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

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Lecture - 12
Liners for Landfills - Part 3

Let us continue our discussion on Liners for Landfill. And we are spending so many lectures on this, because this is critical you have liners which either work or which they do not work. And if they do not work it is a big problem because you cannot access the base to repair them. If you are living in a duplex house and your bathroom floor begins to leak, then you can always go to the top break down the floor and get your water pipes and sewerage pipes to be redone.

If you do not live in a duplex house somebody else is living on top of you he has no problems, but you are getting the white patches in your roof because his pipes are leaking, but if you are in a landfill, nobody is living under the liner and nobody is living above it.

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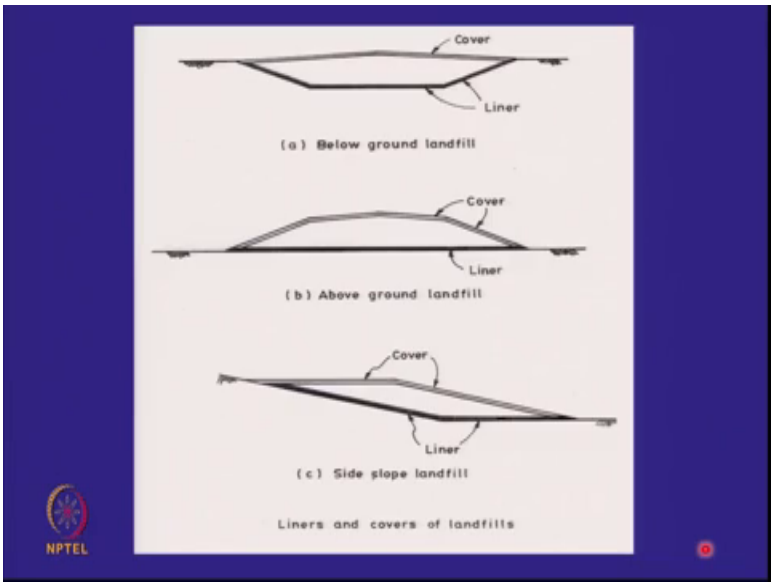

So, it is difficult to repair in such a situation. So, let us spend some more lectures on this and get this. So, just a recap, we have been looking at the liners.

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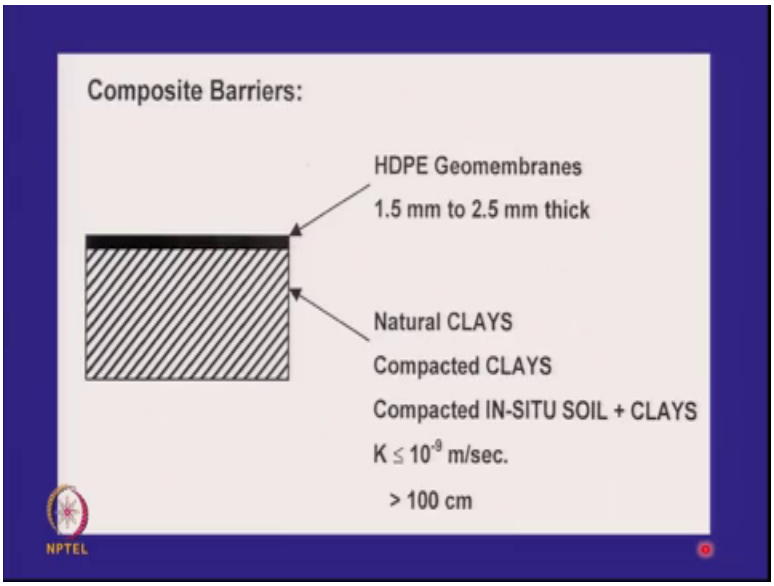

And we have talked about a composite barrier, and we talked about single composite system.

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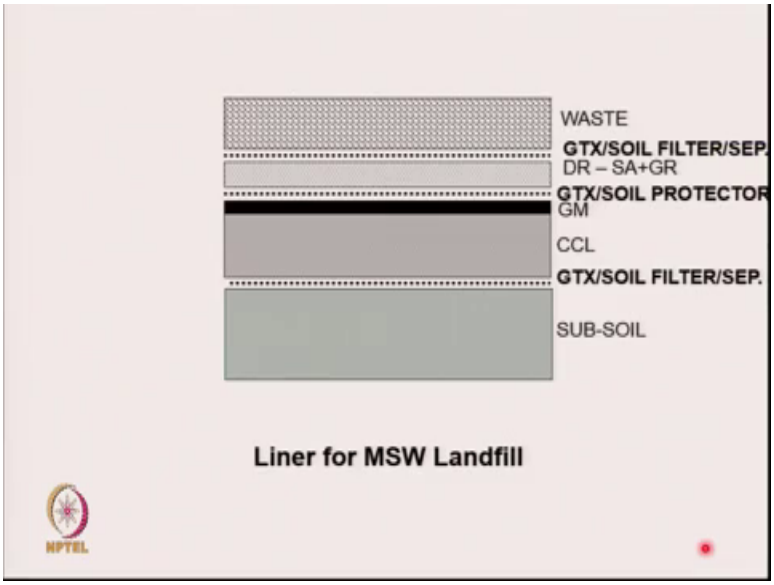

So, this is where we left off last time that if you have a municipal solid waste landfill. You will have a waste you will have a filter separator the leachate collection layer a protector, geomembrane compacted clay a filter separator and subsoil. In a double composite liner this subsoil will not exist again the secondary system, will repeat itself and there you will definitely need this between the coarse grained soil and clay.

Now, you know we had a very nice diagram here which shows perfect geomembrane. Now you have your putting of geomembrane on a football field right. There will be defects it will tear it will have holes you can be very careful about it; you will say nobody will walk on the geomembrane with shoes how do you sign how does that sound.

So, as you can come with cloth shoes or tennis shoes, you know the old tennis shoes light weight light source, none of these hard big boots that we wear. So, there are stringent restrictions as to how do you lay these liners they have to be welded people have to walk on them therefore, all liners have punctures.

