Earth Sciences for Civil Engineering Part-2
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Landslide and subsidence (Part-1)
Module 3
Lecture No 15

Welcome back.

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Now this is one another important topic which is on landslides and as I discussed in the previous lectures that landslides are extremely hazardous in the hilly terrains, so in this topic we will try to cover the different type of mass movements, so I would like to say mass movements because there are number of different type of landslides and landslip, mudflows so in totality we can consider this as a mass movement. So landslide if we define as either very slow sliding of the material sitting on the slope or it may move very fast also, so even depending on the the slip of the material, different mass movements have been classified either it is in mudflow or landslides.

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So landslides or mass wasting we can say okay so downward it is if we take the definition, it is a downward movement of slope material due to gravity. Material may comprise of rock fragments, soil or artificial fill along a defined or we can along a definite plain or a prominent boundary. Movement may be in form of falling that what I was talking about that it may have different speed okay either it it fall it slide or it flows or we can have the combination of both. Mass movement mainly occurs on slope so we need, there is an extreme important parameter, we need slope. If we don't have slope, we will not have any mass movement. May be influenced by natural processes or human activities okay so if you interfere these slopes and if you destabilize the slopes, you may face a landslip or mass movements.

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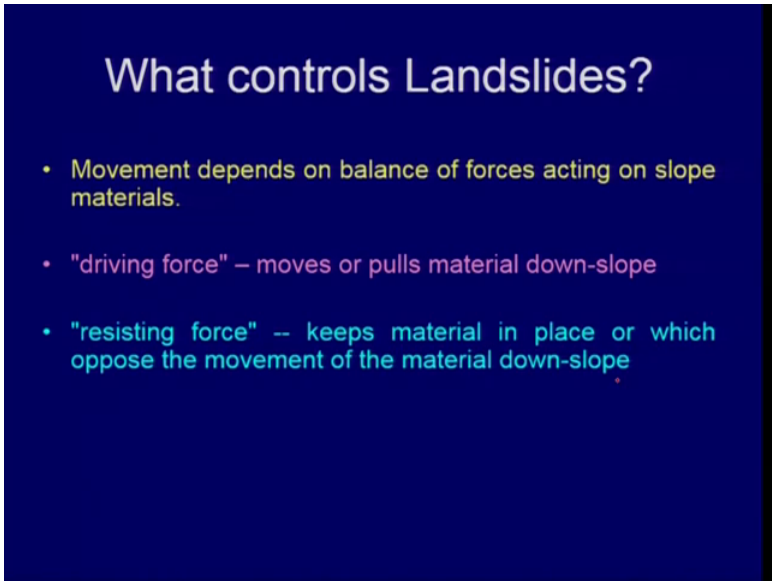

But what controls landslides okay. What are the major factors that controls landslides? So we say that mass movement depends on balance of forces acting on slope, so if you interfere or disturb this balance then you may face a landslides so one is the driving force that moves or pulls the material down slope and another is, your resisting force which tries to keep the material in place or which opposes the movement of the material down slope, so one force is resisting the movement, another force is pulling down the the material okay and keeping at the same place okay.

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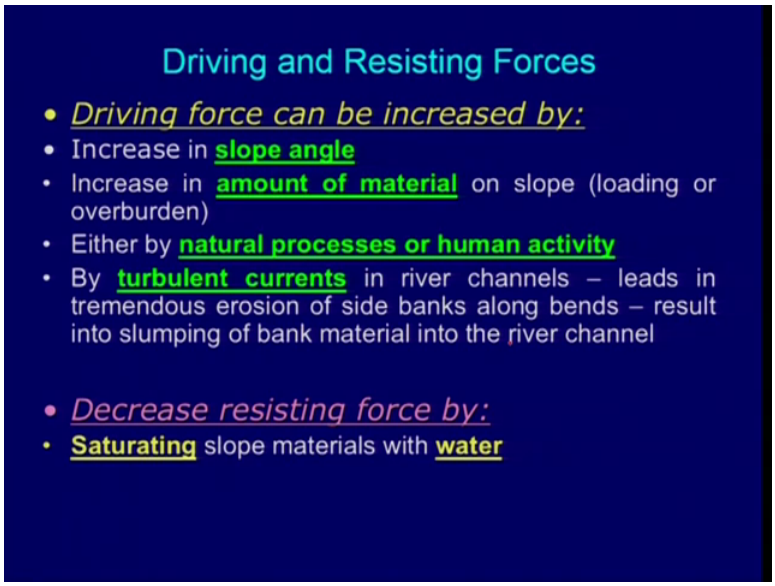

