Geoenvironmental Engineering (Environmental Geotechnology): Landfills, Slurry Ponds & Contaminated Sites
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Lecture - 19
Stability of Slopes - Part 2

So good day to all of you and welcome back to our lectures on stability of slopes of landfills, which I think we are continuing from the last one or two lectures we have already had. These are critical issues for landfill design because I told you that if the landfill is above the ground, the slopes have to be stable and if we have put some geosynthetics inside the slope, the tendency is for the cover soil to slip off. So, we have to be very careful that for 50 to 100 years this mound that we create it remains stable.

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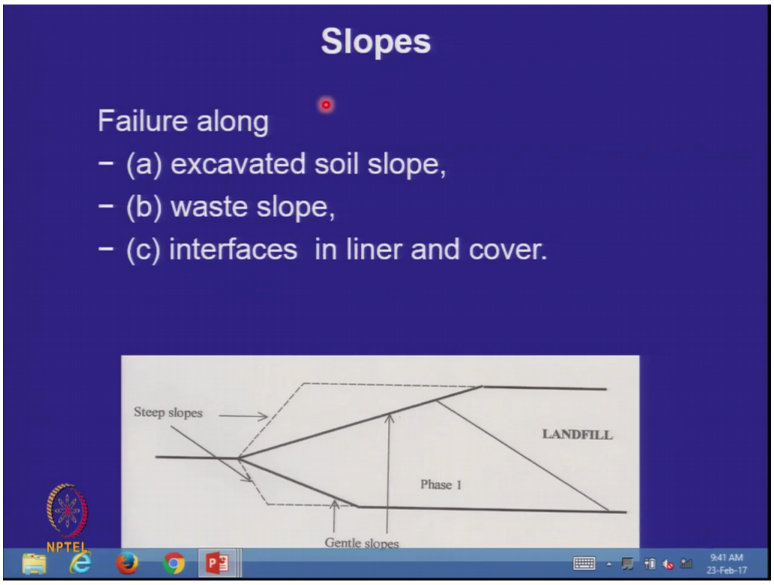

So, let us just briefly recap what we did last time. So, we said when we are discussing slopes, we have to look at failure along excavated soil slope which is this one then we have to look at failure along the waste slope which is this one, that is the temporary waste slope and then we have to look at failure along interfaces in the liner; that means, in this and in the cover and the most critical one was that in the cover it is going to be long term stability issues.

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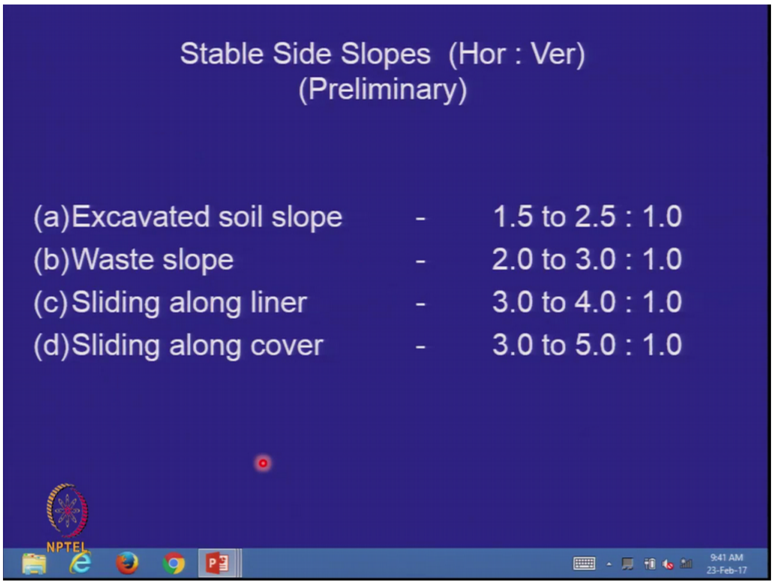

The slopes that we are preliminary section the slopes that we use in the preliminary section typically excavated soil may be 2 is to 1, we may keep the waste slope 2.5 is to 1, for the liners 3.5 is to one and for the covers 4 is to 1 that is the average of these. Now when you do the slope stability analysis you will get a more accurate handle as to what slopes you should adopt and you can fine during these slopes and I know everybody wants to make steeper slopes so that you can store more waste.

So, you do the stability analysis and see; what are the actual slopes which emerge because each site will have a different soil and different climatic conditions, how much rainfall will fall how much earthquake will be encountered.

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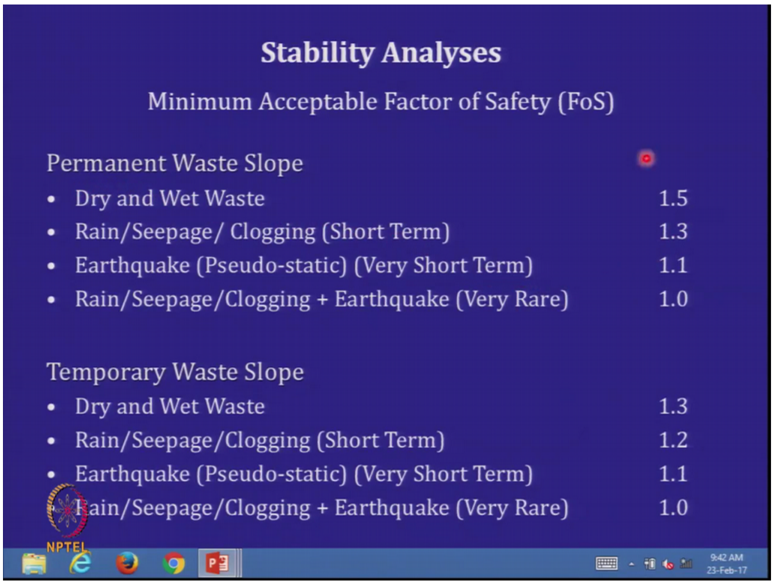

And we also looked at the fact that if you have a permanent slope then what kind of acceptable factors of safety, do we look for and if we have a temporary slope what kind of acceptable factors of safety that we looked for.

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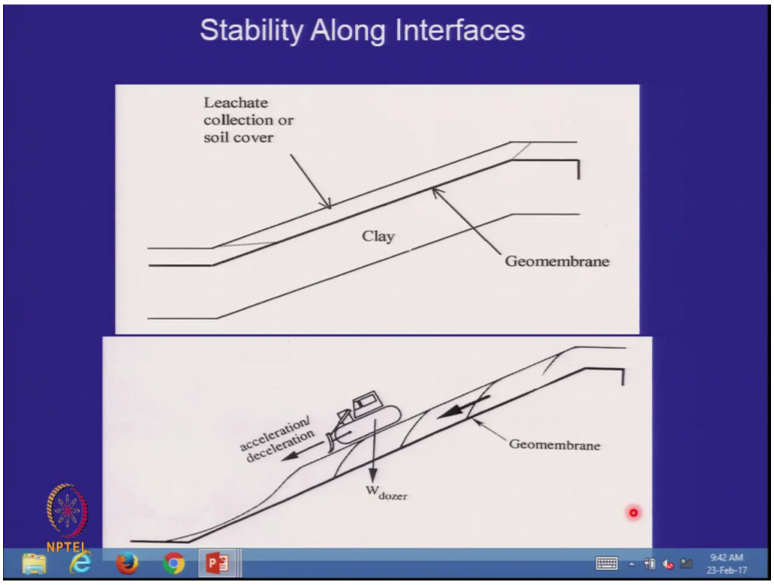

Stability along interfaces is what we started last time and we said that the moment you put a polymeric material inside and interface develops and you have to look at the stability along this, and it is usually treated like an infinite slope, problem because this is a long slope in comparison to the height of the failure.

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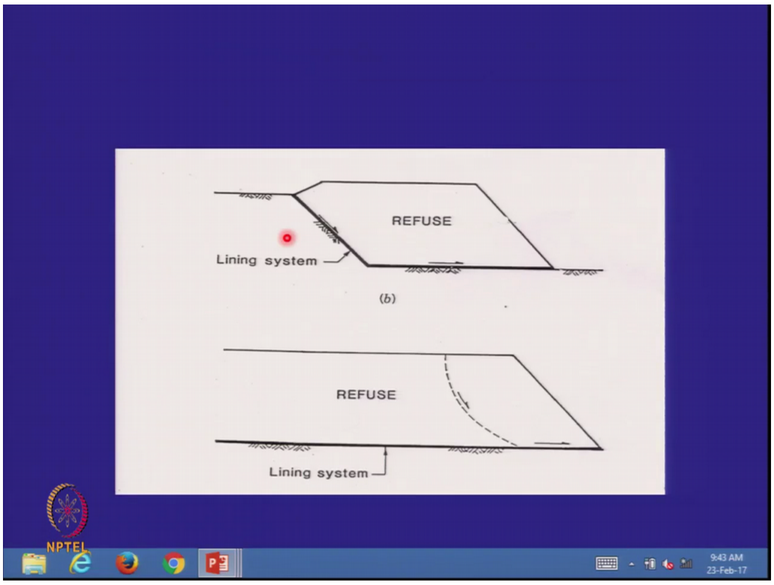

We also said that these interfaces can cause the temporary waste to become unstable because the liner may have low shear in resistance at the base.