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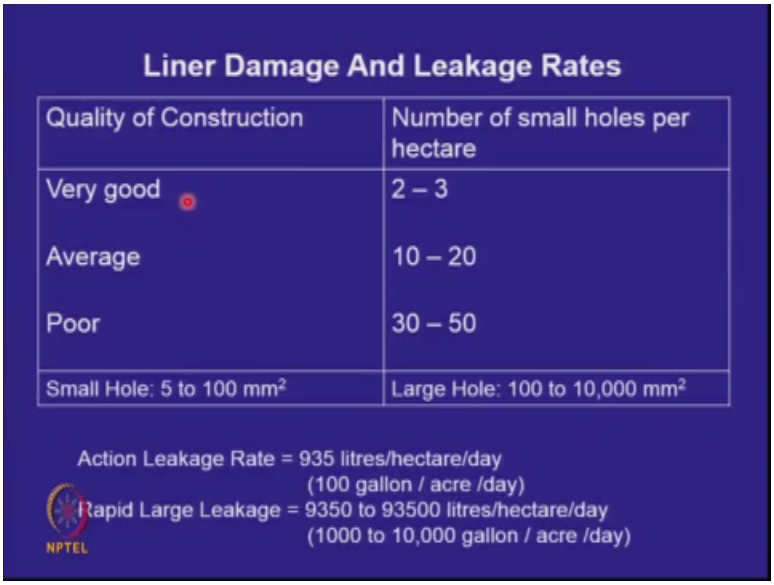

And what it shows to us our literature over the last 15 to 20 years from the developed world is that when the quality of construction is very good. Excellent you will have 2 to 3 small holes per hectare. A hectare is 100 meters. 100 meters like a football field. You have 2 to 3 small and excellent construction all visual inspections everything; however, most of the time the construction is poor. Then you have 30 to 50 small holes. Now that is a lot of holes, but they all they are in somewhere the screw driver fell down somewhere a brick fell down. So, it is all there when you have and what is the definition of a small hole is 100 millimeter square.

So, 10 millimeter by 10 millimeters is 1 centimeter by 1 centimeter, but a large hole is what is large hole hundred millimeter square to a 10000 millimeter, that is hundred mm hundred, mm hundred, mm hundred, mm is about 4 inches by 4 inches. So, that is a tear

in the us this is recognized. And they say if the amount of leachate coming in the secondary leachate collection system that is the leak detection layer is about a 1000 liters per hectare per day. How many how much is a 1000 liters? How many buckets in a 1000 liters? How much is your bucket?

Student: 10 to (Refer Time: 05:03).

I think 15 to 20 liters. So, how many buckets? If 50 buckets come the alarm is on; that means, your landfill is leaking and you have to take action what is the action. We will discuss later and if it continues to leak and it becomes larger you have to close the landfill, if it becomes anything about 10000 liters per hectare, before that you do not take action some leachate will always come in the secondary layer.

Why? Because some holes will always be there and if some holes are always being there something will come out, but that is design. And that our secondary leachate system will take care of this is American practice. And in India whenever I go and talk to somebody whos got a double liner system and say can you share data with me regarding, what is the amount of leachate which comes out in your leak detection layer.

So, nothing comes. So, at least the Americans allow, you to recognize that something comes and I am not going to call that the landfill is leaking. What are they worried about the moment they report something in the secondary leachate collection layer the user liner is not working close the landfill close the landfill. So, there is always an issue of this remember compacted clay is also compacted at OMC or higher optimum. When you put the waste over it also squeezes and gives out it is own water. So, there are liquids which are coming out of it.

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We have done this let us look at a composite liner being laid at one place, this is the landfill at in hemachal, you always get the kind of land.

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That is available and you have to do a lot of earths work for you to understand look at this is the land form.

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So, all this earths' work you have to cut and fill. And you are creating one phase for one year. And here you are I talked to you that if you do not have clay, then you have to mix with bentonite so that you can reduce the permeability. So, here the soil did not have 10 to the power of minus 7 centimeters per second and bentonite is available to us like cement.

Because a lot of people make drilling fluid metro is using lot of drilling fluid for tunneling for making bore holes for pilings. So, drilling; so commercial bentonite is available you can go to a shop and say it will cost you similar to cement maybe half the cost or something.

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So, here you have mixed you have spread the bentonite on the soil. And you are doing what is called increase mixing you are using a tractor with plows.

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And haros something like this a cloud the back; this is not the prescribed method for doing this. Please because India we are doing it because it is the cheapest method, but you are mixing bentonite with the local soil then you will put sprinkle water on it and then you will compact it, but this is called in place mixing to make the soil impervious.

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And we are now compacting it. This is not that a roller you should be using what type of rollers do you use in clays.

Student: (Refer Time: 08:53).

Great, wonderful; so cheap suit rollers are the ones which have to be used not road rollers or smooth steel drum rollers and I have come to that why?

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Now you have rolled it and you made a sump here, but can you get a feeling that this is an inclined flow well that is exaggerated, because I took the photograph by standing a little more inclined. Actually it is almost horizontal, but I took it such that you would feel it is inclined because there is actually inclined in 2 directions you have a slope in this direction also and a slope in this direction and all the water will come here.

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And that is your geomembranes coming in a truck in the form of rolls and remembers my story about not a story, a fact. About the size of the space shuttle and the backside of a horse, but that is because it came by a rail track.

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There are the rolls now you see the way it is being handled you will do not have cuts.

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The geomembrane on the side slope and it is being anchored in an anchor trench at the top and the roll has limited width it is cut to be welded together.

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So, here is the welding going on a people are sitting on it and working on it.

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He is not wearing the tennis shoes, which I asked and this is a HDP when you heat, it melts, it becomes soft. So, you can you can just do thermal welding.

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And there was a he is doing patch welding here there was a tear. So, a batch is being applied.

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I want you to remember this. I come back to this short this is a foot pump. So, he is pumping in air in the joint. Now how he is pumping in here in the joint we will come to later there is a peculiar way this joint is made, but I can tell you whether 20 meters of this length is leaking or not. So, I make a joint it has to be a leak proof joint and in

geoenvironmental engineering or environmental geotechnics, this is the most critical part. The geomembrane is fine the joint should not leak.

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So, we have to assured it is like saying when you weld 2 steel sheets the steel joint should not leave we have to do that. So, now, I on the on the geomembrane, we are putting a protector and I am stitching this, this is nonwoven geotextile. Let me see if I can show this to you on this projector.

