Ground Improvement
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Module No. # 08
Lecture No. # 36
Applications in Filtration and Drainage and Erosion Control

In this lecture, I would be talking about applications in filtration drainage of and then as well as erosion control.

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We have been talking about the use of geosynthetics in filtration and drainage. We have seen some of the design issues that we need to have, we need to examine in greater detail.

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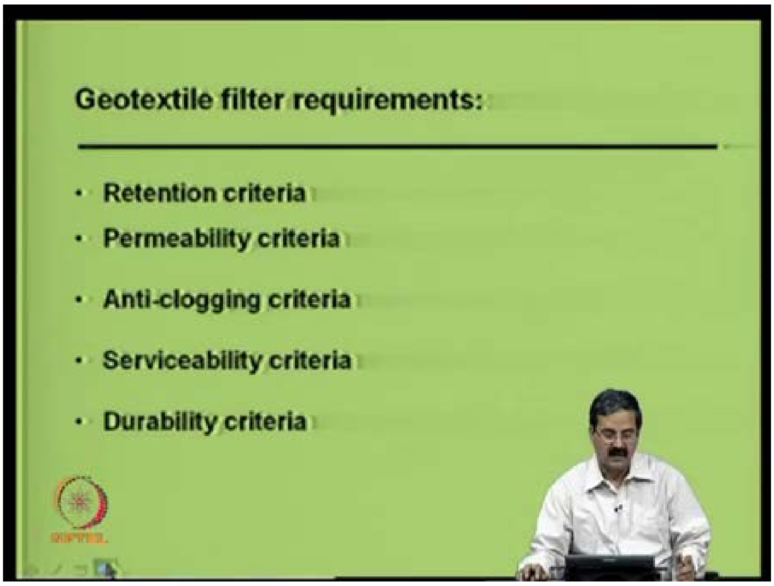

In fact, like we saw that when you are trying to talk about conventional criteria which is for soils, you need to consider soil retention criteria as well as permeability criteria; which means that you should not allow the soils to go out of that medium, and also see that permeability is maintained, which is somewhat contradictory, and when you are trying to consider the geotextile filters, you need to have anti-clogging criteria also like because clogging does occur in even in conventional filters.

So, then it should also when you are trying to use geosynthetic material you should look at serviceability criteria and then durability criteria.

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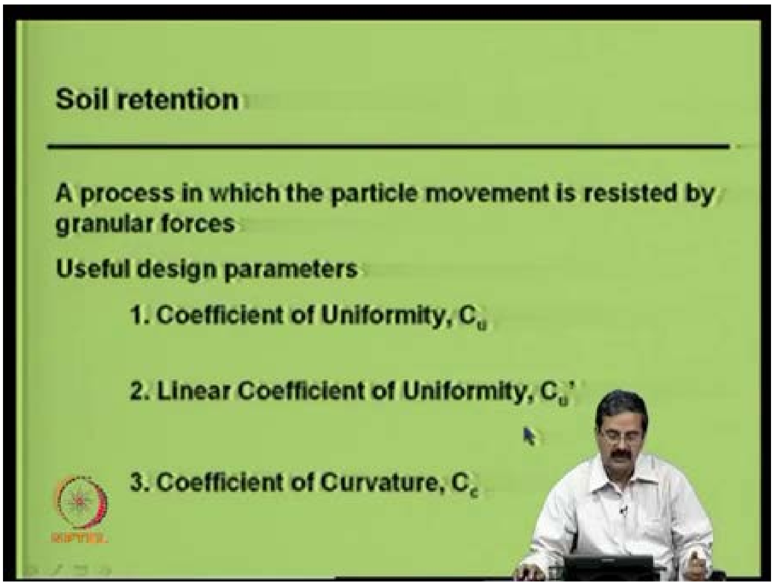

So, these are all some parameters that we have seen earlier that we need parameters like coefficient of uniformity and all coefficient of curvature and linear coefficient of uniformity and all that, in design.

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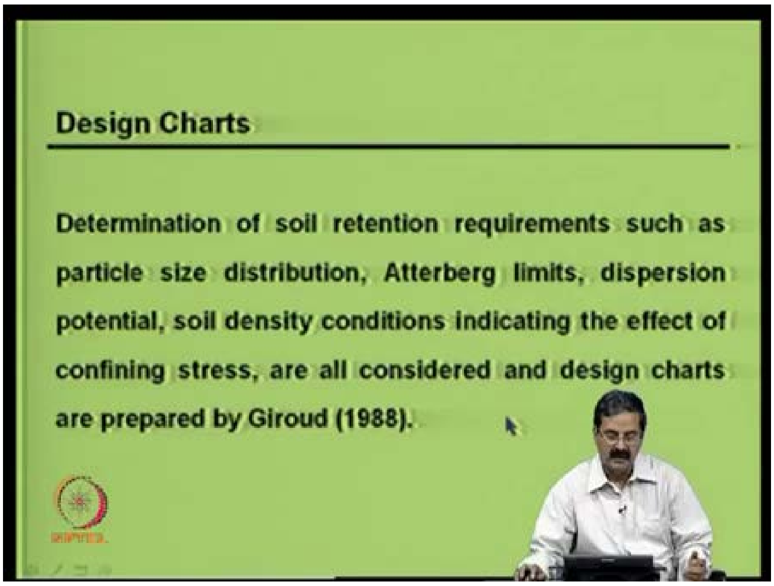

And also we have Giroud charts; charts which are prepared by Giroud, which are very excellent in trying to give this design procedure.

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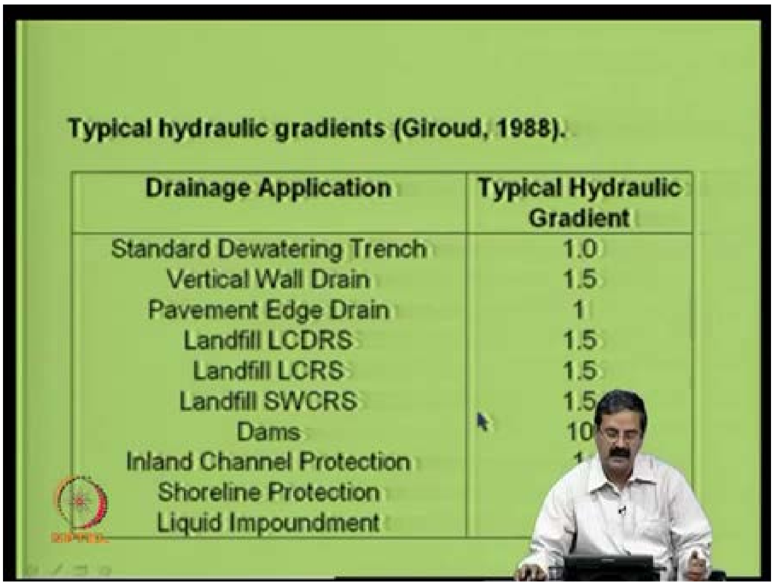

In fact, Some of the contributions in this method are that, they clearly highlight what are the gradients that are there in different types of geotechnical structures like it can be very high in the case of dams, like hydraulic gradient the flow is more if the hydraulic gradient is more and in the other cases like trenches the hydraulic gradient is less and some of these factors have not been addressed in the earlier design procedures.

Whereas some of these ideas on gradients or to some extent incorporated in this design.

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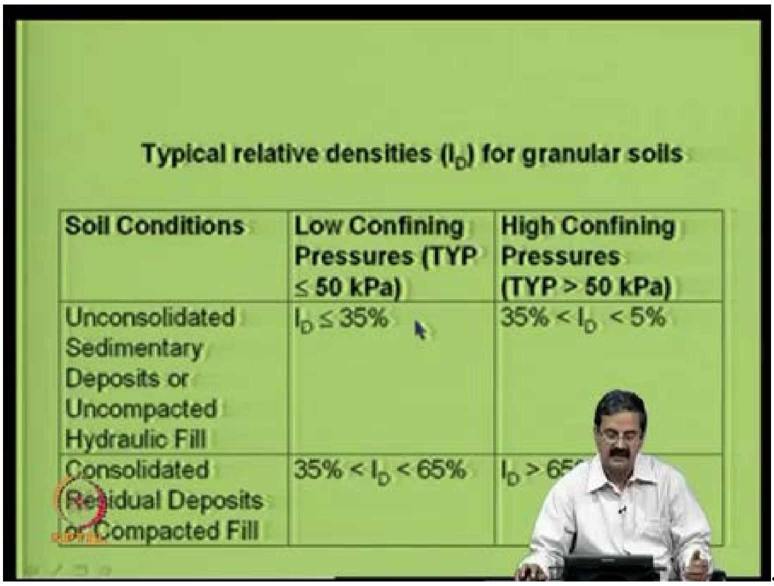

And he also takes care of identifying the stress, the just specifying the grain size distributions alone is not sufficient. He would like to, he emphasizes the role of confining pressure; if the pressure is very low like the relative density is less you know relative density of the materials will be less; but, if the relative density is going to be high, then it is much more pressures are going to be high.

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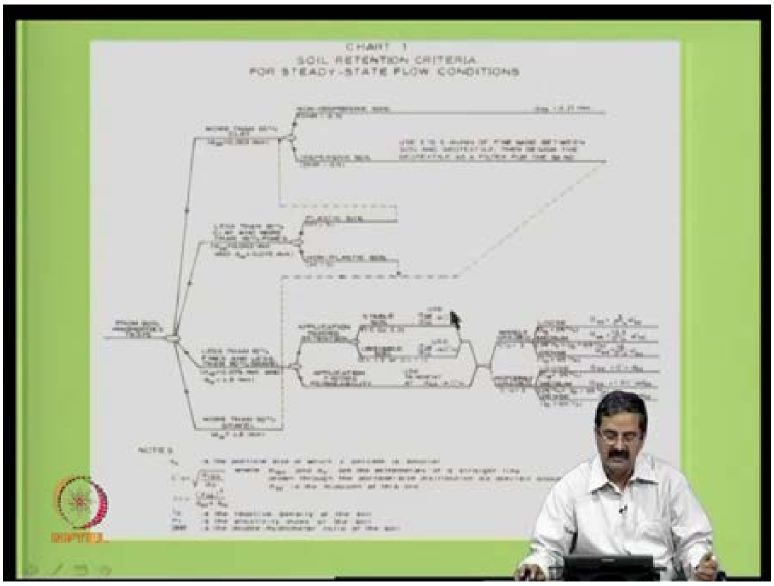

So, he gave some charts which are like this, which are in the sense of; actually, one should pay attention to this soil intention criteria and in fact, we see in the examples that we have, actually I will give that procedure where, you try to take materials in this place of course it is not very clear to you; it is actually, it classifies clearly that the soil should be well graded and the coefficient of linear I mean, this C u dash, it should be more than 3 and it also identifies three conditions; one is a loose, medium and dense; the density is also specified.