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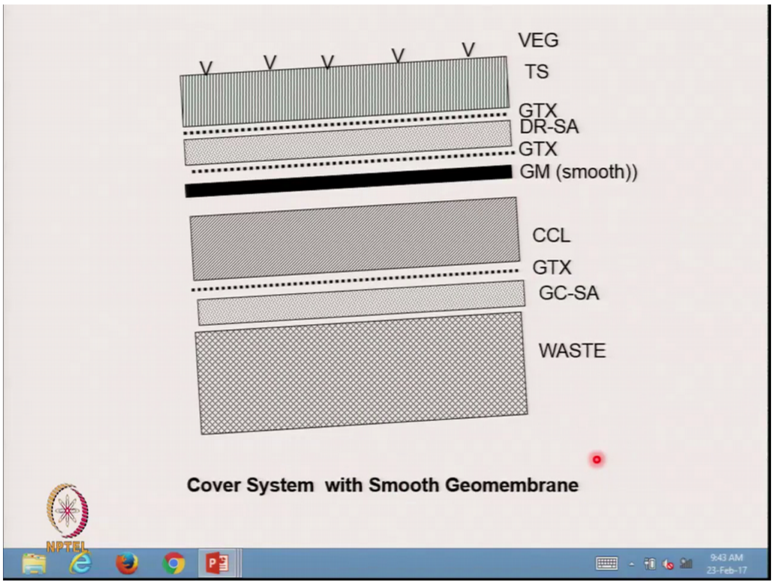

And this is a typical cover system with all the interfaces and historically we started by using smooth geomembranes, but soon we found that smooth is bad.

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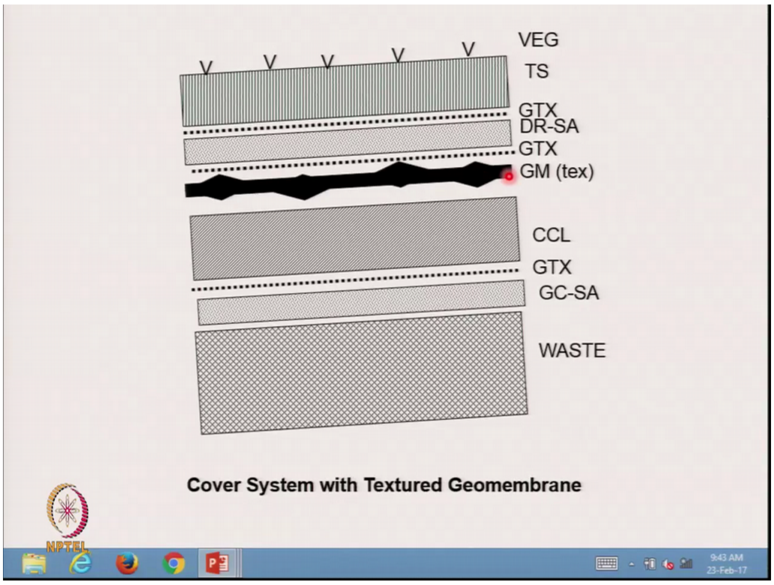

So, the manufacturer start started giving us textured geomembrane. So, the deltas went up the stability is improved; however, the moment of factor of safety would not be met this weight of the soil would tend to move down and you would require some kind of a reinforcement to hold the soil.

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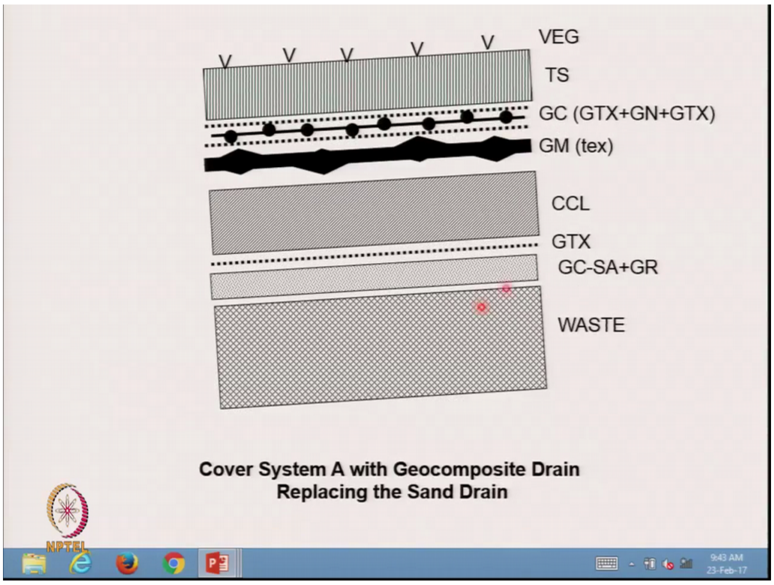

Therefore there was an attempt that can be reduce the weight on the top, you know driving force is what w sin beta if I can reduce w I can reduce the driving force. So, the tension which the reinforcement will have to overcome is reduced. So, one of the ways is of doing it is to replace this sand drainage layer which is thirty centimeters thick by a geocomposite which is 5 millimeters thick that is a lightweight material.

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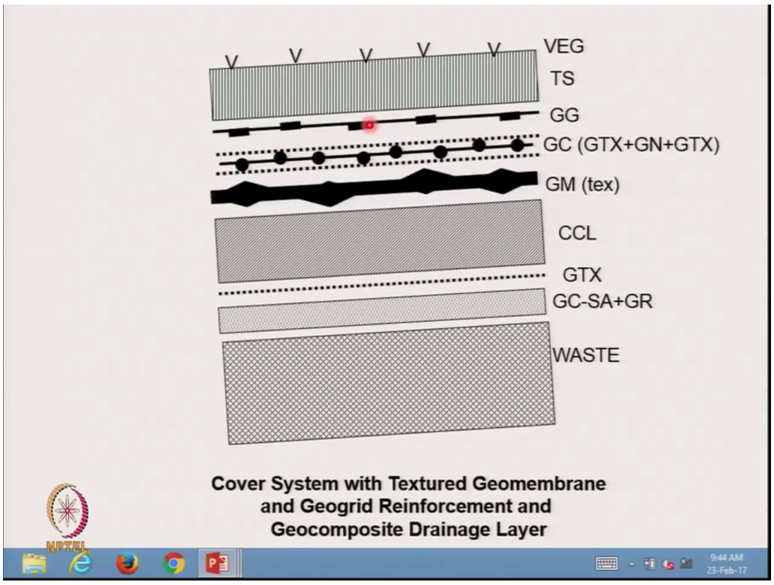

And the if it still is not stable you could introduce a geo grid; that means, a reinforcing element which could give you capacity to hold the tension or which could give you a force in the opposite direction to the driving force, and that could overcome this weight.

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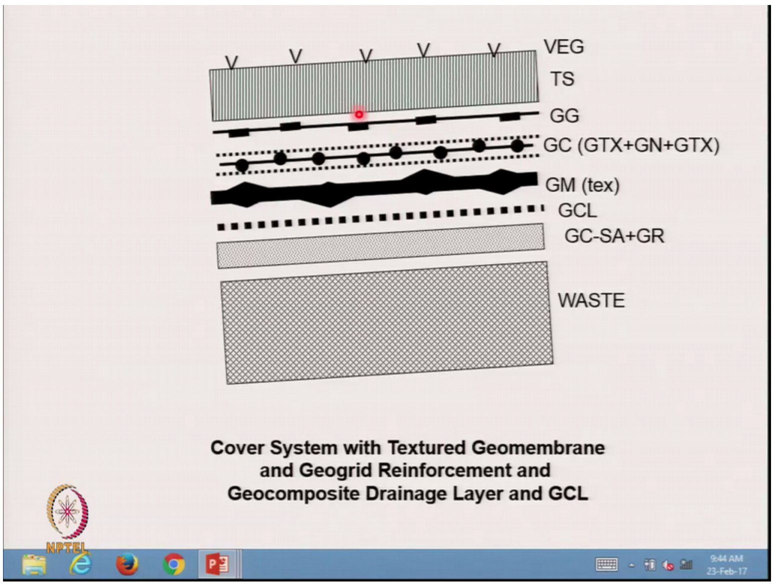

So, these are some of the methods by which we can make slopes to be steeper and of course, we also talked about the fact that there are suggestions that we can use the geosynthetic clay liner at the bottom, to reduce the amount of clear that is you need and get more space for storing your waste.