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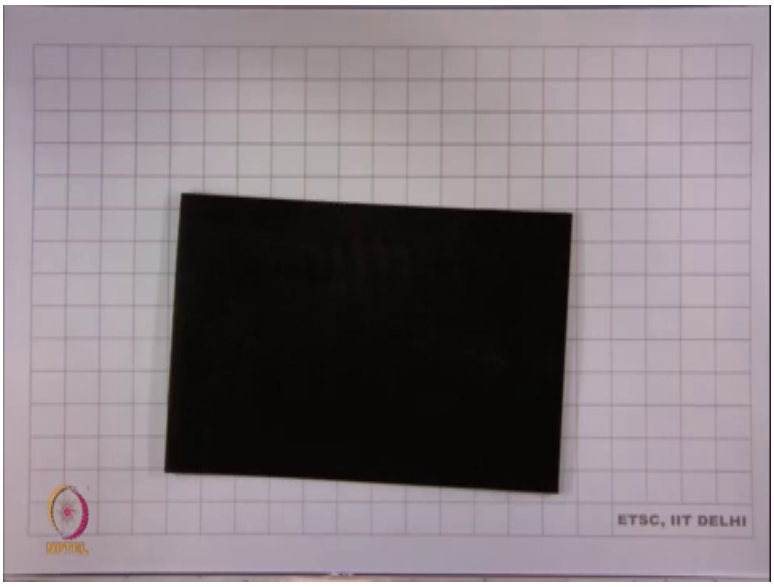

This is a geomembrane the geomembrane is nothing, but a solid thick plastic sheet and it can be smooth or it can be rough. Can you see this it just looks like a square rectangular piece, but it is smooth? And if I put this in the light the light is shining off it can you see. This is a smooth HDPE geomembrane. It is pretty thick you try and bend it and it does not bend. So, easily it is not like the thin funny that you have which is used for making your plastic bag or a vegetable vendor will have on top this will not bend.

So, easily this is a smooth HDPE geomembrane 1.5. This is a textured geomembrane well the texture does not come out. So, well here, but if I now do the same thing as I did can you see the roughness, there is a roughness on the surface and if you feel it will be like a sandpaper. So, this is a textured geomembrane.

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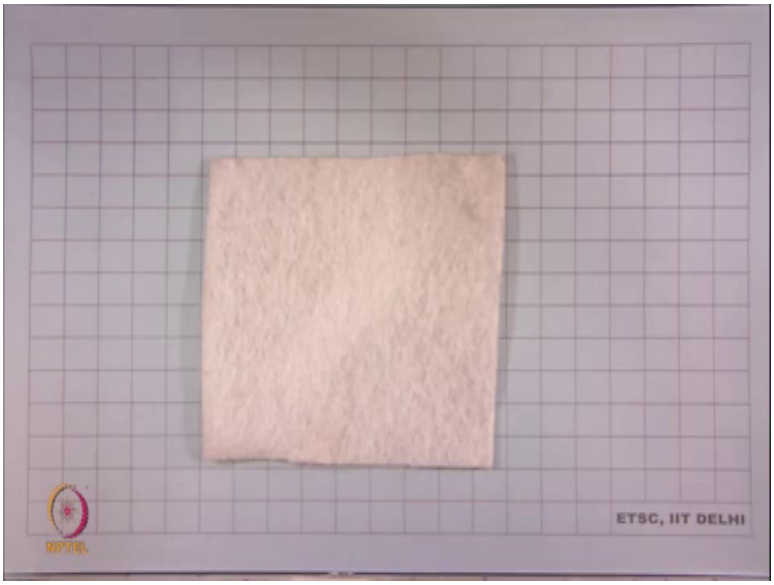

And also are you are seeing something white. As I told you it is like a blanket that is a nonwoven geotextile. You can see thin strands if I just try and you can pull out the strands of filaments from this, but it is like a spongy blankety material. So, these are used in the landfill. This is a lightweight material what you use in the field is thicker than this. That is why I use something called a term called 4 gsm that was 4 grams per square meter.

So, here also, now if I come back to what we were watching earlier that you will see that.

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We have that is the geomembrane that is the joint. That is the nonwoven geotextile being placed over the geomembrane to protect it as a protector and geomembrane and you can see people walking over it of course, he is barefooted and you can see this white protector and on top of it you can see the leachate collection layer and this looks like sand or more.

Student: (Refer Time: 14:14).

This looks like gravel does it look angular or cannot make out well the river, there is a river nearby. So, it is a.

Student: Rounded.

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Rounded, now you can see the soil is complete and it was ready to receive the waste. So, make an impervious thick base, put a geomembrane on it, which comes out in the form of rolls and then make the other elements.

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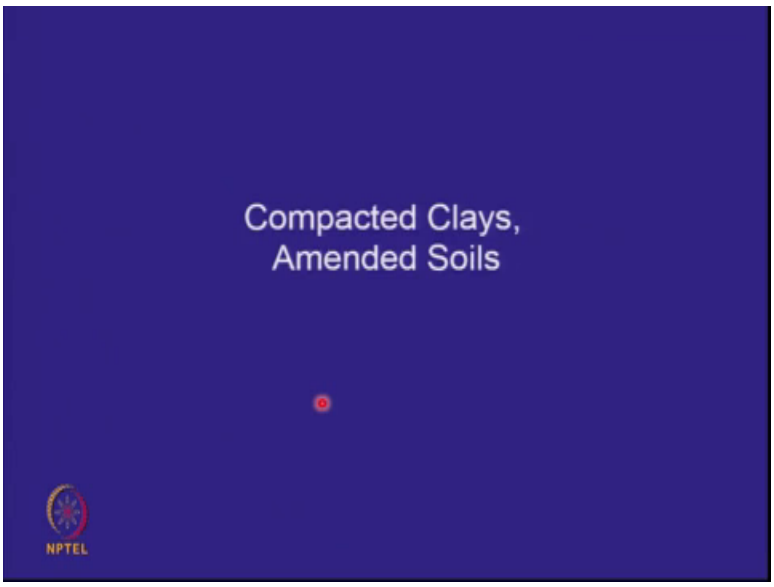

So, for clay we have the following options, because we need 1 meter thick clay.