As I just mentioned in the previous class, apparent opening size where 95 percent of the materials pass in a particular test is taken as O 95 size. That O 95 size is related to this soil parameters and the particularly the soil parameters such as the d 50 size and all that.

You will see that example, that is what i would like to highlight this particular thing which is quite important and as I said C u dash could be obtained from square root of d 100 divided by d 0. These are all some calculate C C we know that d 30 whole square by d 16 to d 10. These are all some calculations.

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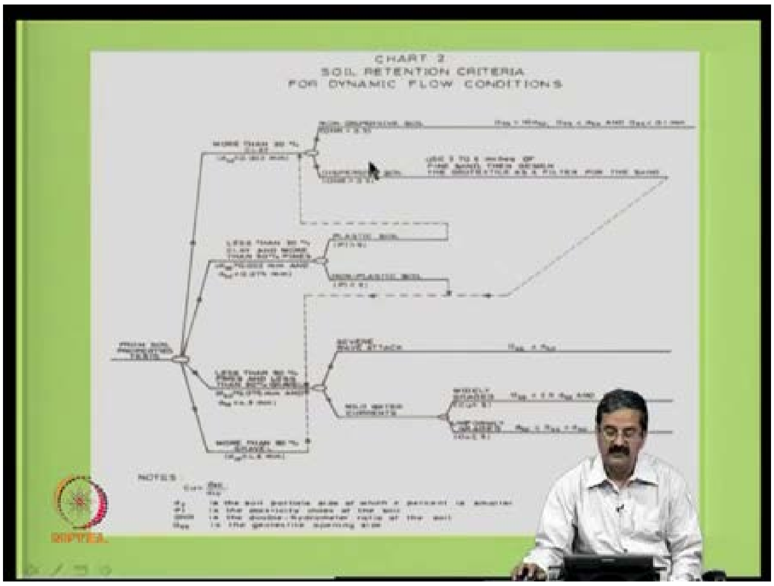

And the flow is, if it is dynamic instead of static like you know, or steady state there is a some more criteria that he has given. So, this is again important.

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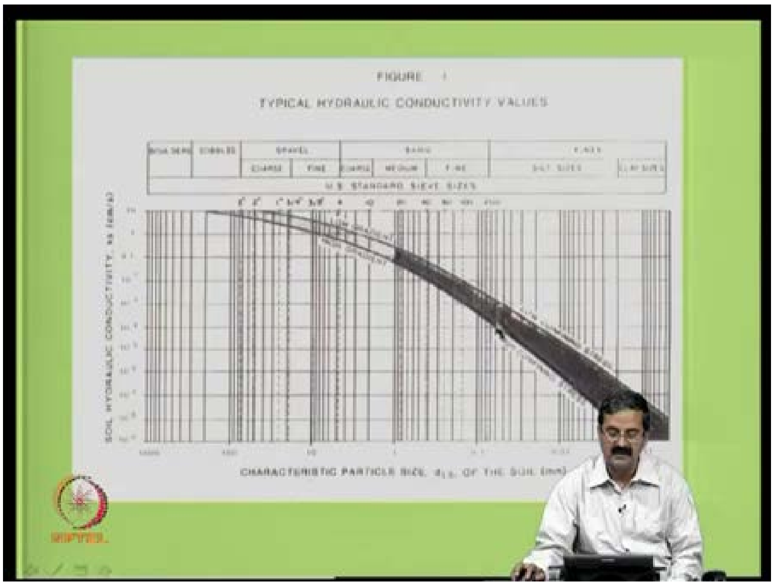

And that there is a relationship that is given, in terms of the hydraulic conductivity and its relationship with the characteristic size of the soil. So, d 15 if you know, you will know the permeability of the soil because sometimes it is difficult to do experiments and if you know the d 15 size, one can do the filter design. Because we need to have the filter permeability criteria.

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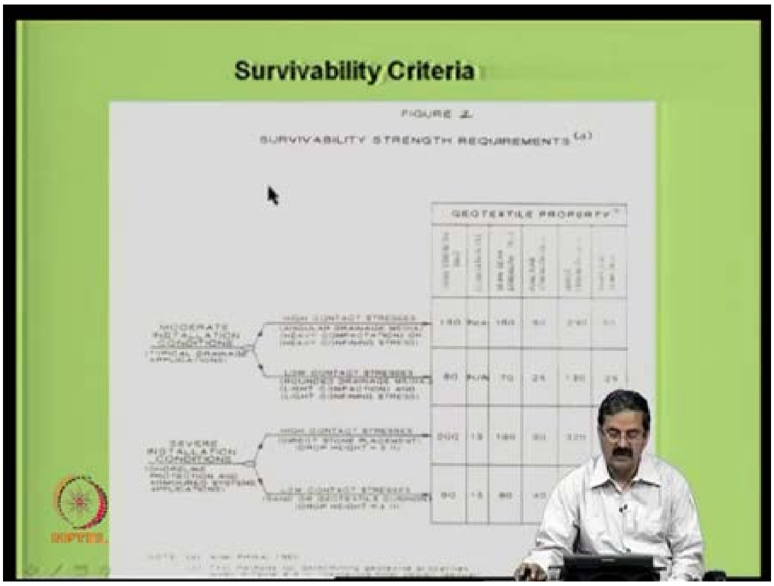

So, he also talks about survivability criteria in which, if the installation conditions are very high, what should be the geotextile properties that you should take is given and if they, there are two things one is a moderate conditions, the other one is a severe conditions. Severe conditions, like shoreline protection systems where there are lot of wave action and all that; then there is in some cases, where there are high contact stresses and low contact stresses; there is again a difference here.

Where, which are in terms of the drop of height you know, some say for example, if you try to put some three take you have a geotextile material you have to put some stone pitching there; say for example, you know in a you’re in a sea shore you have to you know erosion is a big problem in many of the sea beaches and if you want to make a nice slope there, then what they; obviously, what they do is that they try to really compact a sand slope and then put a geotextile and put a stone pitching.

Something like that they do; like a stone pitching can also be little bit cemented in between to see that it is a nice slope that you have; and wave action comes and then touches them; and it should not fail; that particular whatever you have provided that stone pitching and the slope and a whole slope should not fail; it should not just come out because that is an important thing that otherwise it is going to be, if it fails it is the design is not correct.

So, what we try to do is that; we try to do the stone pitching and all that. So, he tries to differentiate the conditions also. See for example, the low contact stresses and high contact stresses, in terms of the drop height and also that in terms of the stone placement and in terms of the sand and geotextile placement; and moderate insulation conditions again on this, in terms of the compaction and other things they try to divide and identify corresponding survivability properties like what should be the tensile strength of that material like grab strength why it is required is that, like I can show you that particular properties where.

All these things are all geotextiles and what you have is that say there is a parameter called grab strength. Grab strength is the load at which it can fail. There is a by you know there are some other parameters like elongation, then seam strength, puncture strength; we have that then we also have what is called a tear strength and all that like you know the you have some standard test procedures; what is the load required to tear it and what is the load required to penetrate it; if you have a diameter of you know, there is you know, you even measure the diameter and what is the load that can clear at a particular diameter.

All that is really measured in some of these products and some of these geotextile and this is what we use. So, the here the geotextile the advantage is that it only allows the water flow, then that is called filtration and its soil is retained here.

So, for all of these materials the strength requirements are also very important because when you’re trying to place all these materials in the field the whatever, it should not get damaged. So, that is the reason why you have survivability requirements.

So, some of these things are given in terms of the strength actually; and many of the products that in the market they have, they follow this and satisfy this requirements. So, i would like to illustrate some of these things with an example. And i do not know whether the.

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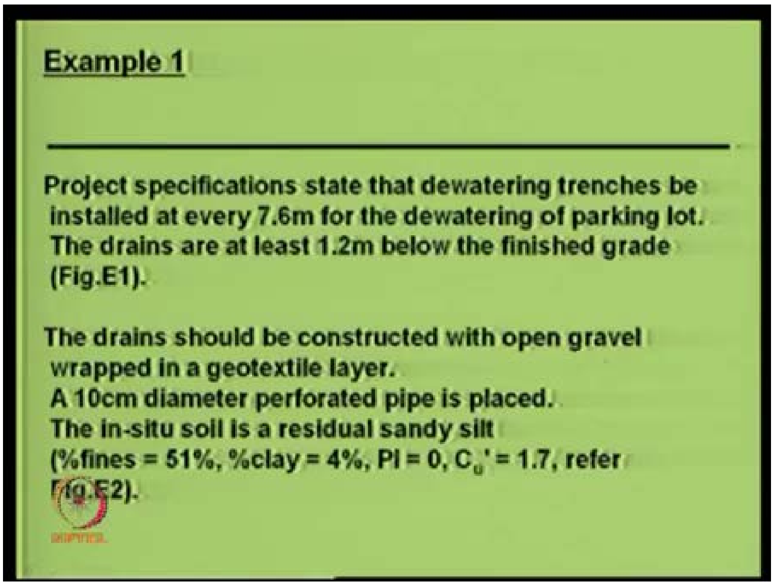

So, the project specifications state that dewatering trenches need to be installed at every 7.6 meters of the parking lot. Actually, for the dewatering the thing is that, if you remember the parking lots are constructed in a low lying area.

Assume that the parking lot is constructed in the place where there is lot of water, you know in previously and there is a possibility that water can come. So, if you are trying to design a parking lot then obviously, you should see that the water is not there at the top. So, you should be lowered.

So, one. So, the design you know you can design how much of ground water lowering is required and say for example, and then you can also come out with the proper spacing of trenches. Trench means a small a vertical cut which allows that you know you have to make lowering of the water table that will enable and then you can remove the water.

So, the purpose of this; suppose a design you can come out with a design which says that the spacing is about at every 7.6 meters in this parking lot, you need to have this trench and the depth of the trench is about 1.2 meters below the finished grade; and you also have some properties like say for example, the obviously, we want to have a geotextile layer here and then that whatever open gravel we have, it should be wrapped around in a geotextile.

That is because that open that gravel works as a drainage medium and you do not want all the clay and other materials to get; they should not contaminate the gravel. So, you would like to have a sort of a geotextile cover, which will help you to see that the drainage of the gravel system is perfectly all right and also see that the soil is not moving into that system.

So, we also have some pipes here and in situ soil properties are known like percent fines is about 51 percent, percent clay is 4 percent, plaster index is zero and C u dash is another parameter that we will see.