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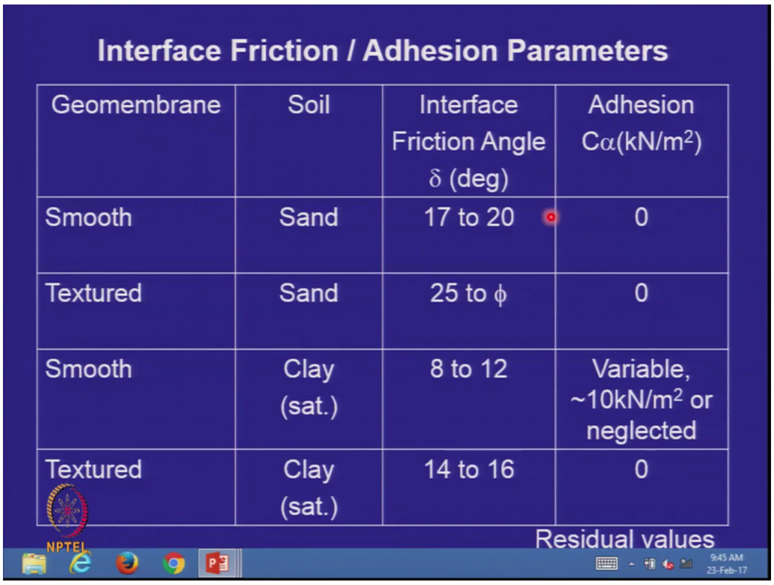

Interface Friction / Adhesion Parameters

Geomembrane	Soil	Interface Friction Angle δ (deg)	Adhesion $C\alpha$(kN/m^2)
Smooth	Sand	17 to 20	0
Textured	Sand	25 to ϕ	0
Smooth	Clay (sat.)	8 to 12	Variable, ~10kN/m^2 or neglected
Textured	Clay (sat.)	14 to 16	0

Residual values

We briefly looked at the parameters and we said we should work with residual values, and the when we looked at smooth and textured geomembranes and we looked at the sand on top is smooth we were having 17 to 20 degrees, but with texture we went up to the phi. The critical one was if you have a smooth geomembrane with saturated clay you would have very low delta angles, but with textured you would get better values.

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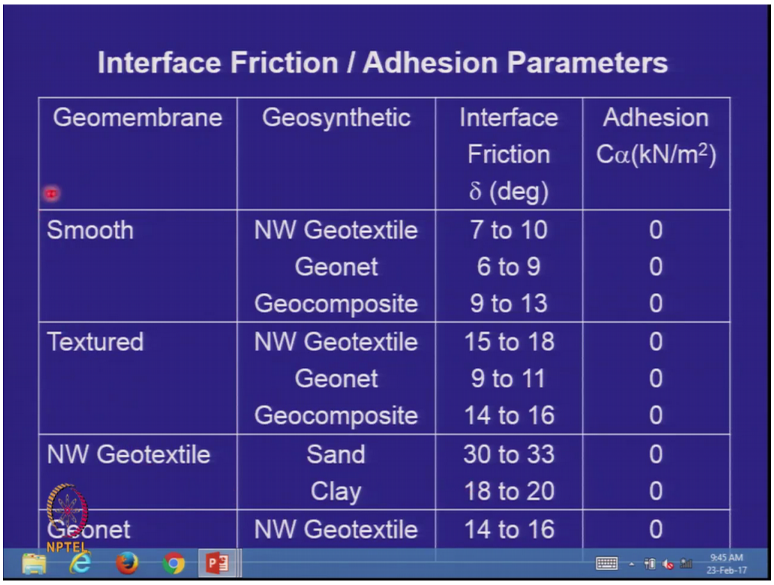

Interface Friction / Adhesion Parameters

Geomembrane	Geosynthetic	Interface Friction δ (deg)	Adhesion Cα(kN/m²)
Smooth	NW Geotextile	7 to 10	0
	Geonet	6 to 9	0
	Geocomposite	9 to 13	0
Textured	NW Geotextile	15 to 18	0
	Geonet	9 to 11	0
	Geocomposite	14 to 16	0
NW Geotextile	Sand	30 to 33	0
	Clay	18 to 20	0
Geonet	NW Geotextile	14 to 16	0

We also looked at because now you have interfaces if you look at these interfaces you will see that it is no longer a sand to geomembrane interface, it is the geotextile to geomembrane interface.

So, earlier we have said if you place the sand directly what happens, but if you have a protector in the form of a geotextile you need this angle, geotextile to geomembrane and that we can see here that if I have a smooth geomembrane and I put a nonwoven geotextile on top it will be 7 to 10 degrees; however, if I texture it will go to 15 to 18 degrees. So, texturing was always better and we need these delta values for design.

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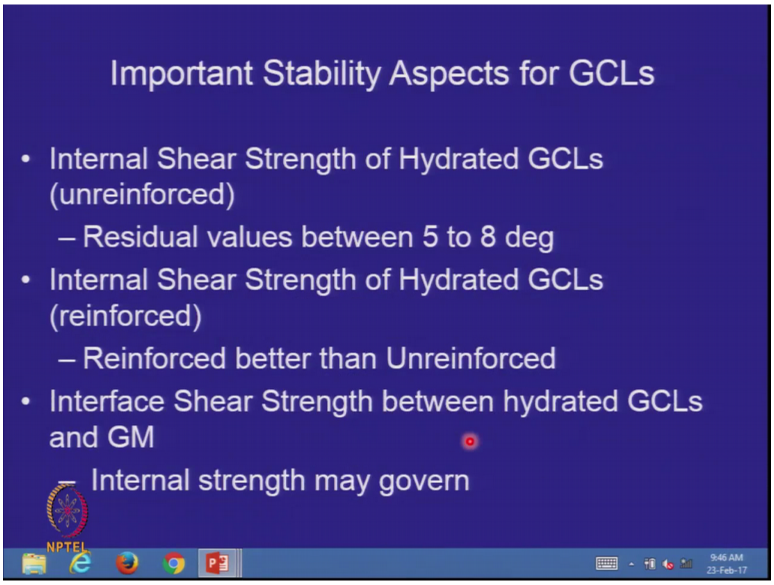

Another important issue that I talked about was the geosynthetic clay liners, and we remember that these are got bentonite between two geotextiles and I said these GCL is only work when they are hydrated; that means, you have put water on them and the bentonite a swollen, and it does not allow any water or air to pass, but hydrated bentonite has very low strength.

So, when you are going to use a GCL on the slopes please be aware of this that earlier just like we started with smooth geomembranes, we started with unreinforced GCLs means they did they had the sandwich there was bentonite between the two geotextiles, but the residual strength very very low for hydrated GCLs, then they what they started doing what they started stitching between the two geotextiles. So, that meant that when these two want to shear if there is no stitching then they want to shear the shear plane is through the bentonite, but if there is stitching then it gives you additional shearing resistance.

So, reinforced GCLs are better than unreinforced GCLs they are more expensive, but all manufacturers will tell you that we have these two types of GCLs and please be very sure that if you are using them on slopes use the reinforce GCL. The other question which comes out is if the GCL is just under the geomembrane and it is hydrated it, when during hydration the bentonite can extrude from the pores of the geotextile the question which comes to our mind is what is the interface shear in angle between the hydrated

GCL and the geomembrane. Well if the geomembrane is rough and the geotextile on top of that has a significant angle with the geomembrane what normally is observed is internal strength will govern which is this one.

So, the interface may not become critical if the internal strength is low. If it is a reinforced GCL then the interface may become critical and you have to ask the manufacturer or you have to perform the laboratory tests where you hydrate the GCL and slip one membrane over the GCL. We also remember we talked about the driving force and the resisting force and the factor of safety being the ratio of the two and if the driving force is more than the resisting force.

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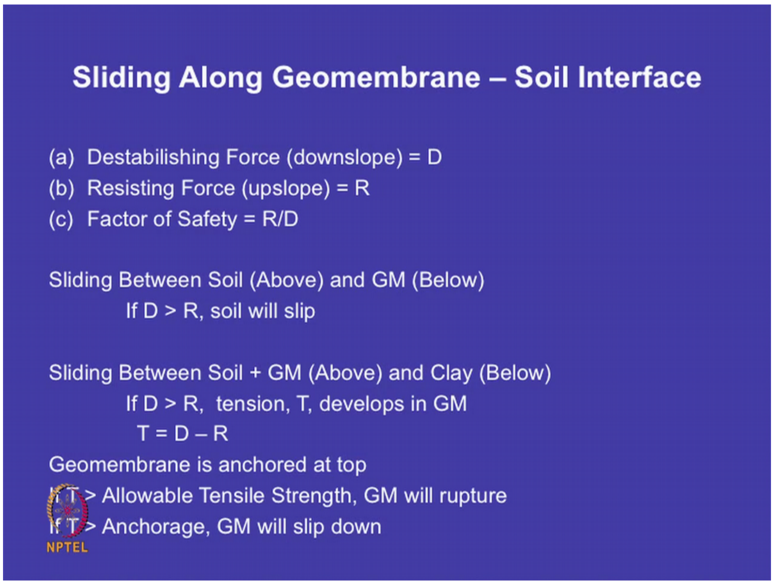

We said we can use a reinforcing element which will take some tension now please understand geomembranes can take some tension, but they are not designed to be reinforcement you remember a geomembrane if you pull for it to get it is full yield strength, it will have to how much does it elongate by when you linearly pull a geomembrane 50 to 100 percent is because you said these are flexible materials, when you want reinforcement you want a more rigid thing; that means,. So, I should not start moving downwards for the full strength of the tensile member to be developed, you wanted more to me like the RCC bars that we have in concrete.