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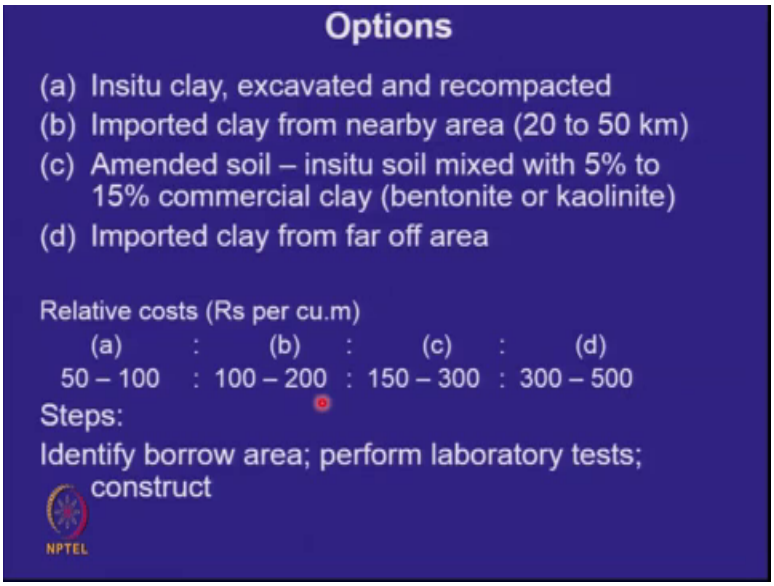

If you have institute clay is very good because you can excavate it and recompact it at optimum moisture content or mode. So, that you can get the required permeability or you may also import clay from nearby areas.

So, clay should be available between 20 to 50 kilometers. In Delhi you would not get play between 20 to 50 kilometers we are sitting on the indogangetic plain. And mostly it is sandy silt and silty sand. Then you do what is called an amended soil, an amended soil is take the soil which is available to you and add 5 to 15 percent bentonite to it commercial clay. Clearly not is not that easily available it is not that effected, but you can add 5 to 15 percent bentonite. And that sometimes brings your permeability below 10 to the power of minus 9 meters per second or less than 10 to the power of minus 7 meters per second. Or you may have to import clay from far a failure right. Now if you are lucky, and this is just a base figure do not treat it as a rupees per cubic meter this is with a base value of 100.

So, if you are in situ play is available you have to recompacted this may be the order of magnitude if you are getting it from 20 to 50 kilometers. This may be the order of magnitude in amending the soil. The main issue is mixing the additive to the soil amended soil is soil stabilization in that it is this is ordinal cost if you have to get imported today from far off it will cost this much.

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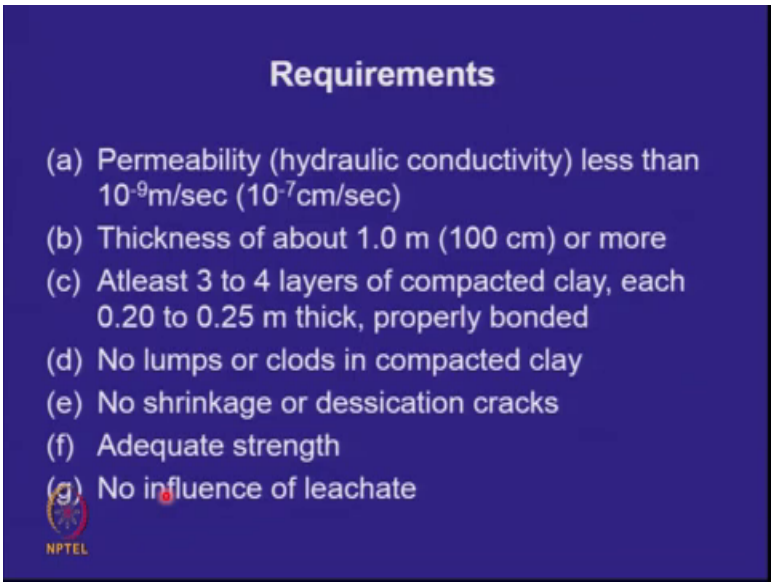

So, the main thing is identifying the borrow area, performing the laboratory tests to confirm the permeability and then to construct. So, the requirements let us not forget we need permeability less than 10 to the power of minus 9 meters per second or 10 to the power of minus 7 centimeters per second. Thickness should be about 1 meter. Now within this 1 meter can you compact you have done compaction of clay what is the layer thickness that you use for compacting sand and for compacting clay. Firstly, what is the type of roller that that you use for compacting sand and compacting clay what role or do you use for compacting sand clean sand.

Student: (Refer Time: 17:05).

So, vibratory smooth steel drum roller just do not use the word vibrator in isolation because you can have a vibrator a cheap suit roller you can have a vibratory pad foot roller you can have a different kind of roller. So, you use a vibratory smooth steel drum roller for compaction for clays, you use a sheeps with roller vibrations have no effect the main issue is what kind of thicknesses do you use for soil compaction.

Student: (Refer Time: 17:43).

What is the layer thickness? Well in sands you can use relatively thick layers if you are using a vibratory roller you can probably use even 60 centimeters thick 45 to 60, but in clays you cannot. So, you typically are dealing with lower thicknesses. So, at least 3 to 4

layers of compacted clay each 0.2 to 0.25 meters thick properly bonded probably bonded means there should be fusion between the old layer and the new layer. And when you compact with a ships root roller the top layer is not smooth, when you compact with a smooth steel drum roller then the layer is smooth.

You remember doing your proctor compaction test you compact one layer, then you do scarifying with your spatula why you want the next layer to be bonded when you use ship suit roller the ships width will create these pock marks. So, you do not have to do any scarify. So, they are properly bonded. The main issue is you should have no lumps or clods. When you excavate clay it is plastic units plastic you get clod sizes. And if you use a smooth steel drum roller it is not going to break up that plot. Especially, if you are using a thick layer, so by using 8 inches of layer and using cheap suit roller you are breaking up the clods.

And therefore, after that you can do the compaction properly there should be no shrinkage or desiccation cracks which means as soon as you compact, please cover with the geomembrane if you compact today and leave it exposed and if it is the high plasticity clay or if it is a clay which shows shrinkage then the cracks will form.