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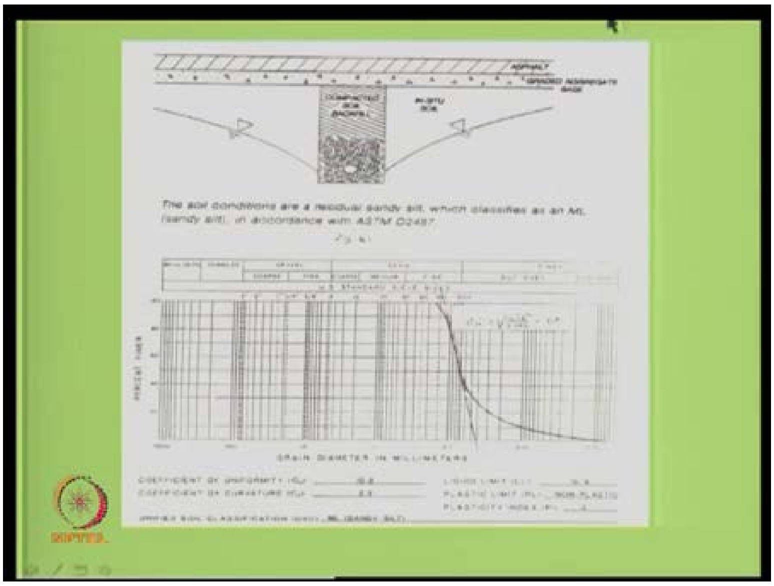

We will see that how it is, like this is that type actually what i want to say like suppose this is you want have a sort of a drain system like this and the objective is to see that water should not be at the top of this; because otherwise it is very difficult to park the vehicles.

So, you would like to lower that and then you came out with a design that, it should be about say 1.2 meters below the finished grade. Then what we do is that, you also have a gravel here and you also have a pipe here and geotextile is placed here.

So, and then you can have a compaction here; compacted sample you can fill it back fill like that and standard procedures can be used. Here instead of the advantage is that this piping system should work very well, this whole system. So, how do you do that; now you have the soil properties like the soil which is supposed to be next to that you have the soil properties.

Say for example, this is a grain size distribution analysis results; and like, from this actually C u dash is nothing but, as i said d 100 by square root of d 100 by d 0 or it can be a square root of d 90 by d 10 all that. So, you can get that number which is. So, you get all these two parameters and then get that C u dash is 1.7.

Coefficient of uniformity is nothing but d 60 by d 10, that is the you can get as 10.8; then coefficient of curvature we know it is calculated, 2.9. So, this is actually another parameter that will help you to understand, as I just mentioned if you remember, this three two parameters will give about the shape and the distribution of the guidation characteristics. This will also give additional information about this, to what extent this material is straight in which portion it is straight and all that.

That is why it is called coefficient of linear uniformity and all that. So, the liquid limit is not there. It is a non-plastic soil and P I is 0 and a sandy silt. So, definitely we know that sandy silts easily get into the gravel. If there is a water table like this and you assume that there is a sand material they enter into this. So, finally, you know it may not be efficient. So, how do you do the design here for this is what we will see.

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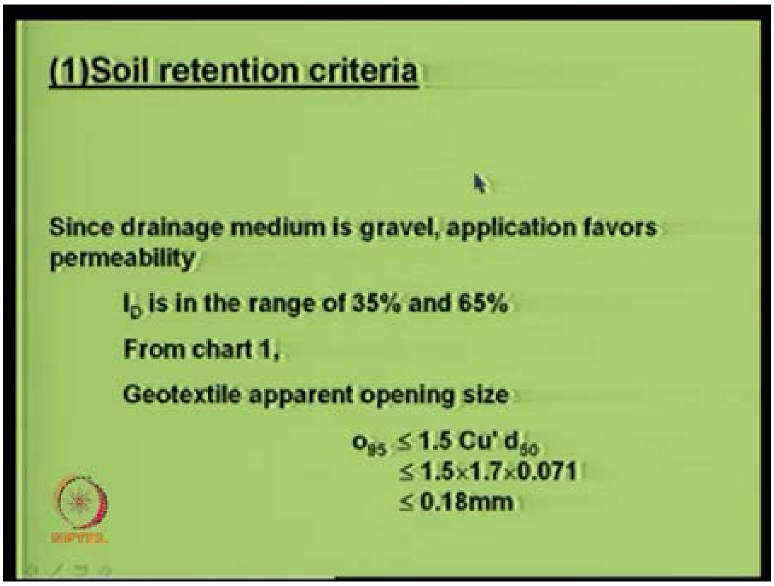

So, here the first step is that our objective is to have the permeability as an important criteria here; and we know that the relative density like this is a small compaction will not be too high because you are just placing a gravel medium here and i do not want to compact it to a very high relative densities and all that.

So, I will just say that the relative densities are in the range of 35 to 65 percent is the range that is given and you got a chart, that i just mentioned which is a Giroud chart; if you just see the chart and based on your grain size distribution properties and this C u dash; In fact, C u dash and all other properties, you finally end up with one specification that O 95 should be less than or equal to 1.5 times C u dash into d 50. This is what it is.

So, 1.5 into C u dash is determined from this thing and d 50 from the grain distribution characteristic is given. So, O 95 should be less than like minimum size is something like 0.18 mm; it should be very small; because our objective is to see that water does not, I mean soil should not go out of this. So, it should be very small.

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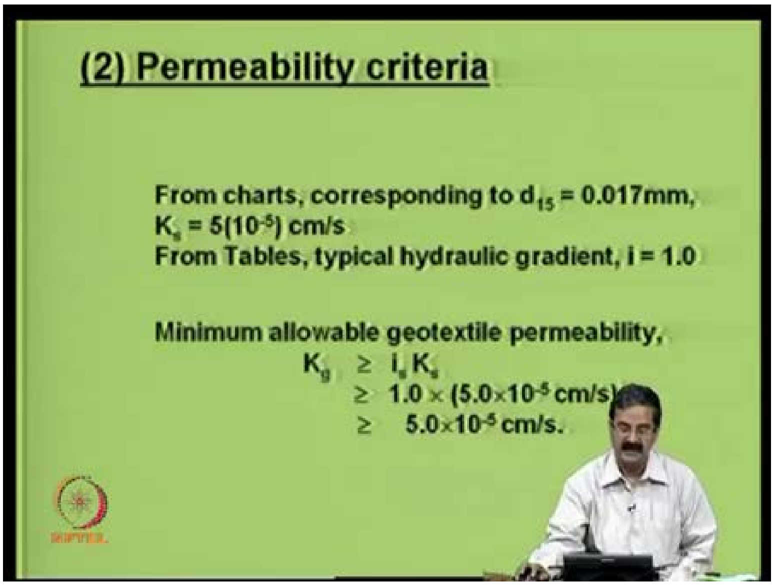

So the secondly, how do you do the permeability criteria. So, from the same grain size distribution you take the d 15 size some from d 15 size like you know, we i just showed you one chart which will give you, if you know the d 15 size you can calculate the permeability.

It will directly read you can read from the graph; and also let us assume that the hydraulic gradient is not very high; The thing is, it is a simple drainage problem of a simple you know parking lot and I do not expect a big hydraulic gradients there unlike a dam or a liquid impoundment where the hydraulic gradients could be higher.

So, what is that permeability value, what should be the geotextile permeability now, like I would like to specify the geotextile permeability now. I specified the apparent opening size of that and now permeability should be must specified. So, the geotextile permeability should be equal to the hydraulic gradient into K s.

So, this value of K s of the soil is known and so the K g is nothing but this thing. K of the geotextile is this.

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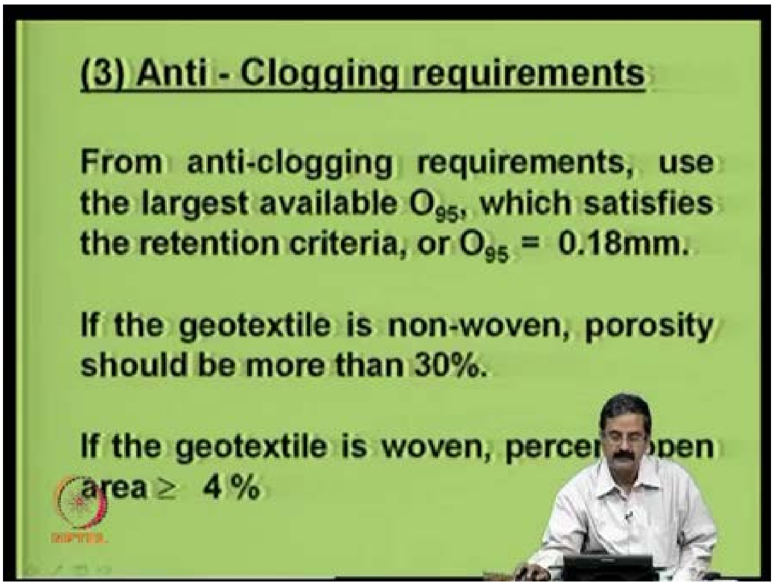

And what we do is that in practice that normally if you just see the geotextile if you go to this particular company and then serious specifications they give permittivity. permittivity is nothing but permeability by thickness. Thickness, higher is the thickness; say for example, you have different thicknesses; here is a thicker one, this is a thinner one, this is much thinner and all that.

So, the K value divided by the thickness will give you the permittivity. So, that permittivity value you check and take the geotextile material and there are two things. One is you have O 95 size and you have permeability size now you are able to see those properties.

Apart from it we should look for other things, like anti-clogging requirements are also important. So, because we do not want it to be clogged we see that we go to the maximum available size in that range. See like 0.18 we have already chosen. So, we go we do not mind going a little extra; like 0.2 it could be all right or something; which is close to this; which is close to this, we will try to take; we have to say that, we have to give a justification.

If somebody asks you how did you really take retention and clogging criteria into consideration, I have to say Sir, i have taken like this 0.18 and I am trying to take a material that can be little bigger than 0.18, like 0.2 I can take.

So, some sort of decision one should make; and the other one that I have is, there are two company, there are many companies that have different types of geotextiles and you need to say for example, each could be, it cost variations there could be many things.

So, once you decide on the type of the company you should just checkup, whether it is a non-woven or a woven; we have seen that there are different types here. So, non-wovens and wovens; if it is non-woven then we say that the porosity. Porosity in the case of non-wovens is important; and the porosity should be more than 30 percent; that is one specification we have.

Then if the geotextile is woven, the percent opening size like for example, this is all weaven woven materials in this case; these are all woven materials and this is all of course woven. So, you can see that the some of this specification should be satisfied to see that, it is going to perform as a good filtration material.