So, geo grids are the true reinforcing elements, but do remember that geomembranes also have capacity to take tension geotextiles has very low capacity. So, they can mostly be neglected. So, I am going to gives a term T later this is T and typically geotextiles you can take very low or neglect unless it is a high strength geotextile, geomembranes would be one order of magnitude say 15 kilo Newton per meter and geo grids would be a next order of magnitude say 50 kilo Newton's per meter or 60 kilo Newton's per meter. So, geo grids are the true reinforcing elements that you can use.

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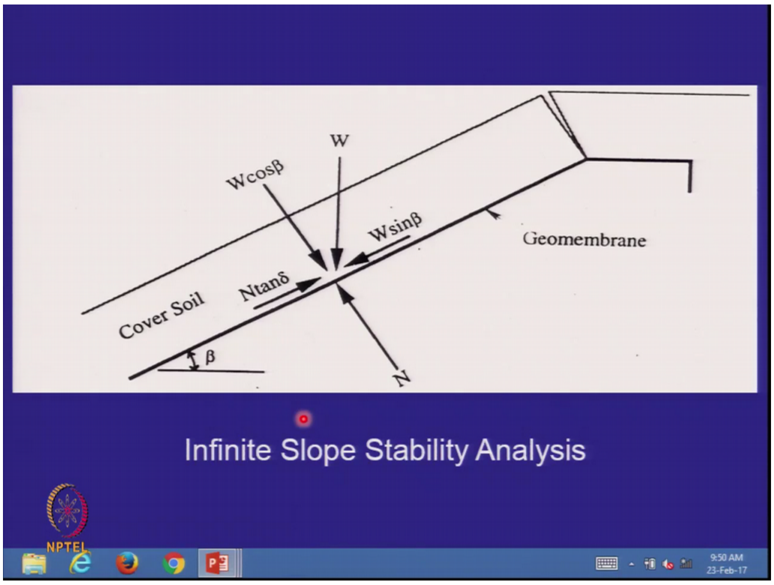

We said that we can do the analysis using the infinite slope method and the factor of safety would basically be the ratio of the N tan delta is the resisting force, and W sin beta is the driving force N is equal to W cos beta. So, it becomes w cos beta tan delta and the factor of safety became tan delta by tan beta; that means, if you have the slope at the angle of the interface shear resistance when factor of safety will be one say delta is 25 degrees, your slope is also 25 degrees. So, tan 25 by tan 25 is one you want your slope to have a factor of safety of 1.5, the slope inclination we have to be less than the delta otherwise you will need a reinforcing element to hold the slope in position.

So, either you can go for a gentle slope should you want to make it steeper you will need a reinforcing element, and do understand reinforcing elements are not going to make this slopes should very much steeper reinforcing elements will change the slope marginally into a more steeper solution.

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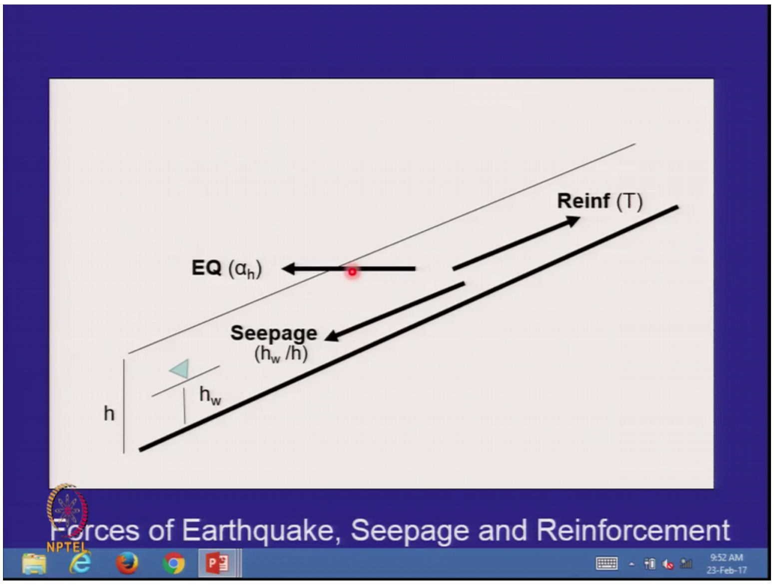

Other than the weight of the soil there are other factors which create cos the factor of safety to go down or go up. So, if you have seepage then the rainwater tends to travel downwards. So, it causes the factor of safety to go down, if you have an earthquake a horizontal acceleration may emerge which will cause the factor of safety to go down, if you have a reinforcement it will give you a T which will enhance the resisting force and therefore, you are factor of safety will go up. So, these are the three major things that you have to take into account.

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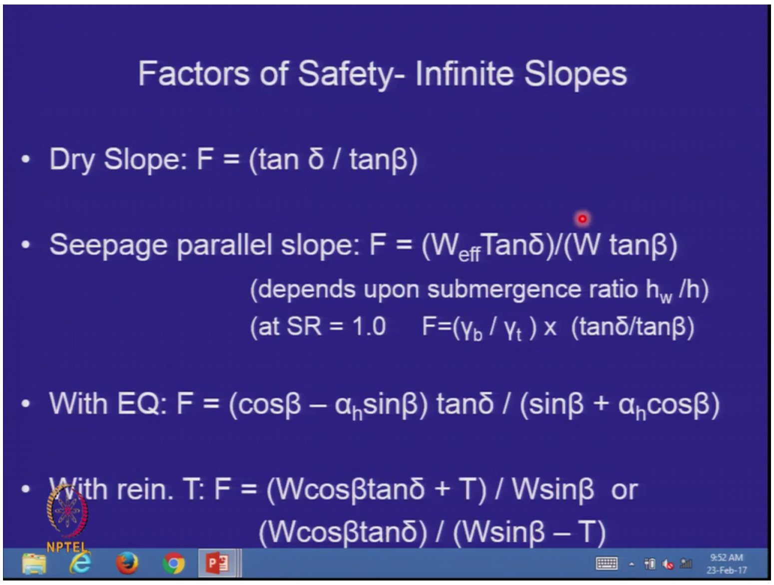

So, let us look at the formula which emerges from infinite slope analysis for stability of this interface element.

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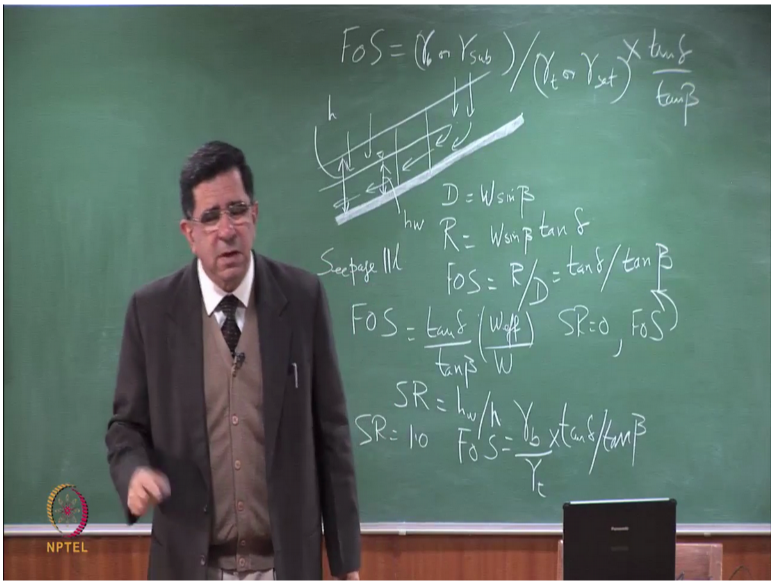

We all that we are saying is this is the geomembrane let us say, and I have a sliding mass and we have said that the driving force the resisting force is and therefore, the factor of safety. Now what happens if I add seepage or if I add earthquake. So, you have to set up the free body diagrams then I am not going to get involved in setting that up, but remember seepage force rainfall it is stopped here therefore, it begins to go like this and therefore, the seepage force or the drag of the seepage force is down slope it causes instability. How much instability it will cause it will depend how much water is inside the system and the formula that is given to you is it is the same formula tan delta by tan beta multiplied by, when seepage is parallel to be slope to the slope factor of safety is still tan delta by tan beta, but it is w effective by w total or w whatever you want to call it.