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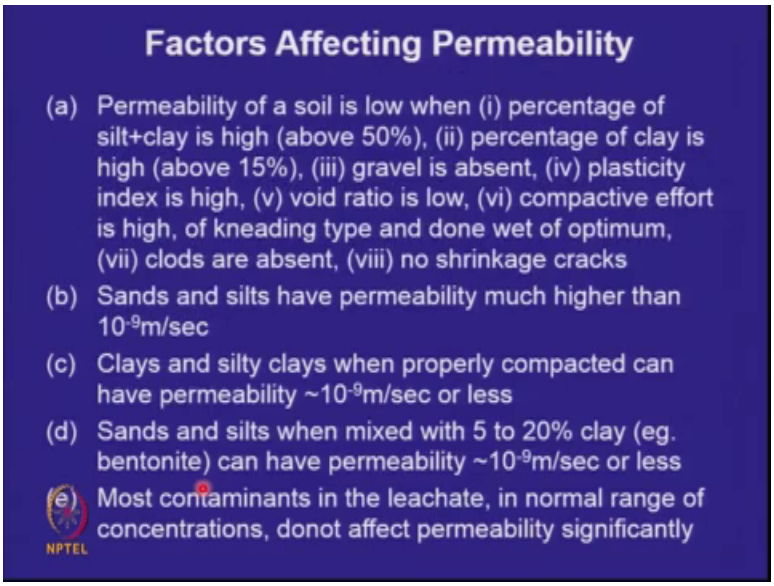

So, critical is compact and cover. And we will look at this influence of leachate extra just in a few minutes. So, a lot of things are written on this slide, but what it says is permeability is low when percentage of silt plus clay is high, when (Refer Time: 19:55)

when percentage of clay is high, gravel is absent, but do not copy this, this is going to be available to you on your moodle. Plasticity index is high void ratio is low compactive effort is high and of needing type. And done wet of optimum clods are absent and no shrinkage cracks. Then you get a good compacted clay liner. Sands and silts are permeability much higher than 10 to the power of minus 9 meters per second, but clays and silty clays have permeability less than 10 to the power of minus 9.

So, this is fine sands and silts when mixed with 5 to 15 percent of bentonitem will have permeability less than 10 to the power of minus, minus 7 centimeters per second or 10 to the power of minus 9 meters per second. Most contaminants in the leachate in the normal range do not significantly affect permeability, we look at this we look at the data on this, but there will be some contaminants which will affect, but most contaminants will not affect it.

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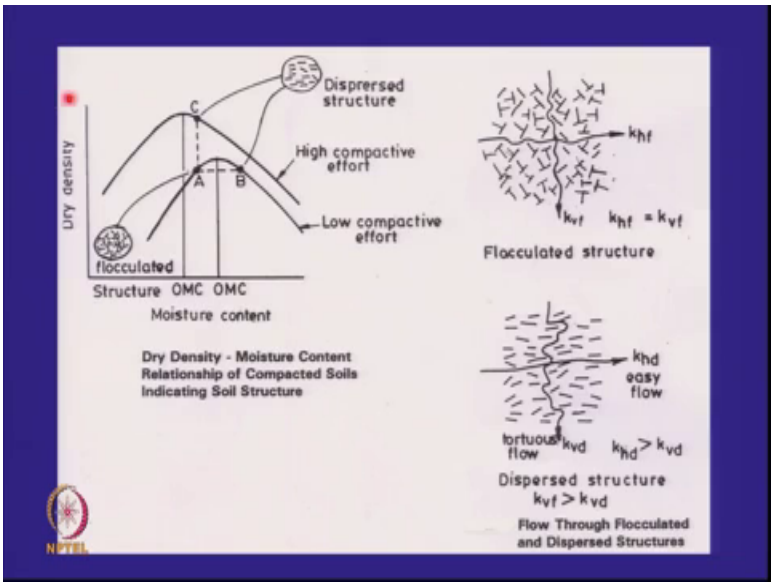

So, remember we go back to our standard compaction procedures; we go back to standard compaction procedures. And this is the light, proctor compaction test this is the heavy proctor compaction test. If you are compacting dry of optimum you are going to get a flocculated structure we all know this if you are compacting weight of optimum you are going to get a dispersed structure. When you have a dispersed structure your permeability is low.

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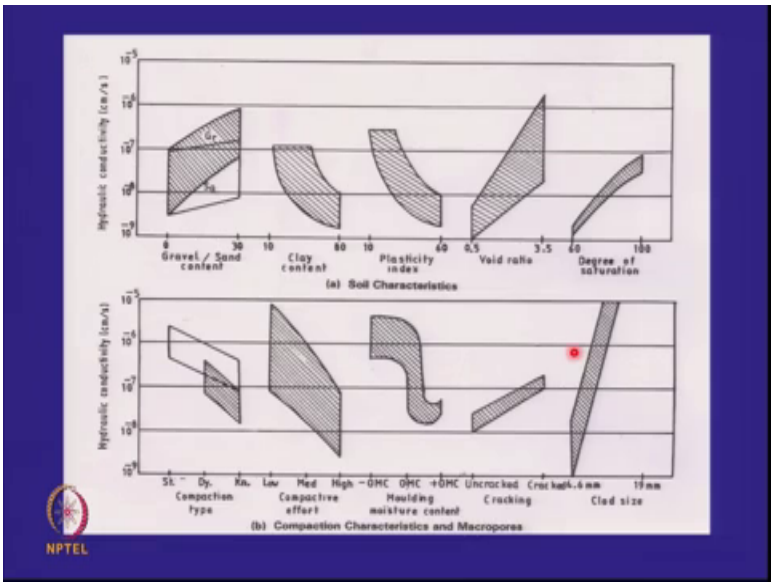

So, we prefer to compact wet of optimum because vertical permeability is lower than the flocculated structure. So, that is an important thing that you should remember. And this is a lot of data which I compiled from various sources, and if you are looking at this horizontal axis as the gravel content increases permeability increases. As clay content increases permeability in the shaded portion is the data from all across the world as plasticity in increases permeability decreases. And remember you have to be below this. Wide ratio increases permeability increases degree of saturation saturated clayey will have more permeability then uncharged if you do a permeability test wrong you wanted to do a test on a saturated soil.

But you are actually doing it the saturation will not complete, you will be under reporting the permeability static compaction dynamic compaction needing compaction needing compaction gives you least permeability higher, compactive effort low compactive effort as the compactive effort increases permeability goes down add OMC minus OMC plus OMC on the west side you have low permeability, if you have cracking you will have high permeability.