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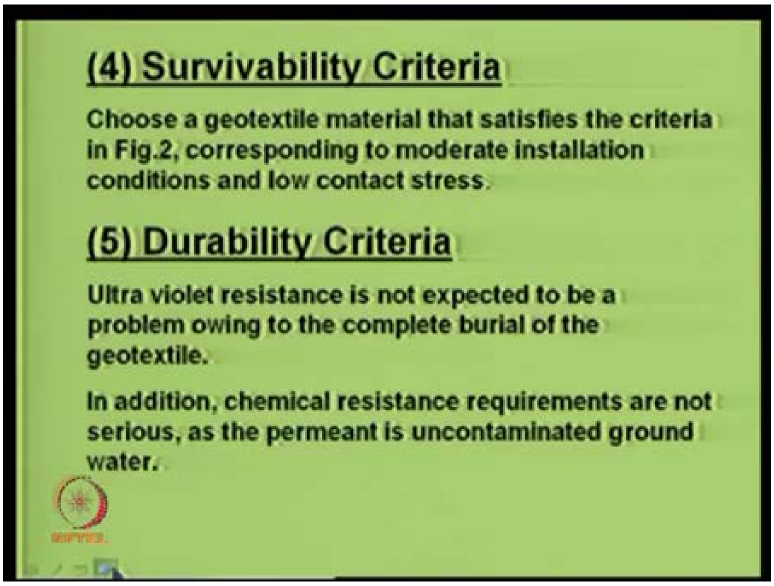

And also see that the survivability criteria we should see that, the company will you know you have already seen that depending on installation conditions you have to specify that the it should have some properties like grab strength and c b r puncture strength and all that you know.

So, it should be able to actually companies will give you that and you just look at the chart and look at the manufacturing specifications then, if its satisfies, it is done and one thing is that you should also get all these tests done by a standard organization like Indian institute of science or IITs or very whatever NITs or wherever you have this facilities one should test all these properties and certify that yes, this material is suitable for a particular application.

And durability is another issue that one needs to see and suppose, since we are placing this geotextile beneath the soil, beneath that gravel and then the gravel cover; as a gravel cover you are trying to put this geotextile you are burying it.

So, exposure to sunlight or ultraviolet resistance is not an issue at all. So, there is no problem. So, chemical requirements are also sometimes important but fortunately in this case, it is you are trying to deal with only water and so, there is no problem.

But in some cases where chemical substances are there and if there are some interactions one should be careful and take a appropriate material. These are all polymeric materials; if there are some chemical reactions, one should see that they will not impede the purpose of this material.

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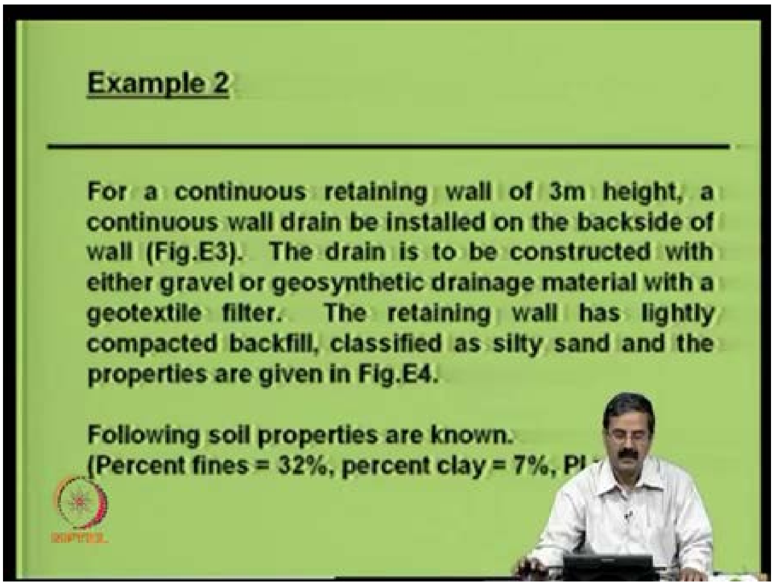

Another example that I would like to give. One is again on a retaining wall, this is a standard application we see in R U walls and other places and the drain has to be constructed with gravel or a geosynthetic drainage with a geotextile filter and then the retaining wall has a compacted backfill and we know its properties; like percent fines and percent clay and all that.

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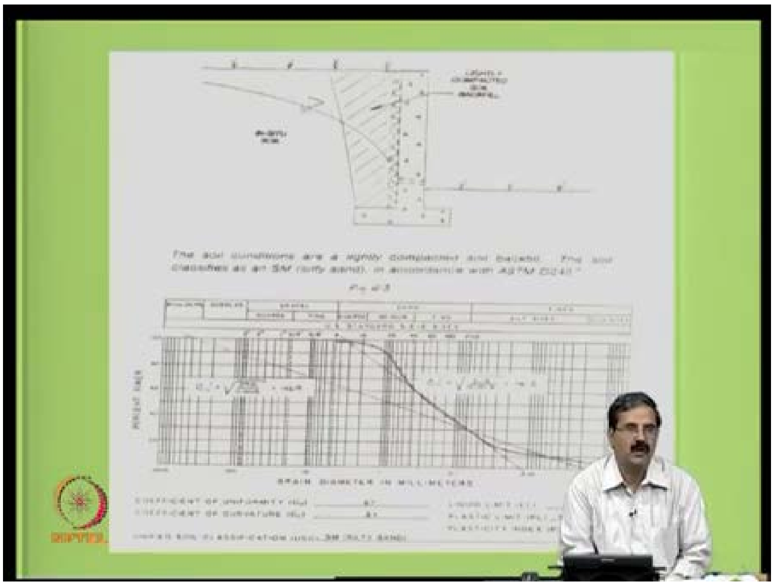

Actually i would like to give an example, where one R U wall, there was a failure of an R U wall they felt that the it is that failure is because of the drainage; because according to the one of the contestants they said that the contractor did not provide geotextile there. The other group says that he has provided only the gravel you know gravel, that is sufficient he did not provide geotextile.

So, I could make some calculations and show that yes, he has in fact, provided a geotextile that was sufficient and then the drainage medium was not required; the gravel material that was required by that either group it was not required; and the company that that person in the particular case study he provided a geotextile; it had the enough what is that apparent opening size all that calculations are done; and i was able to show that yes, though there was a lot of rain and all that, the filter was working; filter was working, it did not fail.

So, this is an example; another example, where you have you the why do you provide drainage behind the retaining walls otherwise the seepage pressures also should be considered in design; it is not gamma h square by 2 is what you do; again you have to take into gamma W h square by 2; like saturated weight water pressure also should be that whatever is a water pressure due to that also should be considered; which is going to be very expensive. So, best way is to drain the water and has proper provisions.

So, like the soil conditions say that the soil is compacted, lightly compacted because particularly as I said close to the retaining wall and the R U wall or any of these things particularly in R U walls, we do not have high compactions because the it will affect the panel.

In this case yes, good compactions is all right, but normally we do not do that because when you have a drainage material here; because of the compaction it should not get powdered or drainage wall, drainage pockets should not get closed.

So, again we have done that same analysis you have the grain size distribution properties are all there. Coefficient of uniformity, coefficient of uniformity is there. coefficient of curvature is given liquid limit is not there; and non-plastic material again it is a the material is silty sand, you try to identify the good backfill which is supposed to be a sandy material as a back fill and you do not want to see that it clogs many of the weep holes here. You also provide weep holes. So, weep holes should not be clogged.

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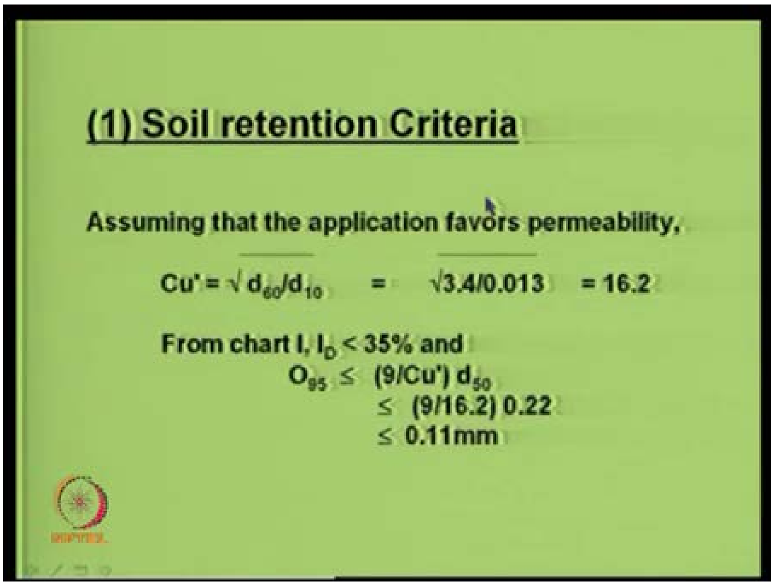

So, how do you do that again you go back to this and C U dash is, again you get this parameter and you can get it is 16.2 in this case and I D, that relative density is less than 35 percent. So, according to that criteria you have any simple equation like this. So, O 95 will come to 0.11.So, O 95 size will come to 0.11 and that is fine..

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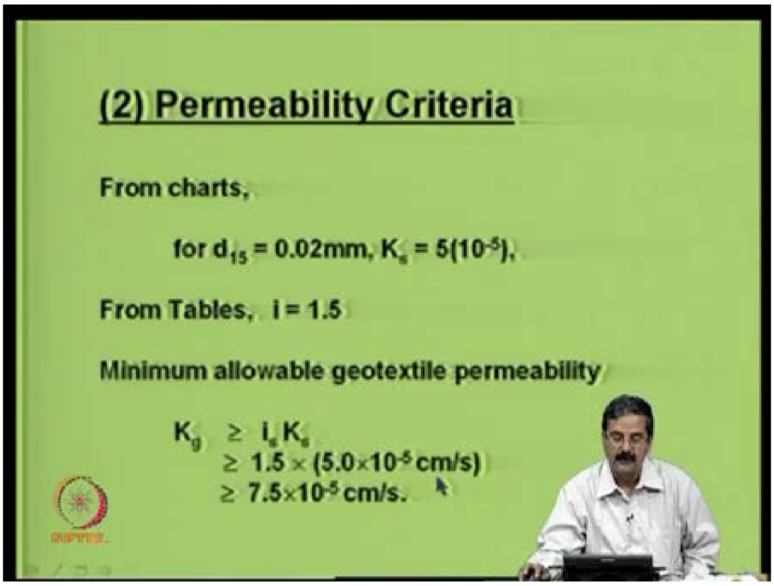

So, again permeability characteristics we get d 15 size and if K s again you calculate from the charts and we also see that. So in this case, the retaining wall we take a hydraulic gradient of 1.5; then calculate the properties of the geotextile required.