Just for the purpose of discussion normally this will not run in the full soil. So, it gives you the concept of a submergence ratio. Submergence ratio is equal to if this is hw and this is h submergence ratio is hw by h, the lowest value it can have is zero and the highest value it can have is one when it is zero it becomes the case of dry soil. So, what happens to w effective? W effective when submergence ratio is zero w effective is equal to w it crosses out and your factor of safety is tan delta by tan beta right. When it the submergence ratio becomes one what happens? Then the w effective becomes gamma submerged into the volume of the soil and the w total becomes gamma saturated by the volume of the soil.

So, when SR is 0, it is the factor of safety is the same as this, but when SR is 1.0 then your factor of safety becomes gamma buoyant or gamma submerge divided by gamma total or gamma saturated into. So, if give me a normal value of gamma saturated this can be gamma submerged or gamma buoyant and this can be gamma total or gamma saturated shall I write this up here because you cannot see it this is the whole thing is multiplied by tan delta by tan phi and beta sorry. So, if you have a normal soil what is typically the value of gamma saturated, 20 kilo Newton per meter cube. So, what will be gamma submerged 10 kilo Newton per meter cube. Therefore, what happens to the factor of safety it becomes half of what the factor of safety is for the dry case.

So, the slope may be stable while it is dry, but it will not be stable when it is raining heavily. So, your drainage layer which we are designing must be able to capture all the water and take it down without the soil becoming fully saturated. So, typically you should be able to work with the submergence ratio of 0.25; that means, you must design your system to keep the water well within the drainage layer. If the drainage layer capacity is not good enough water will point up and you will have submergence ratio coming close to one. Similarly if you look at the effect of earthquake, earthquake is a horizontal force and if I resolve the alpha hw into it is two constituents your factor of safety will become like this.

So, all that you will see is alpha h is reducing the numerator and enhancing the denominator causing the factor of safety to fall. The difference between seepage case and earthquake case is an earthquake will last for a few seconds. So, it is a dynamic phenomenon which we can do the analysis in a pseudo static manner, but we can have the factor of safety acceptable factor of safety fall down to a much lower value seepage case does not happen in a few seconds it may carry on for several hours therefore, it is a phenomenon which is more long term and during the monsoons it may occur repeatedly therefore, the factor of safety which is acceptable is slightly higher.

There is also the third formula here which is when I put a reinforcing element in the system and I have put two formulae little complicated plus T. So, just let us look at the stability without T that is the stability without T right.

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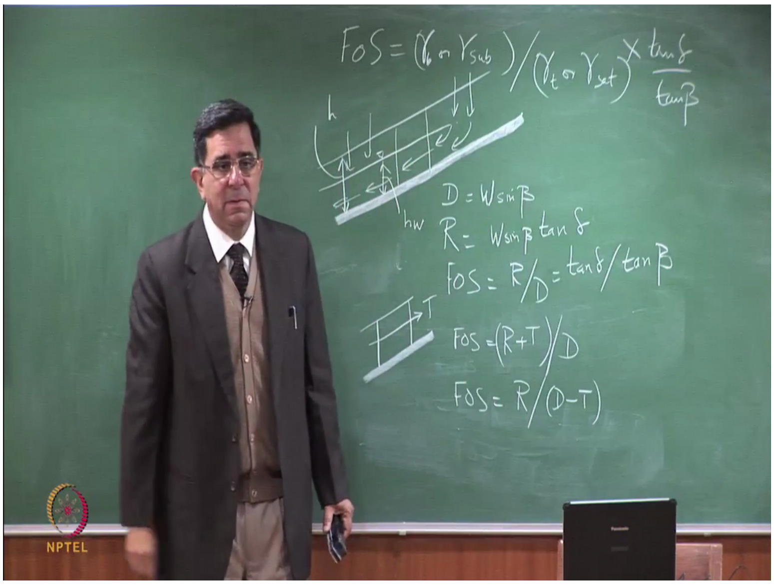

Now, what happens when I have a reinforcing element, the reinforcing element will have a capacity to take tension right and this is acting in which direction is it acting in the direction of the driving force or the resisting force.

Student: (Refer Time: 21:08).

Right now the question is there are two approaches to evaluating the factor of safety, one approach is that my resisting force is gone up that is my factor of safety, and that is the top formula which is shown in the slide. The other approach is what is says that the tensile force has reduced my driving force. So, it is the way that you define your factor of safety that is important and unfortunately the both these formulae have been used in literature. So, I am just putting both of them on here for you that both these formulae have been used, you can use either as an individual I prefer to use the top formula why do I prefer to use top formula if my t becomes equal to w sin beta theoretically I can have a reinforcement with very high t.

So, if my t becomes equal to w sin beta what happens to D minus T becomes zero, f becomes infinity that is a kind of an enlarged or an expanded or an enhanced value of having an infinitely stable slope. So, I prefer to use this formula instead where it will not go to infinity, but both exist and let me see if I can show you.

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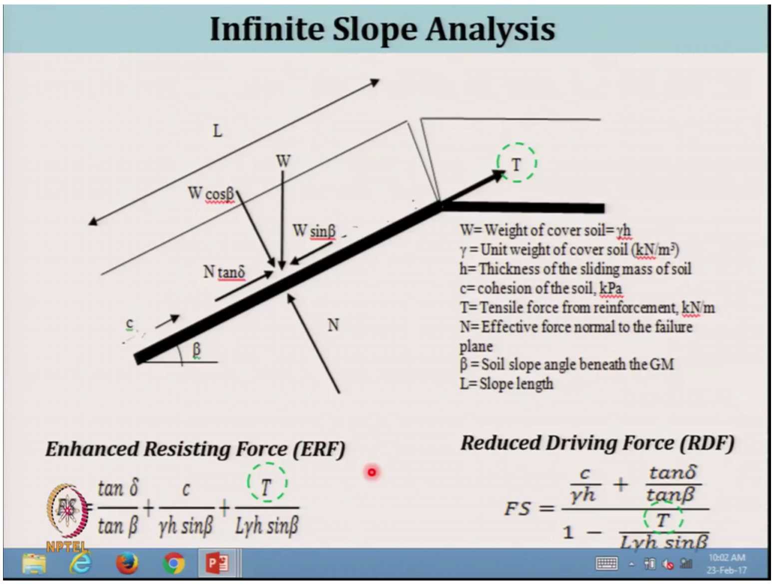

The one approach is called the enhanced resisting force approach and the other is called the reduced driving force approach. This formula is the same as the previous page only there is a term for c. Please remember, here and you do a recall that we have said that for residual case c will be 0, c alpha is 0. So, you can remove this, but this is the general equation because the resisting forces c plus N tan delta.

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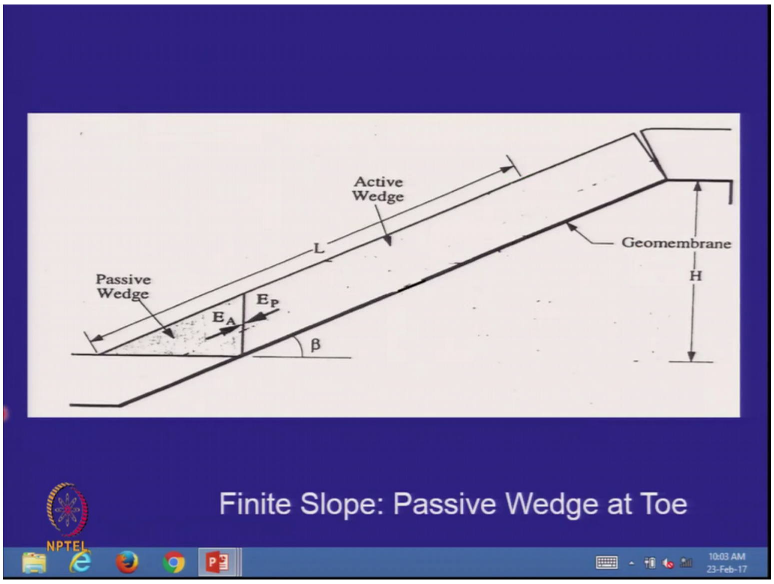

So, here you are getting a c term which you can avoid, but this is called the ERF approach and this is called the reduced fore and I am suggesting that you use this approach. These one more thing we have a neglected is this an infinite slope are covers infinite slopes. Let me understand what you know about infinite slopes is again very important you have been thought infinite slope analysis in your slope stability you done infinite slope analysis your range slope stability your down slope stability are you doing a course on slope stability yes, very good first answer is yes have you begun doing slope stability in that course.