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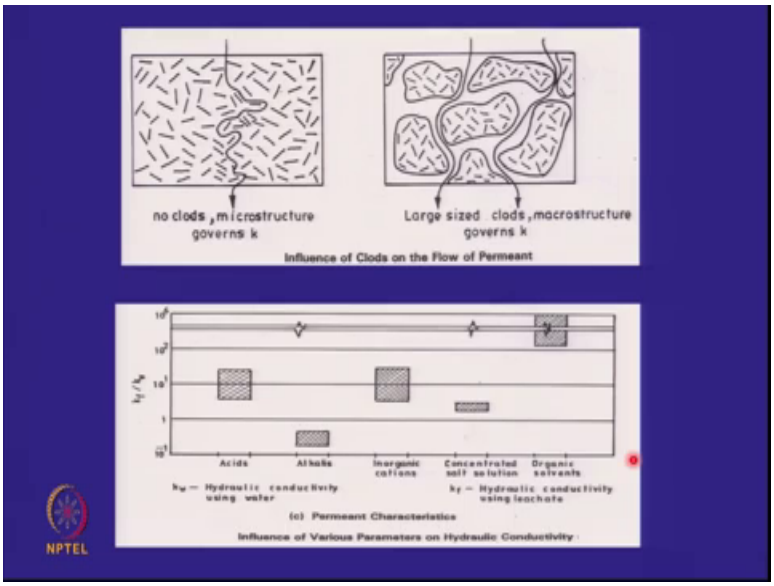

And if you have clods; that means, if you have not broken down the clods then the permeability will be high because flow will take place between the clods have a look at this these are the clods, if you do not break it down the clods effectively function like a coarse grained material. And here once the clods are broken down the more tortuous and permeability is lower, and then the question that we asked how do chemicals affect the permeability of clay. So, this is k with the leachate as a function of k with water. So, if you are higher; that means, with leachate your permeability is higher.

So, it is not good if you are lower it is fine. So, with acids if you see permeability of clays is not much affected. It only 10 times what it was earlier. With alkalize it may not even go beyond the original value. This is the original value of water 10 to the power of minus 7 centimeters per second. With inorganic cations; that means, you have calcium and others calcium chloride, sodium chloride, this may go up a little concentrated salt solutions it may go up a little. So, 10 to the power of minus 7 may become 10 to the power of minus 6.

And this is built into the recommendation that your permeability should be less than 10 to the power of minus 7. Then even if all this happens it would not go beyond 10 to the power of minus 6. However, there is one area that you see here it is called organic solvents and here it goes up to 100 times or 10000 times or more and why does this occur. And this is the most critical aspect that you have to understand permeability.

In clay is determined by what why is it that high plasticity clay gives us low permeability, if I have sand and clay both at the same void ratio, which will have more permeability same void ratio, if I have sand and clay both at the same void ratio which will have higher permeability and why.

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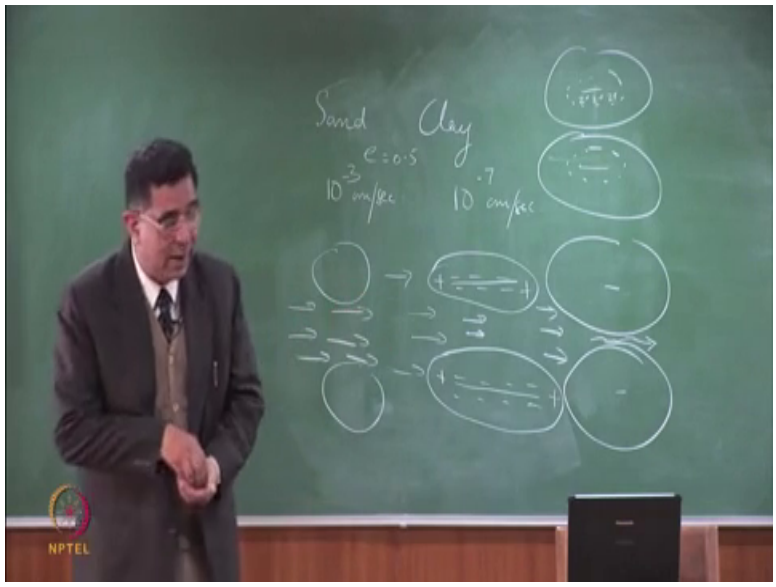

Student: (Refer Time: 25:40).

E is 0.5. Why will stand up more permeability and why. So, much more the white space

Student: (Refer Time: 25:50).

Because of the structure.

Student: (Refer Time: 25:54).

Because the size of the voids ok.

One has less number of bigger voids and the other has more number of solid small avoids. All of them have the same air space because the void ratio is the same volume of voids divided by volume of solids. In both the soils air space is the same. And why should it make such a difference what is the permeability of sand. Typically let me say even, if it is fine to medium sand and clay. So, why should there be a 10000 times change in permeability? Just because the soils are finer; if I take the sand and I crush it and crush

it and crush it and crush it and crush it. And bring it into the silty clay range will the permeability become 10 to the power of minus 7.

Student: (Refer Time: 27:00).

It would not you just want to come that because though you have finer particles though you have finer because though you have finer voids still the permeability will not change by this much a million times. And what is the main difference between the two?

Student: (Refer Time: 27:14).

Sand is inert and.

Student: (Refer Time: 27:18).

Clay is electro.

Student: (Refer Time: 27:25).

So, first is sand is round or sub angular or angular may not be round clays.

Student: (Refer Time: 27:33).

Click like or needle like, but more important is that.

Student: (Refer Time: 27:37).

Clay has large area which is negatively charged. So, here you have sand particles here you have another sand particle. Here you have clay particle here you have another clay particle right. The difference is this is neutral this is neutral this has a net negative.

Charge when water flows through this 2 voids the similar void ratio. The same size is water if you like that when water flows through this what will happen.

Student: (Refer Time: 28:24).

So, for some of the water will get attracted to the clay layer; so if you get attracted to the clay layer and a double layer will form. So, the water will flow through this the higher the plasticity.

Student: (Refer Time: 28:40).

The.

Student: (Refer Time: 28:44).

The bigger the double layer the higher the plasticity the bigger the double layer in bentonite. So, the double layer is the held water the double layer is the held water, therefore the space for the free water is very limited. So, this is smaller space and this hardly has any space. So, the more plastic the clay for the same wide ratio the permeability goes down. It has little to do with the wide space it is the size of the double layer. So, when will a double layer become smaller now that is the critical question, I send calcium chloride solution through the water what will happen to the double layer.

Student: (Refer Time: 29:58).

It will increase or decrease.

Student: (Refer Time: 30:01).

He says increase you say decrease tell me why it will decrease and why it will increase.

Student: (Refer Time: 30:12).