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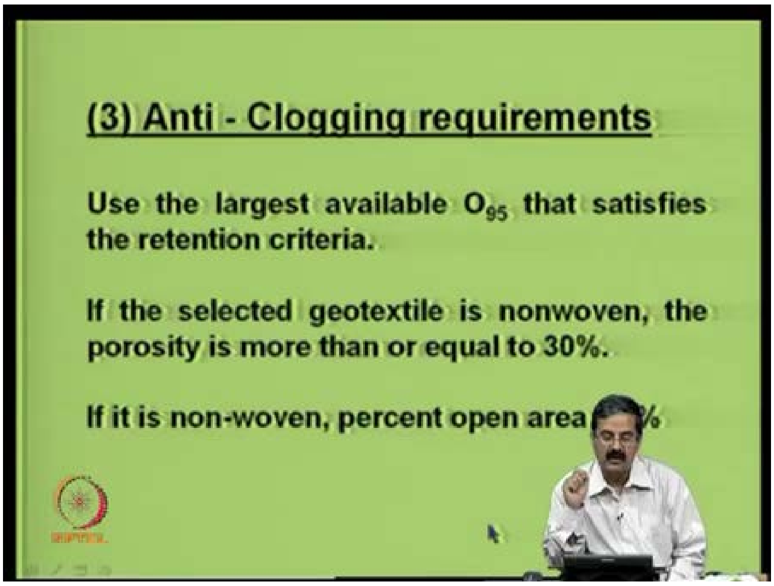

Then, the anti-clogging requirements as I said, we try to go the largest available size that satisfy the retention criteria; close to that or slightly higher. The second thing would then if the we also try to select; if it is non-woven, the porosity should be more than 30 percent or if it is non-woven, the percent opening area should be more than 4 percent. So, we try to follow this criteria, you know in specifications and then come out with that.

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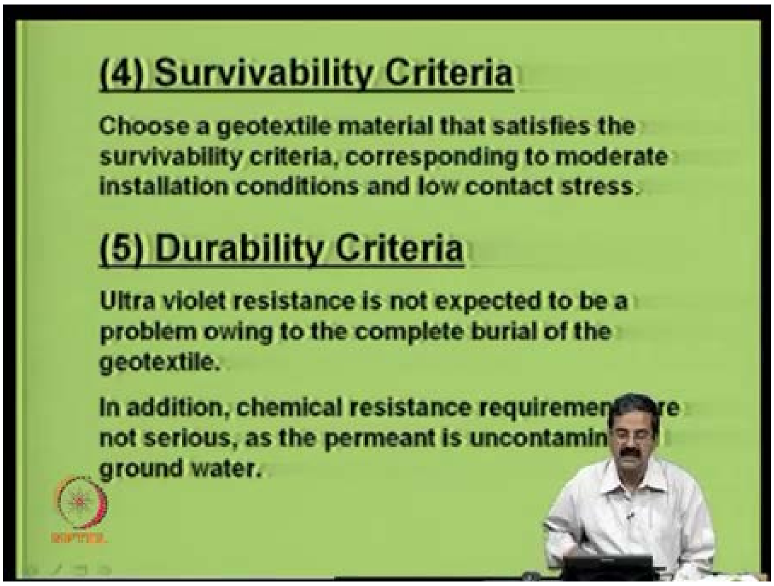

And also see, like again check for the survivability criteria see the charts and see if in this case particularly the retaining wall, it satisfies the moderate installation conditions and low contact stresses. As I just mentioned retaining walls or say for example, you are trying to construct a retaining wall next to the sea shore.

Now, that condition is totally different; and you are trying to put a stone pitching also and then there dropping of stones is there; there are somewhat different. So, the filter criteria that chart you should use will be different here, in if the flow is dynamic.

So, these are all very important and the durability is also if you consider particularly in this retaining wall problem ultra violet resistance is not expected to be a problem because you are trying to put the geotextile in the soil itself. It is not exposed. So, there is no problem of ultra violet resistance and even chemical resistance is also are not serious because the permanently is uncontaminated; like water is not contaminating this material.

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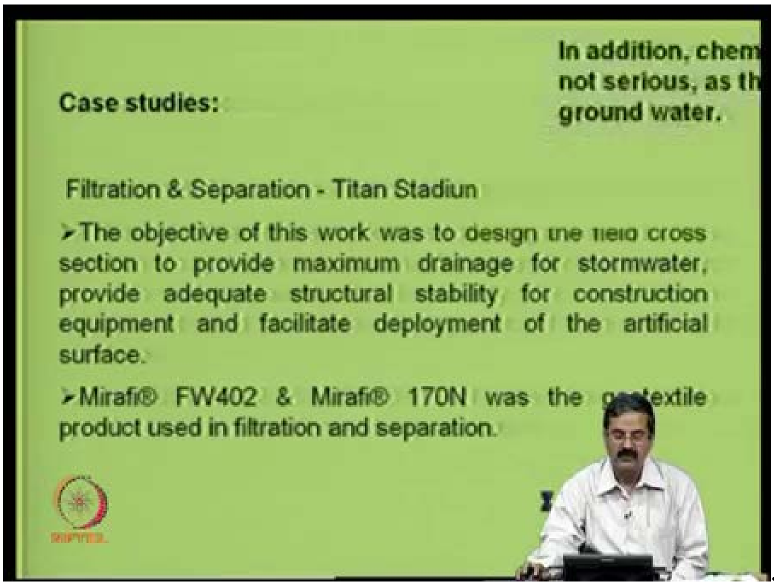

So, with these two things one can understand that yes, one can scientifically design the geotextile reasonably well. In fact, there are have been efforts to come out with some more rational methods and lot of work is being done on this lines.

Now, I would like to just show you a one case study, it is like a stadium; see the thing is that we know that say for example, the drainage in a stadium is a very important point; like nowadays you have a forty thousand, fifty thousand people watching cricket matches and all that; and if there is a rain and you should be able to drain off the water very quickly; otherwise the problem is that there is you know it is a disappointment to spectators and financial loss to the stadium operators.

So, in this case the field section was the objective was to provide maximum drainage for the storm water and to provide adequate structures ability for construction equipment and facilitate deployment of artificial surface.

In fact, couple of things are there here; actually this is I must thank this company for giving this case study Mirafi and they have used some of these materials which is used in this case.

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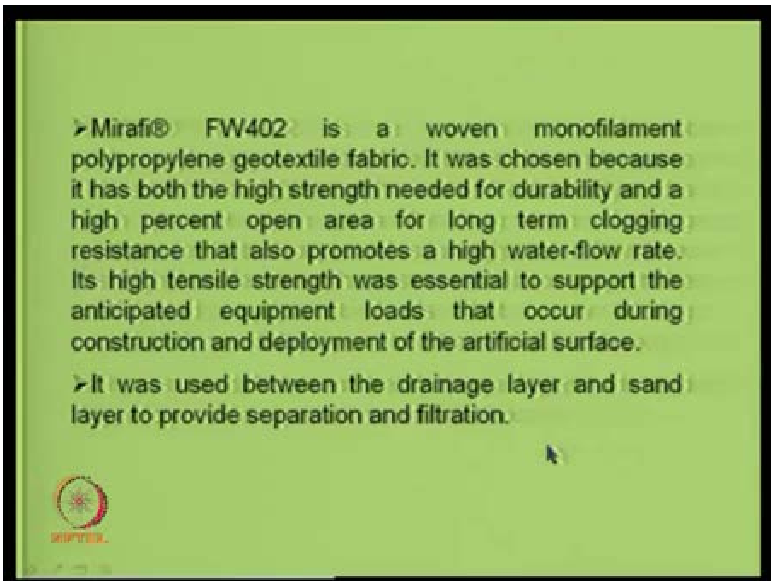

We will see that actually this particular compound is a woven monofilament polypropylene geotextile fabric. It was chosen because it has high strength required for durability and a high percent opening size; for long term clogging resistance and also permits high water flow.

The water flow like the other day I was showing you the difference between a conventional geotextile and conventional filter and a geotextile filter. The water flow is a very important variable. You must be able to, porosity is one thing but water flow is another thing.

So, you may go for a high porous system but then it should also be stable. So, there are some issues; that is a reason why geotextiles are excellent as filtration materials and the it is high strength was essential to support the anticipated equipment loads and that occur during construction and deployment of the artificial surface.

In fact, your this is an artificials they are trying to have a stadium where the artificial surface is being laid; and that during construction and all that there are some loads that are there. So, the geotextile or a geogrid or whatever that material should take care of the tension; must have enough tension to see that the loads during construction are taken care; plus it should also provide for equipment loads you know say some, a few people are playing and then there is some equipment you know rolling and all that is there one should have that strength.

So, it was used between the drainage layer and sand layer to provide separation and filtration. So, the geotextiles whatever was used to provide filtration drainage filtration separation. Actually, I must tell you that any of these materials they serve the separation filtration the both functions simultaneously; because this is a different layer you are just putting as an interface, it serves both separation and filtration simultaneously. The way it is done is like this.

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You can see that, sand is being put and all that it is all the equipment that is there.

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You can see that installation of the this material and you can see that scoring sheet here. So, installation of that material here.

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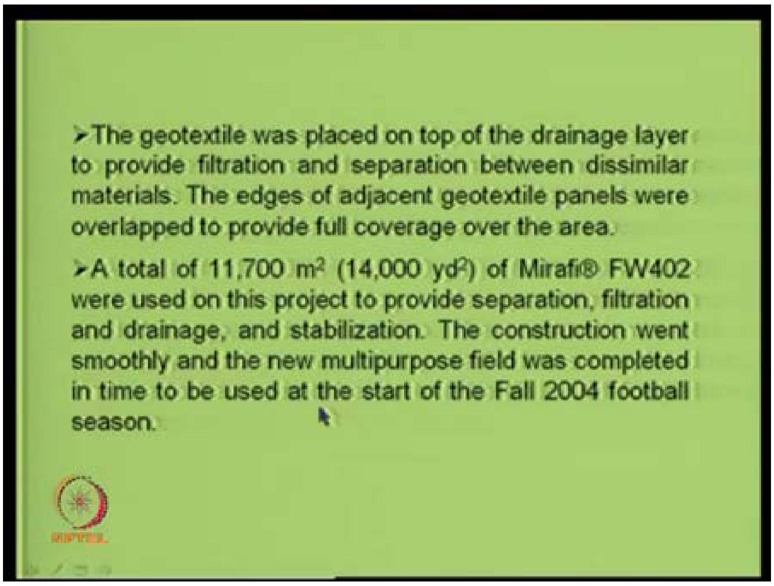

So, the geotextile was placed on the top of the drainage layer you have a drainage layer is a sandy layer like in the previous example, you had gravel and around the gravel you had a geotextile.