Student: (Refer Time: 24:27).

Yes, have you done infinite slope analysis yes wonderful? Now give me an example of an infinite slope in where your infinite slope analysis can be used pardon.

Student: Natural slope.

Natural slope; so let us look at what you are saying it all depends on the scale at which you draw it on your graph paper. I have an embankment it is 5meter high looks like a finite slope and you have a natural slope which is 500 meter high half a kilometer too much 100 150 meter high slope as you can sit down and see. So, you are saying the 100 meters infinite I am going to draw both of them on the same graph paper because I have to fit it on one page will both of them look the same or they look different what look finite to be.

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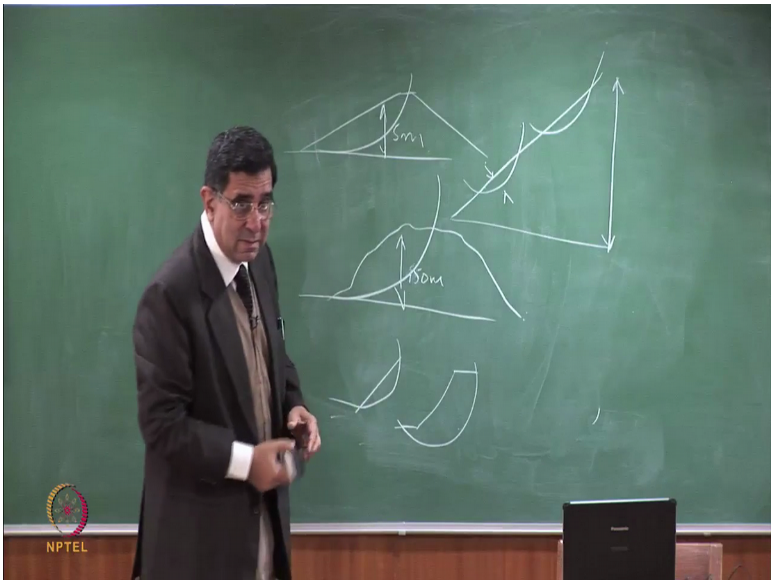

Student: (Refer Time: 25:53).

Scalars different agree.

Student: (Refer Time: 25:54).

Agree with if I use the same scale it will be higher, but I am going to do circular slip surface analysis to begin it just let us assume that I am going to use, then my circle will go like this and my circle will go like this. So, what is infinite about the slope very critical what makes a natural slope infinite? You are right now some of the natural slopes are infinite, but what makes it infinite.

Student: Sir, where is in your depth then (Refer Time: 26:27).

What depth?

Student: there is (Refer Time: 26:30).

There is no wedge here this is the circular failure surface, you are saying if the wedge depth is to be considered you almost there, but there is no wedge in this analysis.

Student: Sir, if we consider it has finite (Refer Time: 26:43). It not has circular surface because there want to be a slope below (Refer Time: 26:50) sir it has to a surface which in parallel (Refer Time: 26:52).

So, height surface which has to be parallel if we are getting somewhere, but let me again explain to ask you this. I have a slope which looks like this my failure surface is this is this a finite slope or an infinite slope? I want you to focus on this as far as this failure surface is concerned these do not exist.

Student: (Refer Time: 27:22) finite (Refer Time: 27:25).

As one of the failure surface is concerned it did not see the ends if I have a slope like this and my failure surface is like this then it sees this end and which sees this end. Let me I have to collect my part I have a long slope this is one this is another the failure surface does not see the top and the bottom of the slope it just sees a single line is an infinite slope or a finite slope.

Student: Infinite slope.

Infinite slope; so let me now bring this together when the thickness of the failure zone is much much smaller than the height of the slope then it is an infinite slope. I will restate this the thickness of the failure zone if this is the thickness is much smaller than this, then it will work like an infinite slope because the edges will not be seen. Otherwise this failure surface is seeing this and it is seeing this it is going to be a finite slope even if it is a 150 meters high. So, why is it that natural slopes become infinite and manmade slopes do not become infinite so, easily? I will come back to this natural slope and we are doing a landslide problem.

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So, we talked about a 150 meter high what makes this slope infinite is the fact that.

Student: (Refer Time: 29:10).

The.

Student: (Refer Time: 29:13).

The thickness of the soil is very less after that there is rock you know. So, therefore, your soil is like this; that means what? That means, the thick this failure surface is not irrelevant because going to go through rock. Failure will not occur through this failure will occur soon and this thickness is very small in comparison to the height therefore, you come back to what you said that if there is a some failure along which the slippage may occur or which is restraining the circle from going down. So, infinite slopes are there in nature because there is rock at the bottom you cannot go very deep, if you go very deep you can become a finite slope the thickness of the failure surface.

Therefore, when you do infinite slope analysis, you are always resuming failure surface parallel to the outer slope and this thickness is very small. So, use stress are where is the failure surface parallel to the outer slope due to circular slip surface are, I keep on increasing my radius of the circle what happens will be one becoming and I make my radius infinite is a circle of an infinite radius of straight line as far as this is concerned. So, in your softwares what will happen unless they have a boundary condition that you cannot take the; you will find that for infinite slopes. So, circles will become very flat they will become almost parallel to the outer slope.

So, we are using the same principle in the cover why, we call the cover thicknesses how much is the soil thickness on top of the geomembrane.

Student: (Refer Time: 31:00) 40.

Both are wrong is the topsoil plus the drainage layer how much is the thickness it is not 45 which is not 60, drainage layer is 30 centimeters or how much and topsoil is how much?

Student: (Refer Time: 31:14).

Six please go and look at the covers which I have talked to you, but typically the total values will be in the range of 60 to 1 meter. It may be 60 plus 30 which is 90 or it may be 45 plus 15 it may be 60 right and what is the height of the slope that is the question which I was going to come to. For the cover slope to be declared infinite the thickness of the slope is one meter agreed what is the height of the cover slope, what is the height of my landfill?

Student: (Refer Time: 31:47).

Pardon.

Student: 30 to 50 meter.

No I said from visual aesthetics we do not want it to be higher than 15 meter, we can be as high as 30 to 50 meters yes, but if you are a designer and if you go and tell your client I will make a 30 meter high landfill, you begun the wrong way because you have made it higher than the four solid structures around you and you know what a landfill to rise above the skyline. You can make it they do not have land they say although we have prepared for this fine, but let us say height of the landfill is 15 to 20 meters 18 meters is what I take.

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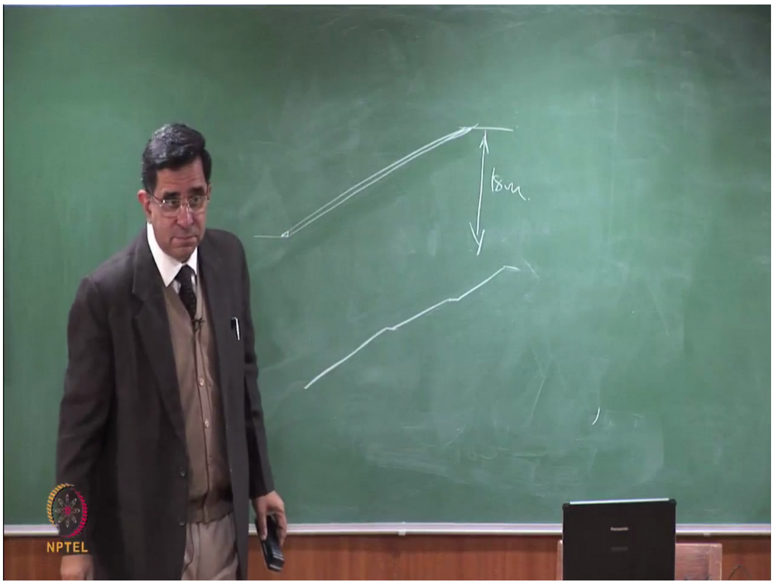

So, this is my landfill, and this is my one meter oh this is nothing too much is this an infinite slope agreed it is an infinite slope why? There is a little wedge at the end; is there a wedge at the end which is resisting this soil yes there is a little triangle, but what is it is contribution to this nothing this whole weight is coming down in the toe there is a little bit of triangular weight string I am the passive wedge I am the passive wedge, yes you are the passive wedge, but you are too small to make a difference to me agree?

When does the passive wedge become significant and it adds will the passive wedge give you better factor of safety or less factor of safety? Infinite slope assumes this is not there this slope is just going down, the moment you have a passive wedge it gives you some enhanced factor of safety when does it become important? It becomes important when the slope length is not that long it is still long, but not that long you will never find a slope of an 18 meter high embankment like suppose it is 3 is to 1 this is 50 meters there will be no continuous slope or 50 meter length in any landfill why I already told you this.

Student: (Refer Time: 33:44).

