	1.91
Fe-ore	2.87	9.9	2.95

However, the optimum moisture content is much lower. So, the optimum moisture content in mine tailings is much lower the densities are much higher, these are higher than soil. That is because the specific gravity is a higher.

So, typically you are getting it between 1.8 to 2, and iron of course, is higher and optimum moisture contents are from 7 to 12 percent. If I take the same samples and I do the vibratory test; that means, I put it on the vibrating table with the surcharge. You have done the relative density test in the laboratory a minimum and maximum. So, this is the relative density test we do find that in under vibrations this 1.99 is similar to 1.97, but 1.99 is higher 1.88 is higher.

So, in most cases you will find that vibrations have a beneficial effect on compaction of tailings. As far as permeability is concerned and these are the results from samples which have been compacted to a relative density of 80 percent which is very high density. Basically you are finding that this is fine sand size range. And then aluminum and iron there must be greater fines therefore, specially in aluminum there must be much larger silt size fractions therefore, the permeability is lower.

So, basically free draining materials, basically free draining materials like sand is silty sands predominant is sand, same thing with the ash predominantly a free draining material predominantly a free draining material, not like clay not like clay. It is not going to take months to consolidate the time for consolidation will be very short like silty sands. And what kind of ah phi dash value do we get? What kind of shear strength value do we get? If it is compacted and from the relative density test. So, I do not thing this heading vibratory test is correct. This is the dry pored minimum density value. So, we will have to rectify this. This is the standard proctor test and this is the minimum density test for the relative density test that we do. So, at 80 percent relative density what kind of phi dash values do we get? 34 33 32 30 38. So, between 32 35 and if I have low relative density this is hydraulically deposited or dry deposited then the values are lower. 32 25 26 25 33 just go back ash and see what was the least values of phi dash for ash 20.

Student: 5.

Yeah, fine ash or ash at the outflow point in the low state would be 25. And pond ash would go from 32 to 40. So, here also please see that the loosely deposited material is from 25 to 33 and the dense material is from 30 to almost 40. So, similar strength to ash and to soils, similar strength to ash and to soils. Is this material plastic or non plastic? What would you expect tailings to be?

Student; non plastic non plastic

Non plastic, it is like if I was to give you a piece of rock and ask you to crush it and crush it and crush it and it becomes rock dust, which is like talcum powder, which is in the silts or a clay size range, would you expect plasticity on a mechanically crushed rock? No, So same thing here mechanically crushed ore is non plastic. So, ash is non plastic and mine tailings are non plastic. So, let us just quickly summarize a brief comparison between ash and tailings. Before we do the summary are these hazardous are mine tailing hazardous. Well, the original ore from which they come is rock which is not hazardous. But there are 2 components to it which are a problem. One is the problem of the metal right. And the other is the problem of the chemicals that have being used to extract the metal.

So, tailings can be hazardous if they have a lot of metal remaining in the end. Now is lead a hazardous metal?

Student: Yes

Yes. So, there are prescribed limits. Under the hazardous waste category there are prescribed limits, if you have your ah tailings waste please do the TCLP test on it, please find out how much lead comes out of it. It means you are trying to see how much lead is coming out of an acidified environment from the tailings. So, if they have left a lot of lead inside and your leaching shows that lead will come out at a level higher than prescribed in the TCLP test then it is a hazardous material you cannot use it for anything; however, if the values are below then you can use it as a non hazardous material.

So, all tailings have to be checked by the TCLP test. Number one, because all of them will have residual metal, but please remember limit for iron will be much different from the limit for lead. So, you are not comparing the same things. That you do the TCLP test and you look at the limit is prescribed there number one. Number 2 we do not know what are the chemical processes that the industry is adopting. So, when you look at mine tailings go back to the industry, find out what are the separating methods that they are using for extracting the valuable material from the rock.

Those chemicals which they add, they must also not contribute to the environmental pollution. So, what will happen is they will add these chemicals they will take out the material which is of use to them, and the balance material is all remaining in the form of a slurry. So, they will add the water to make it more lean. So, that it can be pumped and then it will be sent to the site. What they actually have to do is the waste water of the process has to be taken away, the waste water of the process has to be taken away and treated in a affluent treatment plant. And the balance tailings have to mixed with 10 times the water to transport it in the form of a lean slurry to the slurry pond.