So, here on the top of the geo drainage layer, you have a geotextile and it provides both separation and filtration; separation filtration. So, the edges of the adjacent geotextile panels were overlapped to provide full coverage for the area; like normally these are all available in some square meters and all that you must be able to see that there is an enough overlap and also proper joining such that, there is no problem of leakage or any other issues associated with that.

So, they have used significant quantities like 11,700 meters square which is quite big. So, it was used to provide all these functions and the it was able to you know for the Football season it was getting ready.

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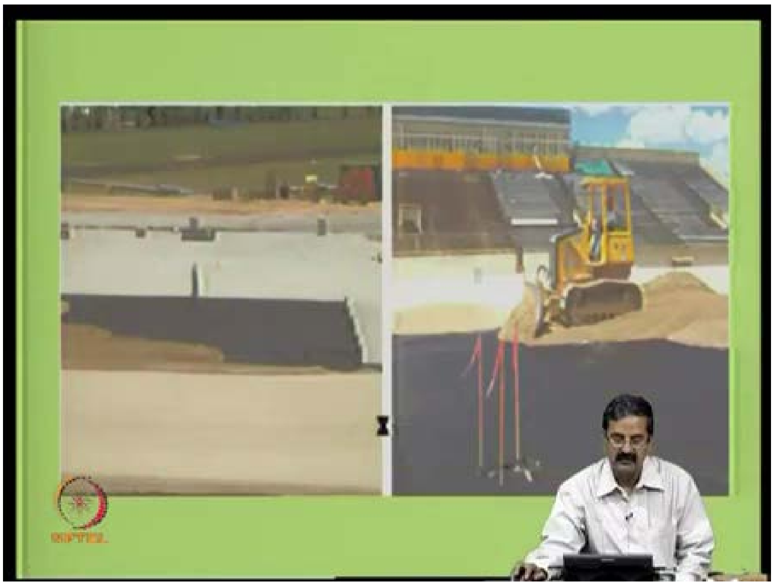

So, you can see that some more figures you know where the things are being done.

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Finally, it is ready. So, this is the way like even you know say for example, places like Sri Lanka, where there is always a problem of disruption of cricket matches or whatever, with rain I am sure that they must have had excellent facilities but at the same time one should look at; yes, are the facilities sufficient; one can do that in any place.

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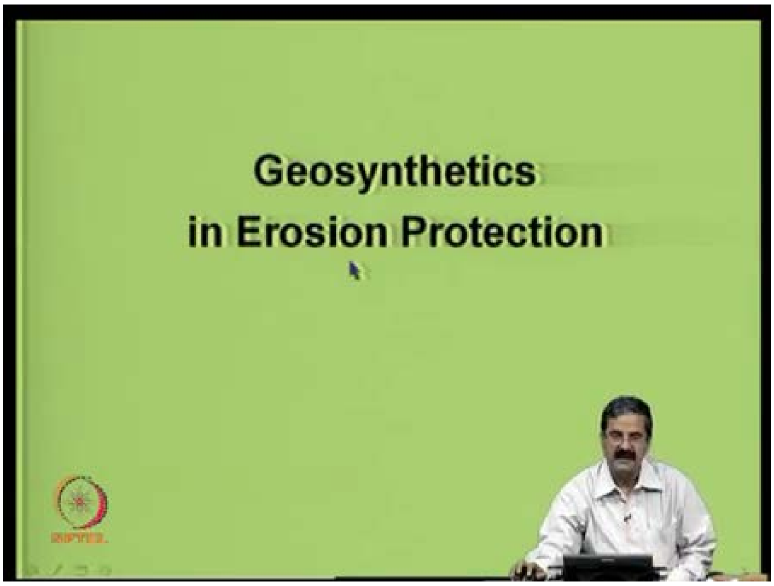

The other thing that I would like to highlight to you is a very important application of geosynthetics materials. Actually, it goes close to some of these two functions namely filtration and drainage. The erosion control is something that is very important and how do we use this geosynthetics in this because it is a if the erosion.

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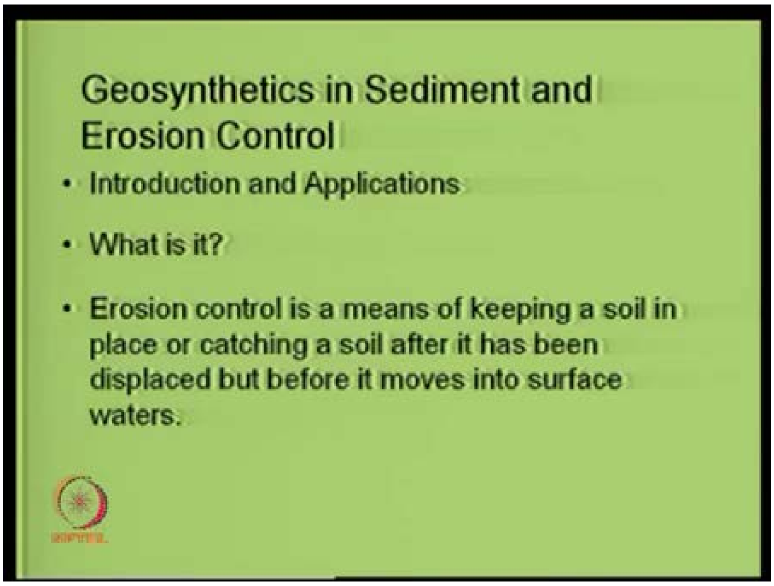

is one significant thing in soils, all rivers are getting eroded, all materials hill slopes are getting eroded and if you want to prevent this erosion only geosynthetics is one alternative. Geosynthetics plus i will tell you like geotextiles and coir geotextiles tree plantation there are many issues that one can have and if you are able to keep this slope stable and because of the rainfall infiltration and all that the material should not collapse; the slope should not collapse; it should not lead to clogging

Sometimes in Himalayas, it leads to flash floods, which are quite risky and it can even, the flash floods can, in one stroke can removes number of villages; in Himalayas, it happens; fields get destroyed.

So, actually the erosion control needs to be an important step; it is an important step to keep the soil in place; like you do not want to the soil to move out of its position and see that it is there.

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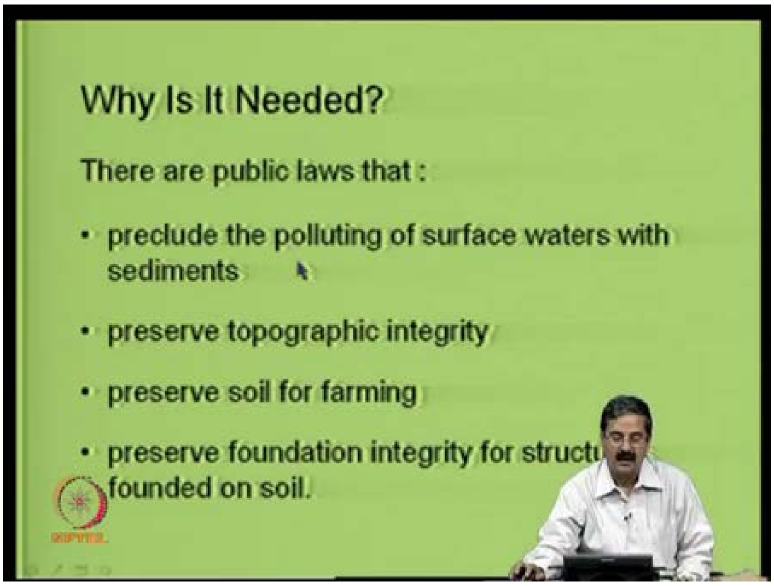

In fact, there is some rules in government bodies and many places that see these are all, if you are trying to do some work, the erosion extra sediment, you see that, if the extra sediment is there, in this it leads to say for example, municipalities the water flow is in the drains get affected if there is a because of it is all erosion.

The soil which is it has come from some place and it is deposited here, that leads to pollution of surface waters with sediments and so if you have that, it prevents that contamination it preserves a topographic integrity. As I said, topography is an important we talk about climate change and all that; topography is a very important thing.

So, preserve soil for farming like particularly in some places where the you try to have farm lands on the hills and if the lot of rains are coming then the possibility is that whole material all that material gets washed away right.

Then, another important thing is foundation integrity is to be maintained; suppose you have a river bed, you have a foundation there and close to the foundation area the soil should be protected; if it starts eroding then the foundation stability is in danger.

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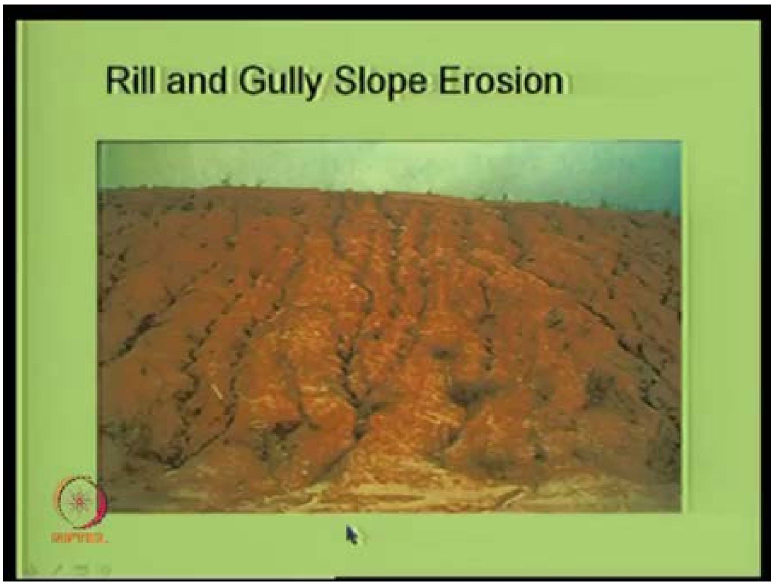

So, this is a typical diagram of how erosion could us be manifested. So, for example, we call this as Rill and Gully erosion, these are all quite common in India and many other places, that is because of the rainfall infiltration and ability of the I mean the inability of the soil particles to withstand that dragged forces. There are the drag forces that are exerted on to this soil particles and they form gullies.