You basically need berms primarily to break the speed of the water of the surface runoff and then we use those berms also for making pathways so maintenance. So, when you will have a landfill of this type your natural thing will be sorry we do this at every 6 meters they should be one. So, there will be three berms now this gets interesting.

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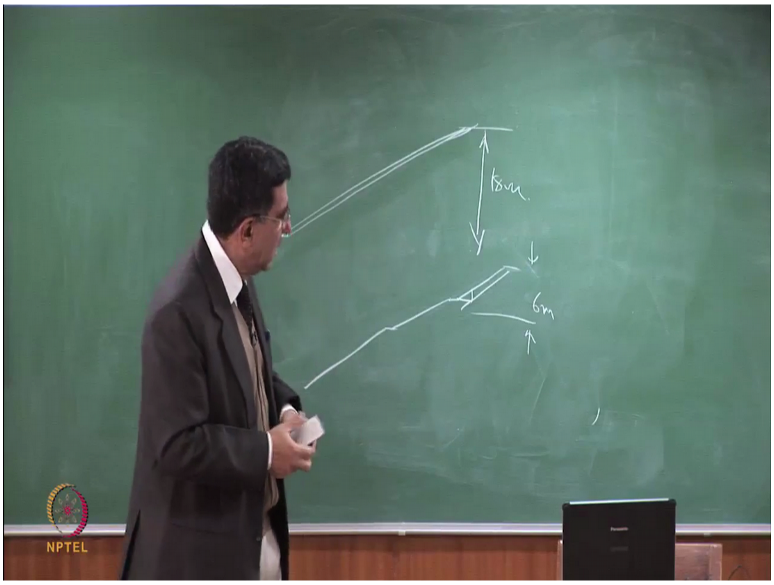

So, this is 6 meters higher now typically, if you go read the railway manual for railway embankments or any other manuals they will say please put a berm every 6 meters you do not need it from slope stability point of view, you need it from erosion control point of view, that when the water falls down the valley valley formation does not take place and it breaks the speed of the water.

And now if you see this my, what is my h? H is 1 meter or thickness is 1 meter what is the height; 6 meters now that is not so infinite it can be infinite, but it is not so infinite. So, if I look at now the passive edge here this passive edge is not that small in comparison to that slope. So, the close are the berms the more the importance of the passive edge.

So, we are not doing those formulae here, but this is a two ways analysis; can you see on the here that we are now looking at this problem as a two wedge problem this is the passive wedge this is the active wedge we are assuming that there is a tension crack at the top normally the effect of the passive wedge will be very small, but suppose you say no I will make a berm it at every 5 meters somebody goes on say no I will make a berm it every 4 meter, slope is becoming progressively flatter because you are giving a berm; however, then you better start calculating a factor of safety taking this passive resistance in your design we are not doing it in this course there are formula which are available you can read up corner (Refer Time: 36:01) and corner and you can look at the formulae the influence of passive wedge.

The passive wedge is almost no influence once the berm, once the berms are a ten meter spacing because the h is only one meters.

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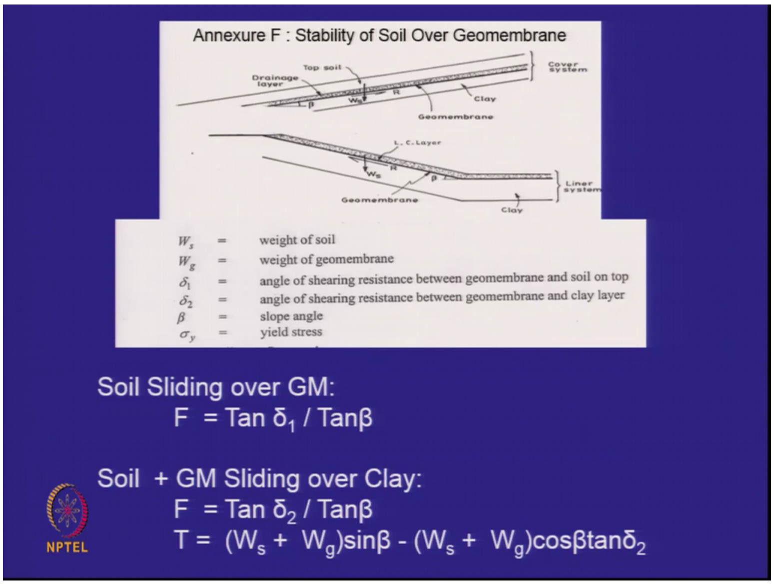

So, I am going to come back to this analysis if I look at this diagram I do not know whether how clear they are, but we are looking at the cover and we are looking at the liner, and I have already said first we look at the soil sliding over the geomembrane, and very simple soil sliding over the geomembrane is the tan of delta of the soil on top of the geomembrane no I am not a now I am not having a geotextile protector then I will have the sand directly on the geomembrane.

So, above the geomembrane we have said here that it will be tan delta one tan delta one is the sand to geomembrane interface angle below the geomembrane it will be tan delta two. So, there will be two different factors of safety and if there is difference if this is less than one then you will have to take out the tension.

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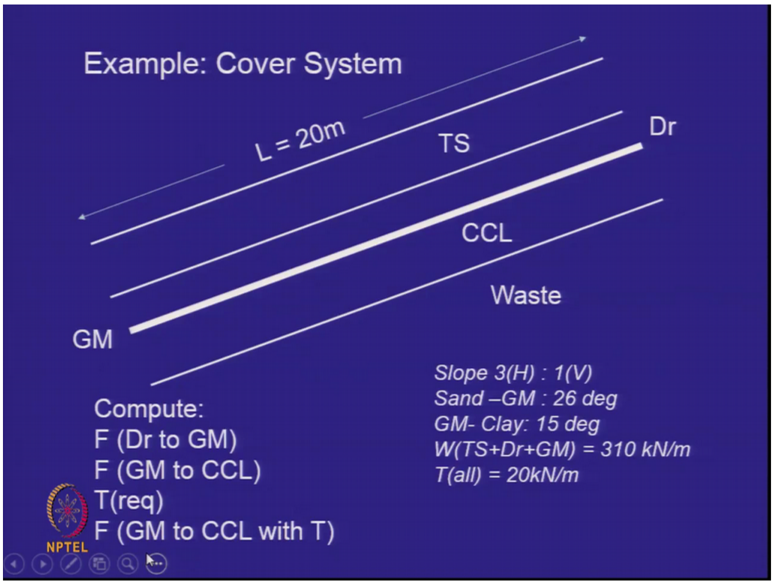

So, let me give you a problem and you will have to take out your calculator for this if you have if you do not we will try and work something out, but let us look at this problem. What is the problem say? You have a 20 meter long slope, 20 meter long slope and that is your geomembrane, on top of the geomembrane is the drainage layer and the sand to geomembrane delta angle is 26 degrees, and the geomembrane to clay delta angle is 15 degree.

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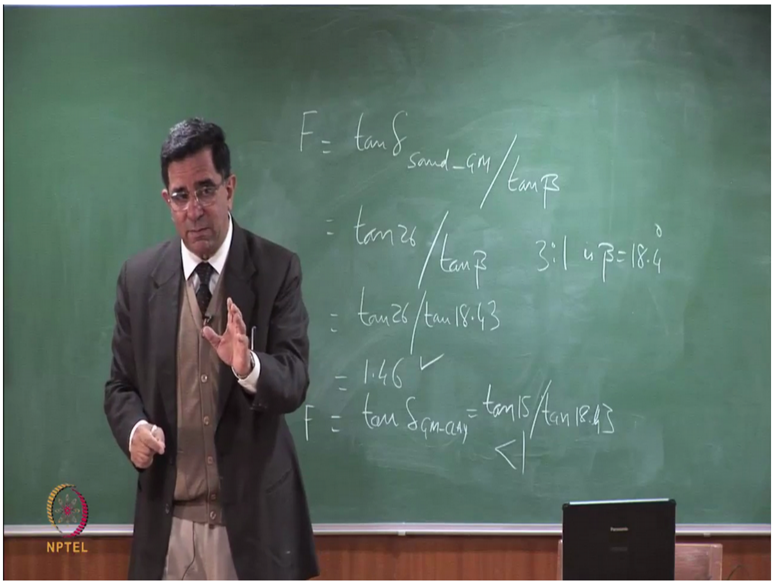

So, first I want you to find out the factor of safety for the sand to geomembrane interface. Can you please do that for me? The slope is given as these is to one and sand to clay is tan 26 degrees, what is tan beta what is beta in this case one is to three is given. So, can you give me inverse of 1 is to 3.

Student: (Refer Time: 39:07).

Three is to one is beta equal to 18.

Student: Point.

Point.

Student: 4 degree.

18.4 degrees; so can you give me what is this value pardon.

Student: One point.

1.46 this is acceptable what is the acceptable factor of safety for.

Student: 1.5.