So, some plants which are duly certified for meeting all the environmental standards, the tailings will come out without significant quantity of the chemicals which were used for the purpose of extracting the material. But in other plants it may so happen that some of the material may come out. In that case knowing the chemicals you see to be able to do a test. You have to know what you are looking for, what you are looking for will only come from what they are using in the in the plant. So, you look for that and check the presence in the tailings and if there is if it is present check the leachability to what level it comes out. And then designate them hazardous or nonhazardous. I do know that I have been to a gold mine in India, whether you cyanide for the purpose of extraction of the metal of the gold.

Now, cyanide does get oxidize very quickly to become harmless later on. But the question is once you know that cyanide has been used you got to be very carefully that does not exist in significant quantities in the tailings. So, you go and first look at the process and then look at whether that chemical is being separately treated and the tailings are being washed before they come out. In many cases tailings do turn out to be hazardous, in many cases tailings do turn out to be hazardous and therefore, you need a

Student: Liner

Liner at the bottom; Because you do not want any of these hazardous materials going into your ground water, you do not want any of these hazardous materials going into your ground water.

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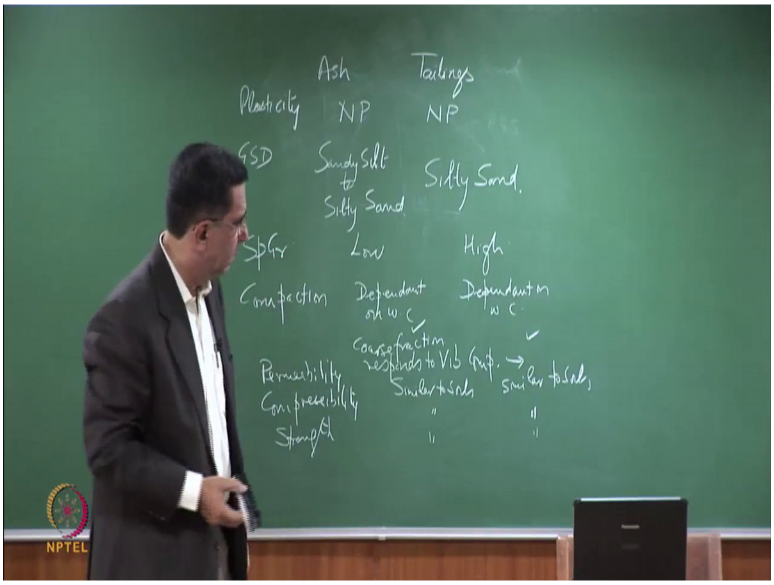

So, ash tailings, please remember this is not the only set of slurry deposited a waste. If you go to Rajasthan there is a lot of marble industry. You know marble is taken out in the form of big blocks right. And you get marble tiles for your homes. So, this block is cut with saws, just like wood. When you cut it when you cut wood what happens, what is the waste material which comes out? Saw dust, similarly when you cut marble with a saw is got cooling water what comes out marble dust. So, there are a lot of marble dust which is around, which is fine like soil this has to be disposed.

So, the marble dust is mixed with water it is already there mixed with water and then it is put into tankers and then it is sent to a slurry pond. When the slurry dries then the dust in the Rajasthan is a hot climate aired if the slurry dries then the marble dust tends to blow and everything around it becomes white colored like or marble colored. Even marble just pure marble cut dust, chemically no problems. We are using marble in our houses. What is the problem? Erodibility dust and rain water erosion. So, the solution may just be putting a soil cap on it. The solution may be just in the form of putting natural soil and vegetation So that it does not become mobile. But we have to recognize that.

So, there are other types of slurry waste which you will also have to address from time to time. But as far as ash and tailings are concerned non plastic, non plastic as far as grey size distribution is concerned sandy silt to silty sand whereas, tailings are normally silty sand. You do realize that in this the second one is the predominant fraction. Sandy silt silty sand means here silt is more here sand is more here sand is more specific gravity low in comparison to soils high in comparison to soils.

Compaction usually there is an OMC, dependent on water content. But in both cases the coarse fraction response to vibratory compaction, in both cases coarse fraction responds well to vibratory compaction. This is also both for this as well as here same permeability similar to soils, compressibility similar to soils, strength similar to soils, similar to soils of that gradation that is what I mean.

So, the causes of concern for us are erodibility to rain, dust and presence of leachable deleterious material. And that we will discuss when we use this for the purpose for design. Whenever we talked that we can reuse this you are talking of a material which is not classified of hazardous any material which gets classified is hazardous cannot be used. So, we will stop here today and discuss design of slurry ponds in the next class, but if you have any questions, will be glad to address them any doubts or questions in your mind? Okay then.

Thank you and we will meet in the next class.