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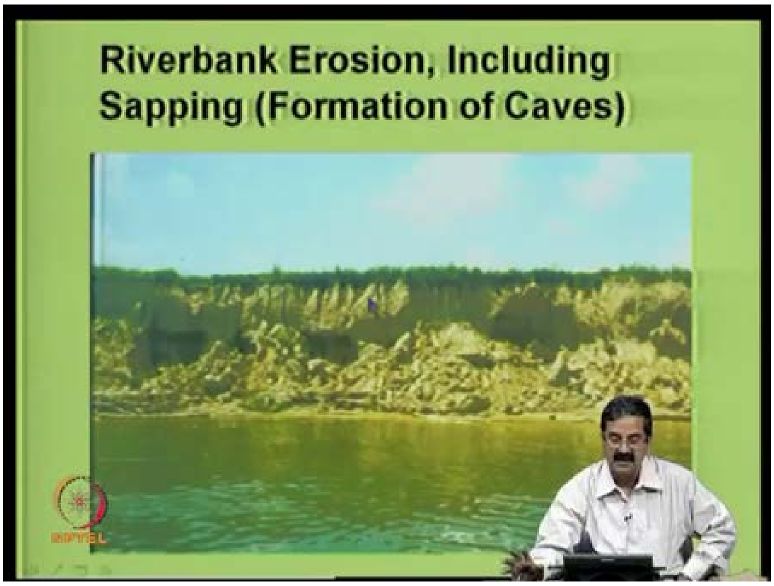

This is another classical example, many places you see along the rivers and the possibility is that, if you continue like this the whole river course could change; a whole river course could get affected, the nearby water supply to the villages and everything is actually is a very risky thing. So, this is called erosion.

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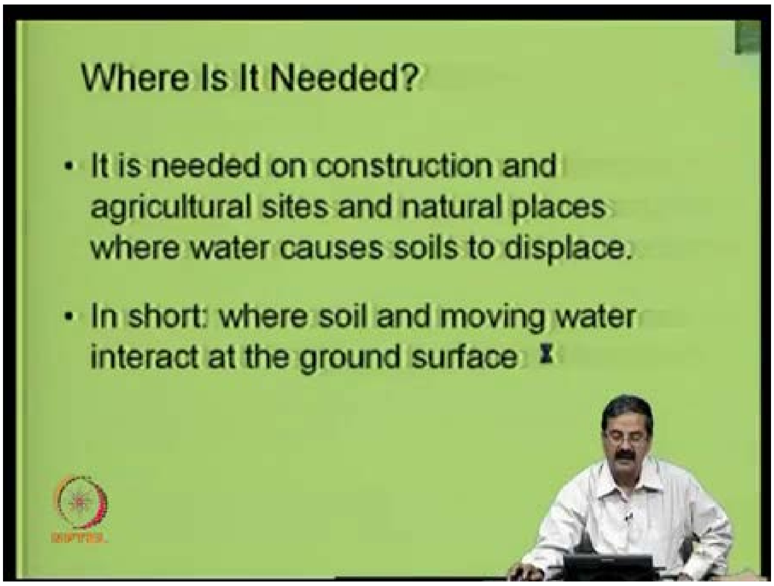

And it is required on all many of the places where water leads to instability in soils like particularly in agricultural sites, natural slopes and some places like that; and we need to see that the soil wherever there is a soil interaction between the soil and moving water, the soil should not move. That is an objective, like we should see that only the water flows comfortably the soil should not move. That is an objective here.

That is the reason, to at to some extent the apparent opening size and all that, whatever discussed has a role in this erosion control as well.

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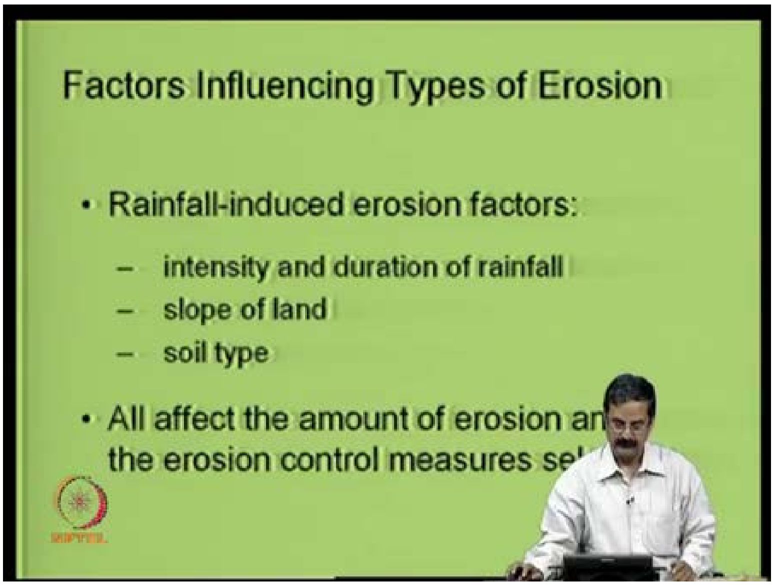

So, what are the factors influencing the erosion. Actually, intensity and duration of rainfall slope of the land like what is it a one is to one slope or a vertical slope or a flash slope and then the soil type; the soil type is another important variable may be if it is a sandy silt or something it is more erodible, maybe it is a clayey it is less, but still the possibility is that yes, if the rainfall intensity is going to be high it is risky.

All these factors affect the amount of erosion and erosion control measures are selected based on some of this other factors, above factors..

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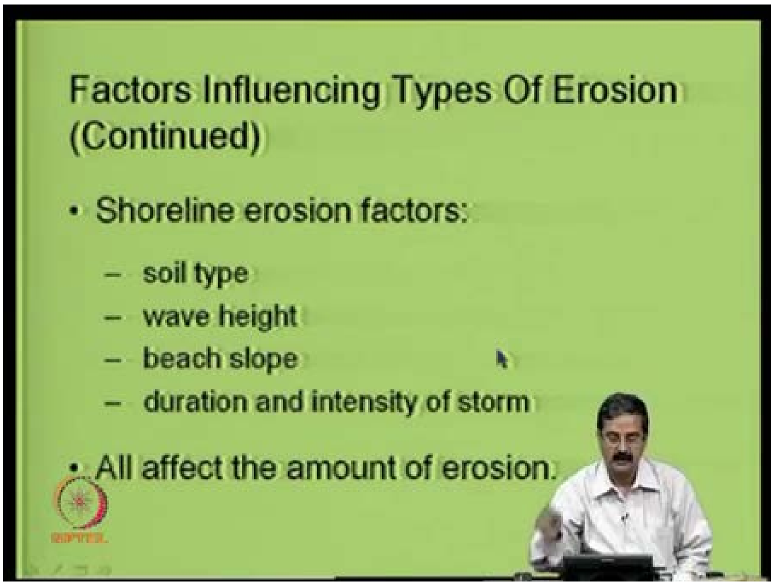

In fact, the as I said erosion is even quite common in beaches; like we call it shoreline erosion factors; and as I said wave height is a serious variable because wave height can, higher is a wave height, higher is a force that it can transmit to the bund or slope or whatever; the beach slope like some slopes like if you go to beaches the slopes are also a very important.

Duration intensity of the storms particularly in coastal areas; they are all quite important all of them affect the amount of erosion. So, the thing is that, this is all very required In fact, there is lot of work nowadays going on, because the fact is that nowadays tsunami alertness has come; awareness has come.

And the tsunami in fact, straight away hits the shores and if you do not really design the slopes or the retaining walls properly, it is a very risky; like the one can design a slope so that whatever may be the tsunami, you know what is the type of tsunami and what is a wave height tsunami generates waves and if you know the height of the wave and you can design the height of the retaining wall. Retaining wall and its base; base should be strong. There are so many issues there. So, some of these things can be properly understood, based on some of this factors.

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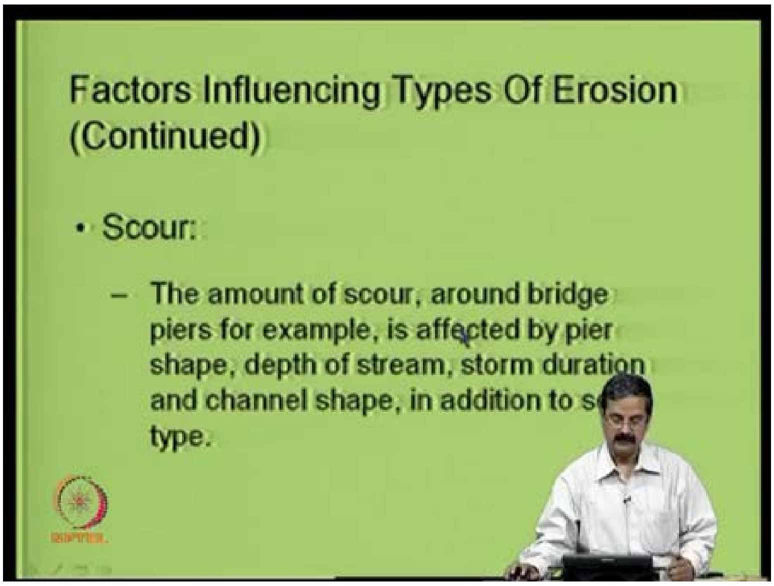

So, another important thing is the scour; like this is a standard thing similar to our tsunami structures resistance structures where the scour, the amount of sand that gets deposited; is an important problem and the thing is that around.

See the thing is around a bridge piers you have a you would like to see that there is a confinement affect; see that we try to calculate the foundation bearing capacity with gamma d into f , surcharge effect is considered; and suppose in some cases the surcharge is not there. It is wave, imagine that water level is at some point but then water level slowly rises and removes all that burden; next to the pier what happens the bearing capacity of the pier comes down is it not the pier.

So, that is possibility is that it is very important. So, the thing is that we should be able to understand that the amount of scour is a function of the velocity of the water flow the I mean. So, that way you must be able to see that whatever pier foundations you have do not have the problem of the scour. So, the amount of scour around a bridge piers is affected by pier shape like it also depends on the shape of the pier whether it is a rectangular or whatever shape you have. Depth of the stream, storm duration, channel shape even the channel shape as well, in addition to soil type.

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So, people may try to provide you know some sort of erosion control measures and river banks like this. In fact, say this is a concrete cast in a geotextile form. Geotextile filter is provided of course, it is not visible.

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Some of this measures in fact, the concept of geotextiles in geotextile bags we call them. Instead of the stone pitches, stones are okay but even you can design geotextile bags also like put lot of sand into the bag; put that it is a small contaminant system and place it here like that.

So, this is an example that the channel erosion damage was there; that is because of the inadequate filtration beneath the area, like is possible; this some of these things you can see that all this materials have gone into this material

So, if the design is not perfect, all these things are possible; even, we had a case study here about two years back, where the water level rose and they constructed a small retaining wall, it over turned and see it was a nice tank, which is called a Sankey tank which is close by and in Bangalore.