So driving and resisting force can be increased okay, so driving force can be increased by increasing slope angle so if you vary the slope angle there are chances of landslides. Increase in amount of material so if you are increasing the load on the slope also, that can also result into the landslide so here it is extremely important that if you are having a sloping surface and you are putting any coming up with any construction on it, you need to understand whether it may result into the slip in future or not because you are increasing the load on the slope. Then either it is by the natural processes or human activity. For example, turbulent currents in river channels lead in tremendous erosion of side banks along bends okay – results in slumping of bank material into the river channel, and this exactly happened during the Utterkrati (kuch) Uttarkashi flood okay as we have seen in the previous lecture that there was an bank erosion along the bends of the riverbank and that resulted into the collapse of the the houses which were sitting close to the river channels.

Decreasing resisting force okay. So one is driving force and another is resisting force. What parameters will affect in reduction of the resisting force, one the saturating slope material with water, so if you are having a lose material and if you keep on adding more water to it, it may lose (it) its shear strength and result into the slip okay and then another is shaking of slope during earthquakes. This again will reduce the or decrease the shear strength of the material sitting on

the slope. So we have couple of important factors so one which we can look at is very important is the slope, then we are having the saturating the slope by water or we are reducing the shear strength by shaking so this you should keep in mind when we are discussing further this topic okay.

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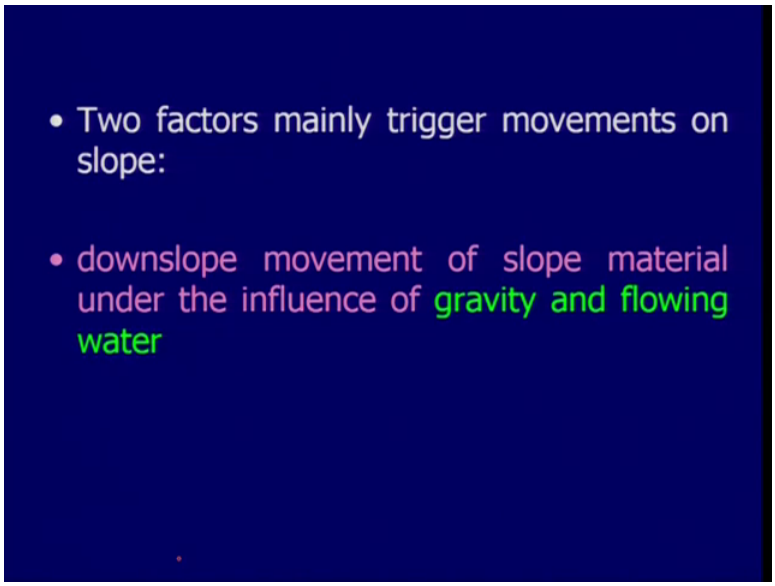

So 2 factors mainly triggers the movement on the slope, one is the down slope movement of slope material under the influence of gravity and flowing water.

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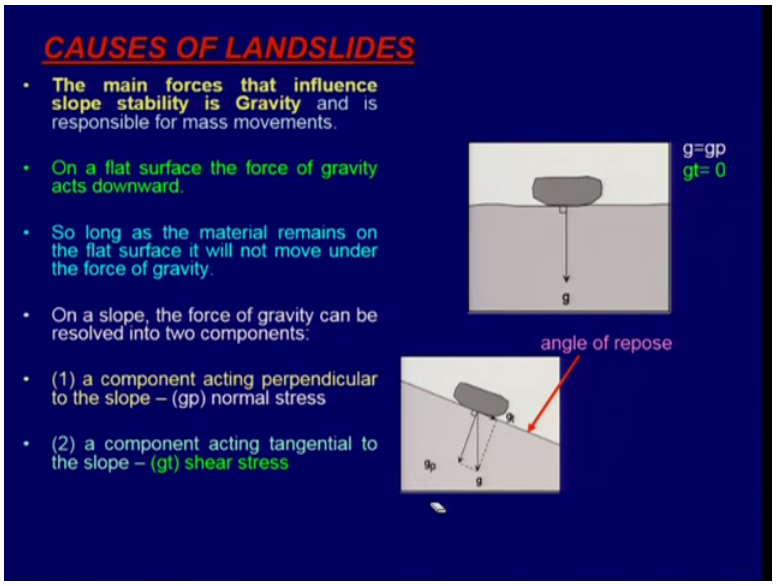

Now causes of landslide if in total if we take okay, the main factor influence slope stability is gravity and it's responsible for the mass movement so on a flat surface suppose if we take, the force of gravity acts downward so nothing will happen okay if you are having a flat surface, no movement will take place because your normal stress is acting perpendicularly to the the ground surface and you have no forcing or no forces which are trying to drive this material okay. So here you are having the gravity what we we are talking about the this is a normal stress okay is equal to the gravitational force whereas here you are having the shear stress okay that is the driving force which is almost zero here because no slope angle is available.