1.5, it is almost 1.5. So, we can for the purpose of this class say this is acceptable. Now what I want to know is it going to slip below the geomembrane this is sand wanting to go down it would not go down it is more than one, but will it go down below the geomembrane then what is the tan delta geomembrane to clay, what is the value? Tan 15 by quite clearly this is less than one quite clearly this whole soil mass is therefore, with the geomembrane wanting to come down it is going to slip and remember you have a very gentle slope of three is to one.

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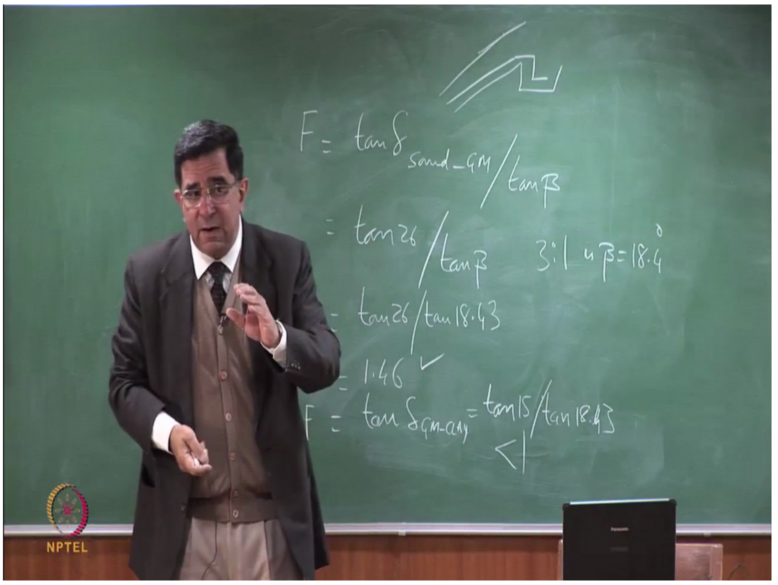

Now, can you hold this from happening can the geomembrane hold this from happening well if the geomembrane is anchored at the top in a anchor trench, it is buried in an anchor trench which is holding the geomembrane, we will come to the design of the anchor trench later.

But if the geomembrane is anchored at the top it can take a t agreed and what is the t that you need please look at this formula, weight of soil plus weight of geomembrane sin beta minus weight of soil plus weight of geomembrane cos beta tan delta right this is very simple it is the driving force minus the resisting force. So, w becomes important suddenly, the more the w the more the t that you need. So, luckily for us in this problem classroom problem w is given to us w is top soil plus drainage layer plus geomembrane it is 310 kilo new tons per meter ok.

So, can you go back to this formula 310 sin beta minus 310 cos beta tan 15 degrees please give me the value of t .

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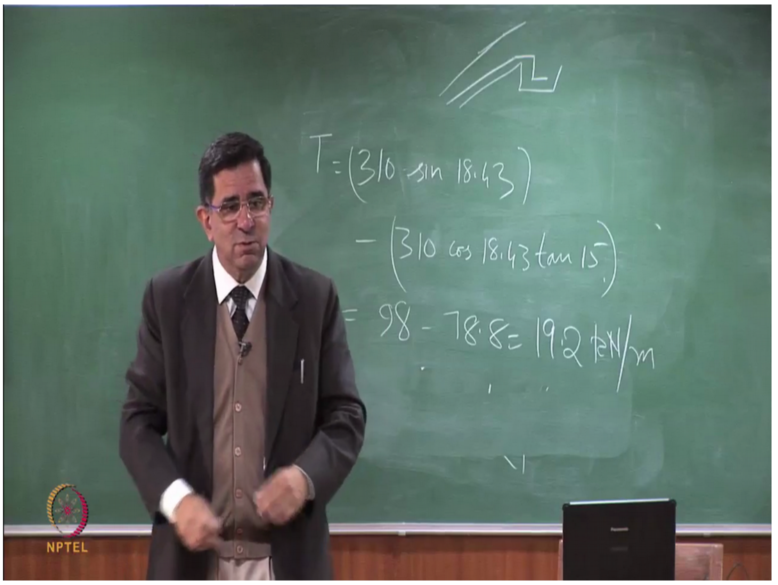

Sorry is that just now write- sin beta can me give me what is this value, what is the first value? 310 sin 18.43 90.

Student: 98.

98 and what is the second value? 310 into cos 18.43 into tan 15.

Student: (Refer Time: 43:40).

Minus 78.8 which makes it 19.2 kilo Newton per meter right and let us see what is the strength of the geomembrane. T all well is twenty kilo Newton per meter. So, will the geomembrane hold this?

Student: (Refer Time: 44:06).

Just about just about you want a factor of safety in your geomembrane tensile capacity you will have to put it, but at the moment it says that it will just hold it and you can calculate the factor of safety with the t now in our formula there was no t in this formula there was no t right, but in this formula with t there is a t, you can now add the t and see what factor of safety you get you can do this at home and you have to reach the acceptable value that you want. So, with this I would like to close that this is just one of the cases what we have done just now is without seepage and without earthquake, but I have shown to you the interplay if I reduce w what will happen? That nineteen 19.8 will become lesser because it is all coming from the weight.

So, there is a tendency to reduce the thickness of the layers. So, that the t can be lower here is an example of where what you have to do when there is a vehicle braking force, when this vehicle is going down the slope.

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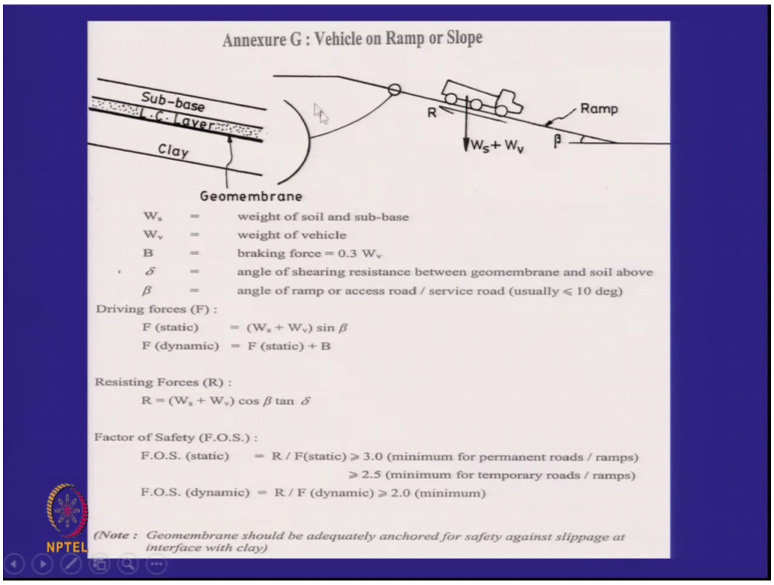

Let me give you a vehicle braking force b and the equations are the same, but you will have to tackle vehicle on a ramp. So, there are 5 6 cases now that you have dry slope with rainfall, with earthquake, with vehicle and all of them have to be stable for the purpose of stable analysis.

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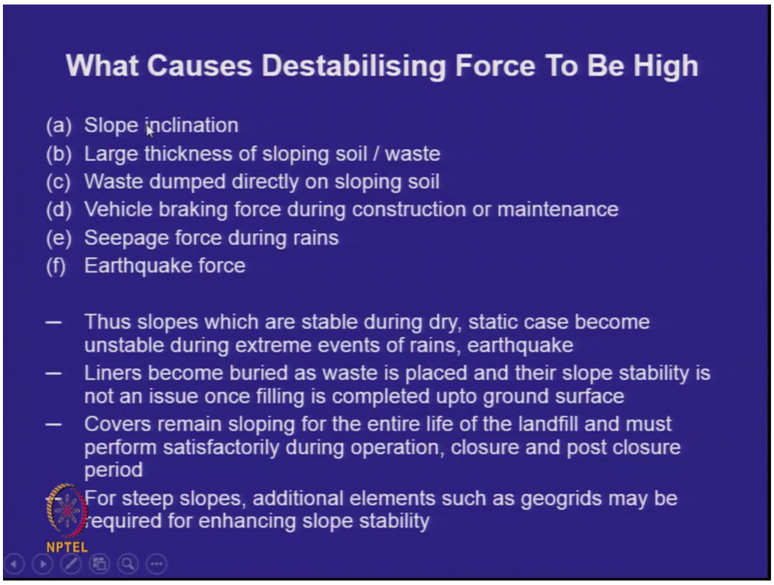

So, what causes instability high inclination, large thickness, large weight dumped vehicle braking force seepage forces and earthquake forces and we have to do all these analysis for the making the slope stable and let me tell you there are a lot of slope failures in covers in landfills. So, you have to be very careful about it.

So, will stop here we just opened our eyes to how the low delta can cause instability even in a three is to one slope and in the next lecture I will take up a couple of case studies to show you how this really comes into play in real life problems ok.

Thank you.