So what people thought was that, there is a water level at some point and then to increase, to beautify the lake they thought that; see what they have is, this is a water level and then you have a nice walk path next to this water level about.

So, for that they constructed about 2 to 3 meters of high retaining wall and it was all stable and then the retaining wall is somewhere close to this and all that; it is fine actually, in the initial stages about may be five six years back; and when they thought that you should increase water in a lake; then, they pumped in lot, they try to store lot of water into the tank.

As a result yeah tank level water was fine, it just went up but then along the footpath; in some places, the footpath got totally inundated. So, it became useless; in some places many the all retaining walls got overturned; because the retaining wall does not, did not have a proper drainage and there was a serious issue there; like you know the because of this what happened the base of the retaining wall also gets saturated and there could be like a case like erosion can come; the soil is under a saturated conditions now and the effective stress is very low.

It tries to come out and when it tries to come out the possibility is that a retaining wall can fail. The bearing capacity of the small retaining wall is low. Bearing capacity of the soil below the retaining wall is low. So, it collapses.

So, these are all some issues one should be very careful in designing and understanding what are the remedies, what are the issues that are involved in erosion because erosion is a global phenomena. You do something here, it affects something else.

So, one should be suppose you try to stop water here; or increase a water in some place it may affect in some other place; one should have an good understanding of the water and its flow and it is how it to contain and if does it carry water along with that. If the water is carried along with that, if the soil is carried along with water then, it is a very risky issue.

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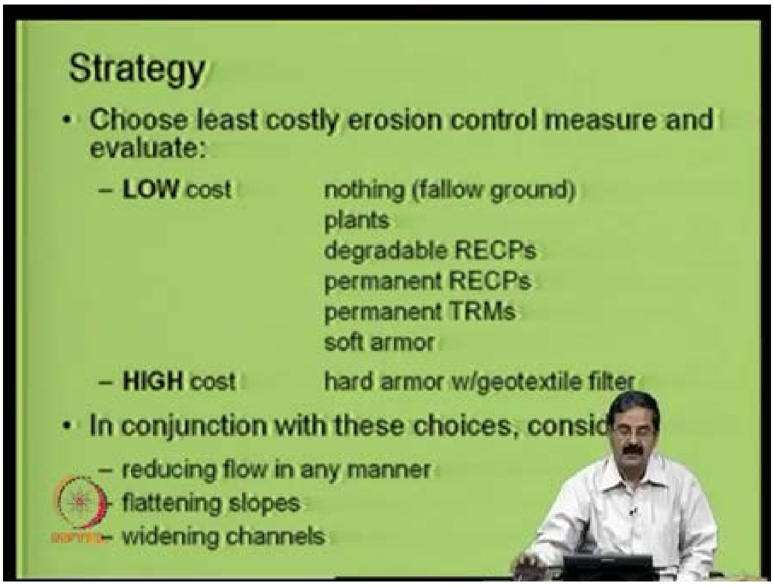

So, there have been different strategies to control this; like, there are some, the strategies are like this; of course you do not do much, but the simple thing is do plantation. What happens is that the plantations offer a resistance to flow. This will be like you will be knowing about the concept of fiber reinforced soil. You put fibers into the soil and soil is weak but then, if you put plant fibers what happens is that the overall shear strength of this the material increases and it is possible that strength is maintained.

So, one can have plants, one can have geotextile materials or even many of these materials one can use here, depends on the slope and all that. Actually, if it is a very steep slope, it is very difficult to you know rain off the run off will be high.

The forces will be high. So, you need to really provide in a proper way. So, plants are the one alternative. Some degradable materials like the, you have materials like this; which is jute or coir one can use; and this coir and jute can be used to provide the sort of a cover for this; and we also can have permanent systems where you can design what is a velocity of flow that is likely to be there; and how it should be a permanently anchored; there should not be any difficulties.

You have again two options. One is like soft armor; in the sense armor in the sense you try to contain and then suitable anchoring system is there. Hard armor you can also have with or without geotextile. It can be like you know hard facing, hard pitching stone pitching is something like armor hard armor we call it. Soft armor you can have a geobags, I mean bags you know jute bags one can have where which are filled with sand and local material and so, like you know as I just I showed you I think I will go to the previous diagram.

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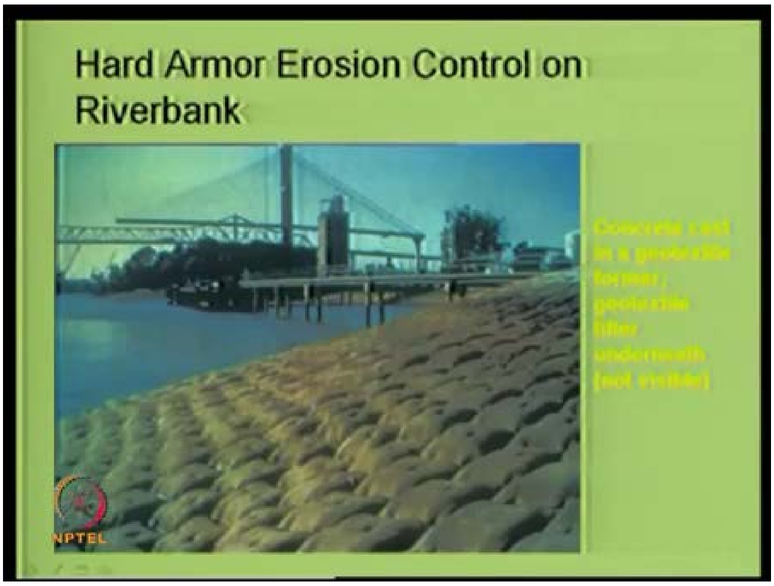

Where, this is that armor hard armor control. Why is it hard. It is called concrete cast in a geotextile former. You know it is like this when a concrete material is placed. So, we call it and then at the bottom we have a geotextile. Similarly, one can this can be flexible also, it can be soft also one can have many materials.

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One can have and this is also another type of armoring in fact but then here the problem was that it is not the conditions are not cleared, that design was not good and maybe there is no connection between the two panels and if one panel comes out the all rest of that materials come out.

They design the choice of the system itself one should be very careful. Suppose there is a lot of subsurface flow that comes and if you do not design for surface sub surface flow and see that the sub surface neatly comes out. There are many issues; like one should carefully see that and then do this design.

So, the. So, you have strategies there are varieties of cost that are one can have; you have many materials using whether it is a bio-degradable or non-degradable materials and which have expensive and soft options; and these choices need to have, like you may just say that yeah this is one option. Some of the concepts that we should think of is say for example, if there is a water flow how do you reduce a velocity of the flow in the area. Of course it is not possible in some cases because it all it is a site dependent.

But if it is possible in some cases, say it can be done because sometimes what happens you must have seen erosion in the form of rivulets. Just, it just turns and turns and creates cutting of the toes of the materials would be there; that is quite difficult. So, there should be a way of energy dissipation mechanisms. Then sometimes, in slopes widening or the flattening of the slope is another variable. Widening of the channels because once we widen, the velocity of the velocity decreases, then it is nice.

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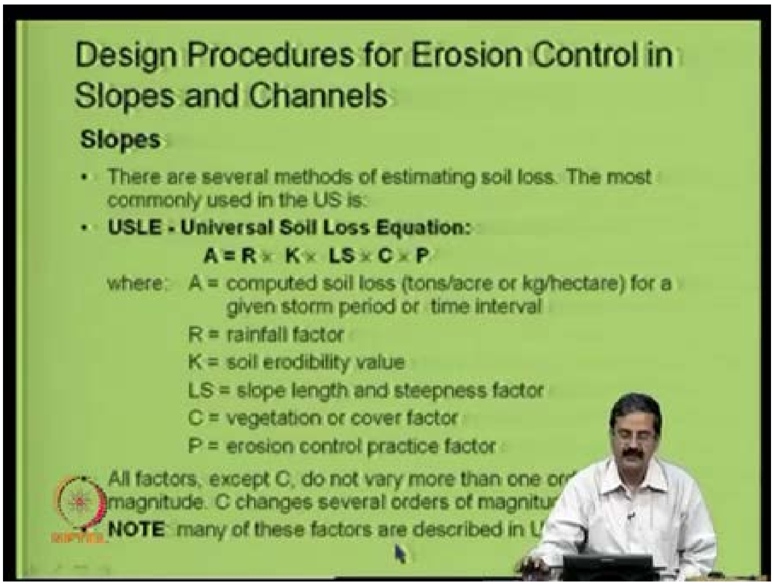

So in fact, say for example, people try to use many concepts in this erosion control design procedures. One common thing is that they try to estimate soil loss. Actually, estimation of soil loss is something that is very important; like the soil cover, the way that you know see soil needs to be considered as a very very important system when a component of our eco system.

When you're trying to look at the eco system and its stability, the soil removal whether it is for construction operations or whether it is otherwise like you know because of this problems like you know formation of flash floods and all that, it is serious issue. So, you would like to see that, need to calculate how much is soil loss.

So In fact, there are some empirical relations given by various equations, say for example, area the A is a soil loss here. This is an equation A equal to R into K into L S into C into P. A is nothing but the computed soil loss, R is a rainfall factor, K is a soil erodibility factor, L S is a slope length and steepness factor, C is a vegetation or cover factor and P is an erosion control practice factor.

So, essentially they are trying to multiply many factors and they have made some calculations and calibrations, how much is amount of soil loss depending on this and how do you get. So, they have some calculations that are made and then weightage factors are also given, which will help us to arrive at the soil loss. And then in some standard books, the details are also available and even for Himalayas and many other places one should look at some of this information and calculate soil loss. Otherwise one can back calculate also; and you know do some experiments on soil loss.

Many of the people in agricultural engineering and many others do this and so, what i would like to say is that, the application of geosynthetics is a very significant, very important in filtration drainage and erosion control applications because this is the maximum, this is the place where maximum application of geosynthetics is available; and all of them are very important in terms of the ground improvement because without filtration of water and proper drainage, bearing capacities are low. So, ground improvement techniques need this.

Erosion control; yes, it affects many of this projects in an indirect way and erosion control is another important variable; and I must tell you that lot of information is available on this matter and like even from geosynthetic companies, you have International geosynthetics society and many other organizations.

Say for example, coir board, jute board in India at least; and there are many places which are really working for production of eco systems, natural in many systems.

So, you have many people have been working towards this and I am sure that use of these materials will benefit many of this concerns. In the sense, they reduce the concerns in this case and benefit many of these issues.

Thank you.