So long as the material remains on the flat surface, it will not move under the force of gravity. However on a slope the force of gravity can be resolved in 2 components so you have one the normal stress and another you are having the shear stress here and gravitational force will be always perpendicular irrespective of the slope here so this is what we call the angle of repose so if you change the angle of repose then you may or result into the landslides so here you have the normal stress is equal to the shear stress. So until this is under the equilibrium then nothing will happen and all material on the earth's surface has certain angle of repose so beyond which it will slip okay if you increase it, so if you increase the the angle here and if you vary the shear stress okay and if it is greater that is the shear stress is greater than the normal stress then you result into the landslide.

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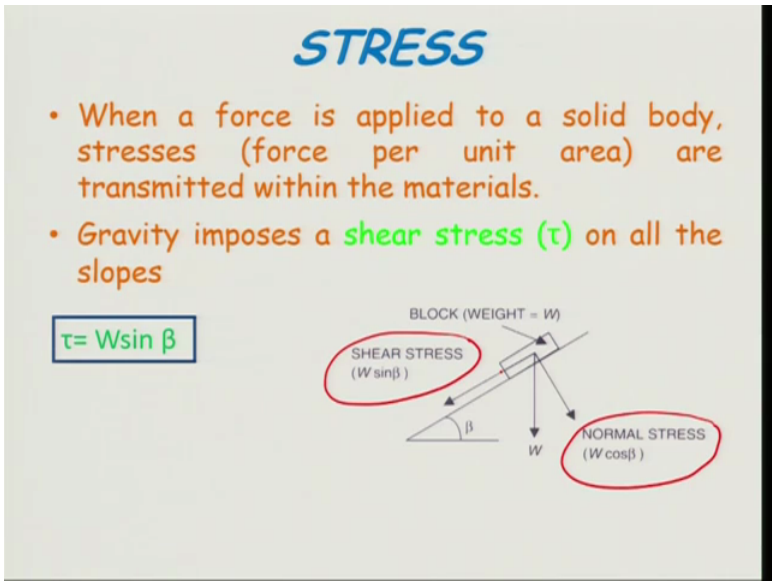

So stresses in terms if you take okay when a force is applied to a solid body, stresses that is force per unit area are transmitted within the material and we have the shear stress and we have normal stress okay. Now gravity imposes a shear stress Tau on all the slopes okay which you can give with the equation W, where is the weight and sin beta. Okay that is the angle with the slope with respect to horizontal and normal stress is W Cos beta and W is the weight of the material sitting on the slope.

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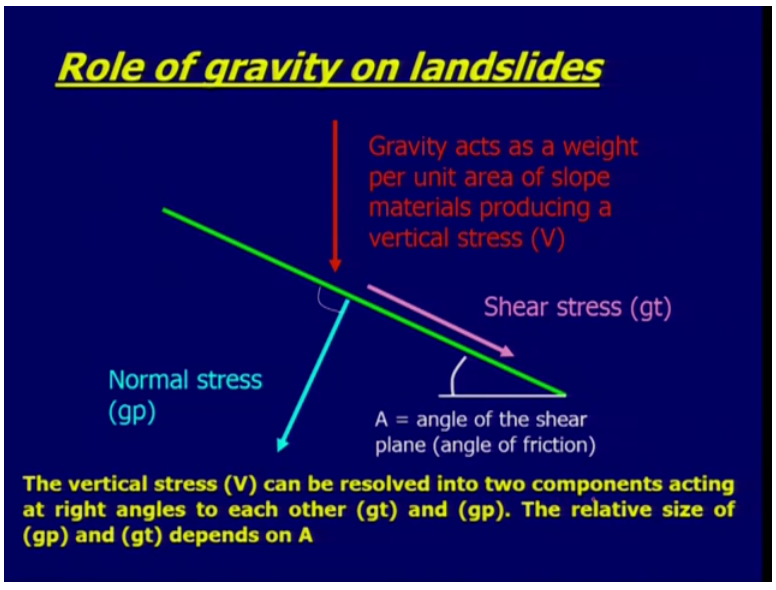

So role of gravity on landslide so gravity acts as a weight per unit area on slope materials producing a vertical stress V okay and you have a normal stress and you have shear stress okay and this is your angle or you can say it theta or beta or whatever it is, you want to take is the angle of shear or angle of friction. So the vertical stress V can be resolved into 2 components acting at right angles to each other okay. That is between GT and GP. The relative size of GP and GT depends on the angle so if you change this angle, the relationship between the normal stress and the shear stress will change. Eventually if you increase the slope angle, the shear stress will increase and that will result into your landslide. So until GT or shear stress is equal to GP normal stress then no landslide will take place.