So, calcium is Ca2 plus right and water is electrically neutral. So, calcium will go to the clay it will be attracted to the clay once it gets attracted to the clay. And it is 2 plus a relative less amount of calcium can remove the effect of the negative charge. So, when you send in a concentrated salt solution, the double layer will decrease. Because the 2 plus ions will come and sit here, and for the same bentonite which are these huge double layers, if I put the 2 plus ions here this will become this much. So, first the calcium will go in sit on the clay, the white space for free water will increase and the permeability will go up. And that is why you saw in this diagram that when I have inorganic cations or concentrated salt solutions everything goes above one, but what happens when I have organic solvents organic solvents are nonpolar water is electrically neutral, but polar.

So, a double layer is formed, if there is no water then you have a non polar. If there is non polar fluid which is flowing pure non for polar fluid what will happen there is no double layer, the net negative charge may exist, but the fluid is nonpolar, it will flow like

water. So, that is why nonpolar fluid can make the permeability go up a million times, but luckily for us there is no pure nonpolar fluid which flows through as leachate.

Always there will be some water film always there will be some water no nonpolar fluid, but if you are having a storage tank of nonpolar fluid, then what will happen and all nonpolar fluid. And in the storage tank is leaking then eventually only nonpolar fluid will be flowing through the white space, and then the permeability will become very large. So, that is the problem with bentonite that it is badly affected by nonpolar fluids.

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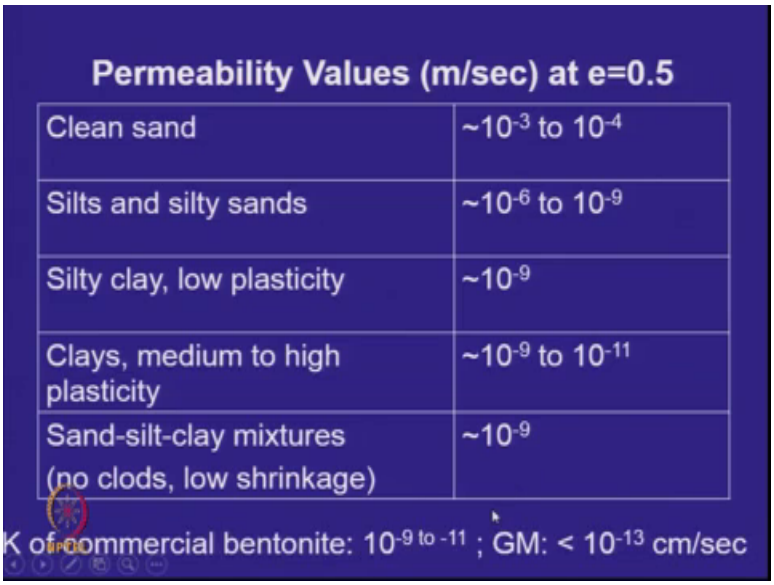

So, I just want to give you this. So, that you remember I am talking meters per second at equal to 0.5 clean sand silts and sand silty sands. We want 10 to the power of minus 9 silty clay, low plasticity clay; clay of medium to high plasticity, bentonite commercial bentonite 10 to the power of minus 9 to 10 to the power of minus 11. Please see here, but commercial bentonite is the one which will be most affected by polar fluid, because the more the net negative charge the bigger the double layer and the more the effect.

So, I would not use for the purpose of my liner a high plasticity clay or only commercial bentonite, because it is extremely highly affected by polar fluids right. I would like to use low plasticity material if it is low plasticity. It is not that effective it is like your crusts, and it is like your clust stand, and if I have sand and silt and clay mixtures. See bentonite will also show high string catch cracks. Bentonite layers are swelling and shrinkage. So, you have issues of desiccation cracks a lot of cracking if it dries up by mistake.

So, we like to make our liners with sand silt clay mixtures; that mean, you mix the silty sand in Delhi, if you mix the silty sand with commercial bentonite or some commercially available clay in Delhi, the nori clay is available, then I can get. 10 to the power of minus 9 that is what I want, it will show no shrinkage no clods, because the plasticity index is not very high, but the fine particles of the clay have sat inside the wide space and it is reducing the path of flow. So, just for our discussion commercial and bentonite clay this is in centimeters per second both of these do remember that.

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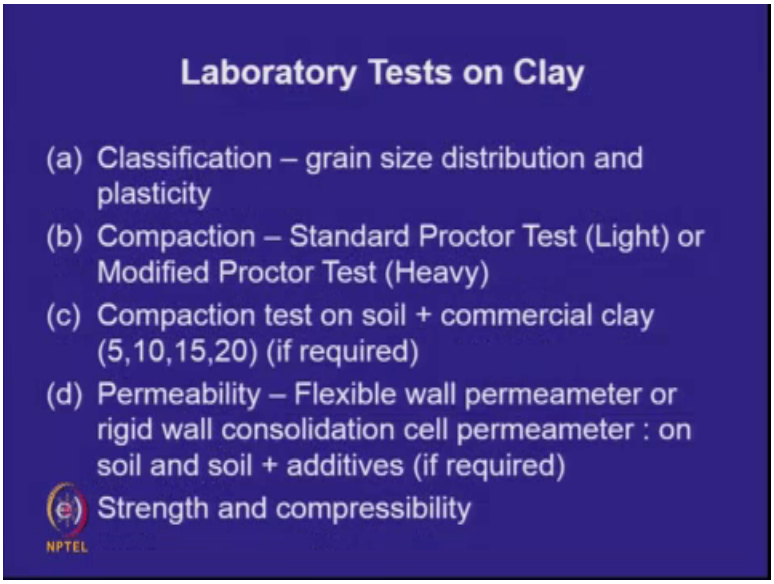

We are now 10 to the power of minus 9 to 11, and 10 to the minus 13 centimeter that makes it 10 to the power of minus 11 to 10 to the power of minus 13 for meters per second, and 10 to the power of minus 15 meters per second for the geomembrane. Eventually we have to perform these laboratory tests on clay.