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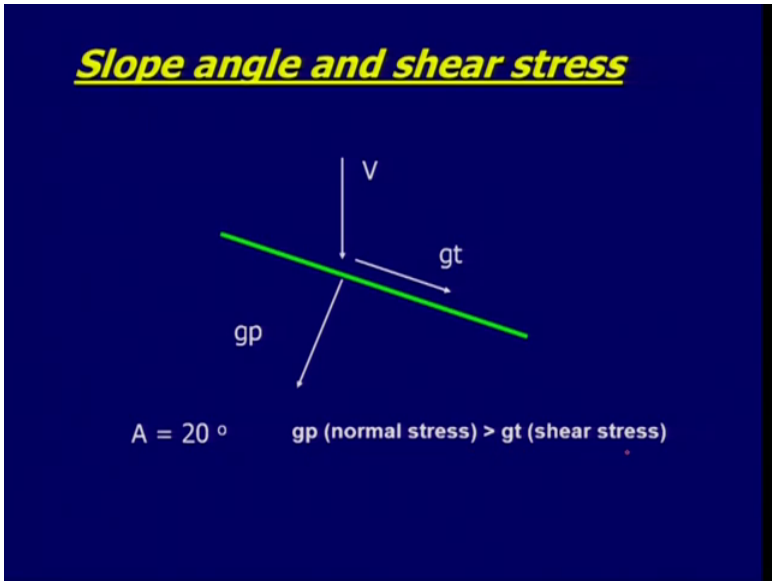

So slope angle and shear stress if you take okay, suppose it's 20 degrees, you have almost like here, you are having the normal stress greater than the shear stress okay, nothing will happen here.

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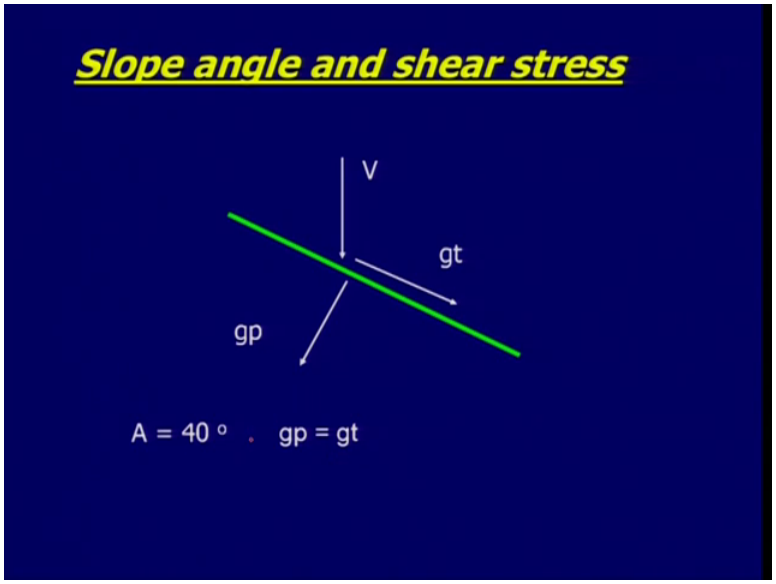

If you are increasing the angle, slope angle, still until some point, it will remain the same okay.

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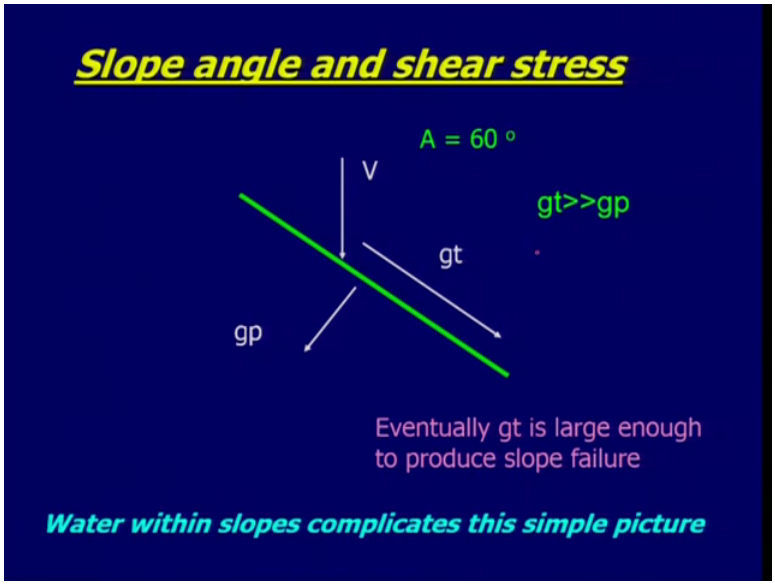