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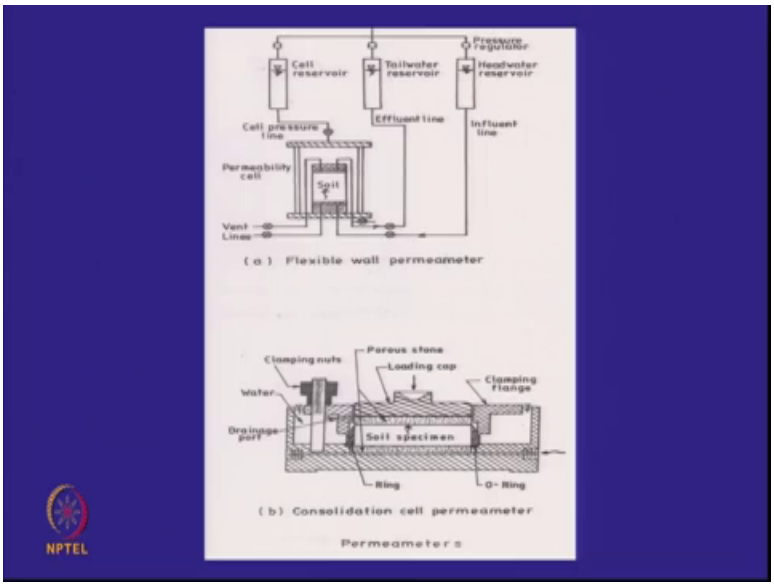

And we have to use some laboratory testing devices for finding the permeability of clay, because we have to assure this 10 to the power of minus 7 centimeters per second.

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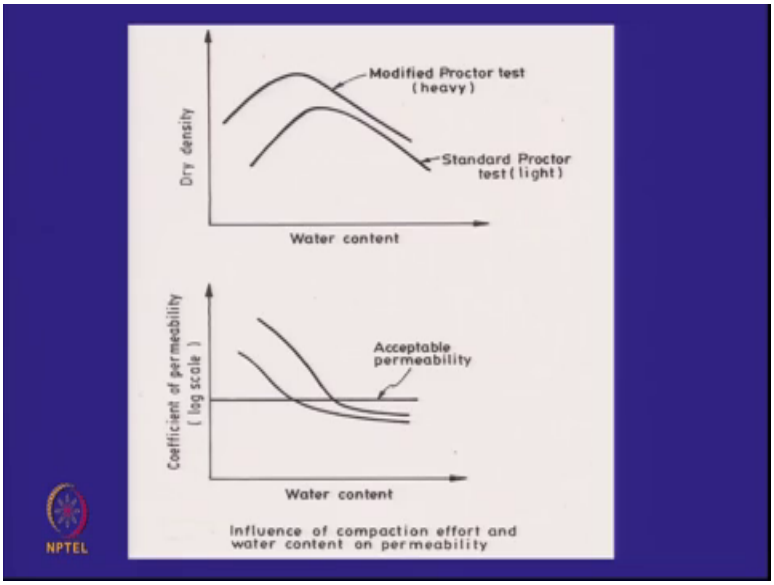

And these are not your standard falling head permeameters or constant head permeameters will do this in the next class. And we have to then work out how do I get the coefficient of permeability below the acceptable level.

So, we have to do this proctor test in the modified proctor test and get these permeabilities.

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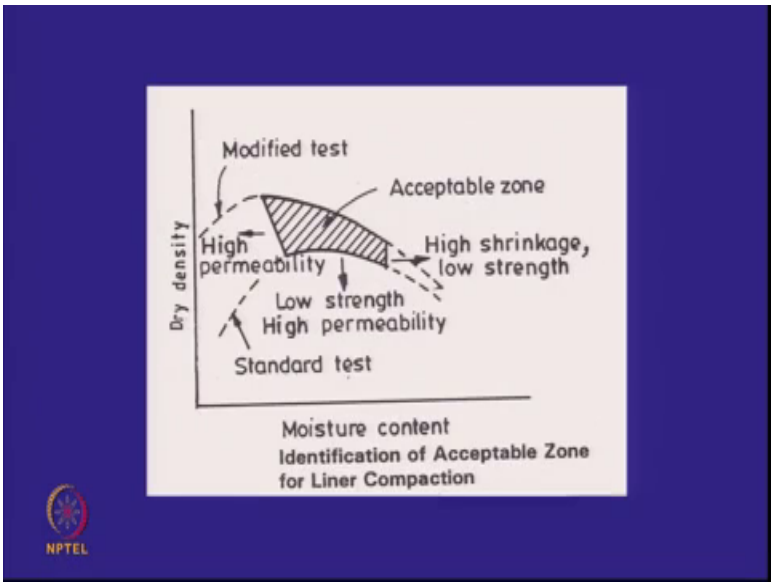

And we have to compact wet of optimum as I told you last time. And here you will be able to find out through your laboratory what is the additive content that you need for example, in Delhi silt we are adding bentonite clay. And you see about 5 percent clay is sufficient for getting the permeability that we need.

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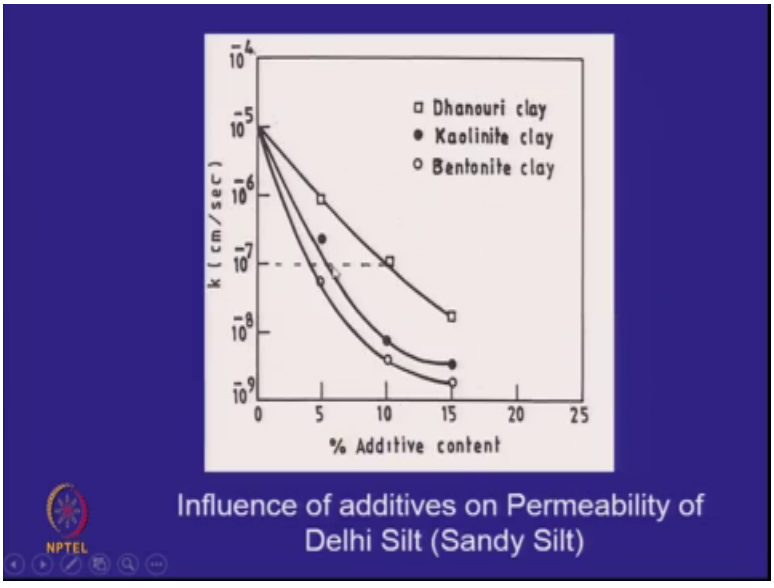

So, we will do this laboratory testing and a little more detail in the next class, but what we found out is it is a very careful quality control condition construction that gives you the good liner. If you mess up on any of the things not good quality clay if you mess up

do not compact it properly you do not mix it properly you do not use the correct rollers you can have difference in the permeability of your material. So, it is a high precision construction quality control job.

So, with this we end this today and in the next class we will take up the permeability testing of clays.

Thank you.