But if you increase further then here what you are having is GT that is shear stress is greater than the normal stress and eventually will result into the landslip so GT is larger, large enough to product the slope failure so in in terms of the human interference, if you increase the slope angle by excavation then you may face the landslide so water within the slope complicates this simple picture okay. So even though we keep on talking about that GT should be equal to GP to have a stabilized slope but in the case where you are putting more water then it may result into the landslide because of the loss of shear strength of the material.

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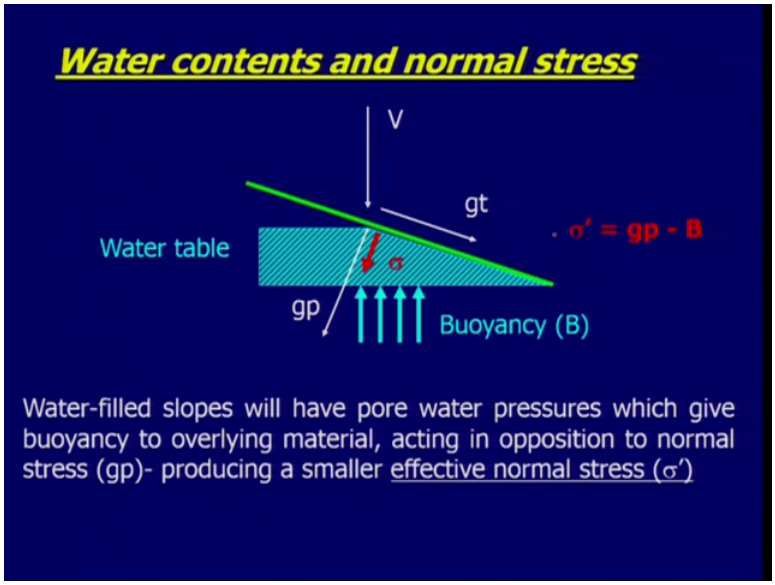

So water content and normal stress, why it happens because it result into and give rise some Buoyancy effect okay. So here we have the water saturated material which will result into the Buoyancy effect and that will change your normal stress, so as soon as we have disturbed the normal stress and normal stress here because of the water interaction will be reduced okay and that is what we call the effective normal stress. As soon as this has been induced, this will have to hold the drive the material down slope okay so water filled slope will have pore water pressure which keeps Buoyancy to overlaying material active in opposite to the normal stress producing a smaller effective normal stress so we will have this Buoyancy effect which will result into the effective normal stress where effective normal stress is normal stress minus the Buoyancy effect. So we were talking about that as soon has this has been disturbed, this will take up the work okay and that will result into result into the slope failure.

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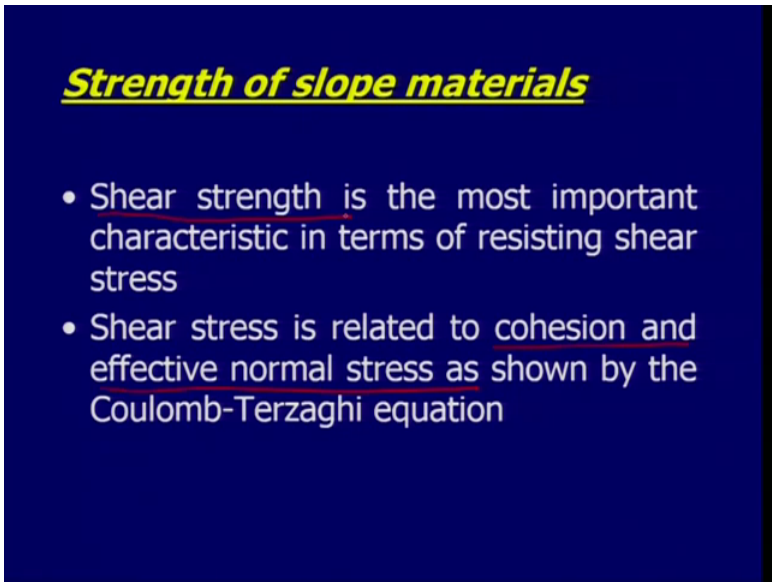

So strength of the slope material okay so shear strength is the most important characteristic in terms of the resisting shear stress. And the shear stress is related to one the cohesion and the effective normal stress as given by the Coulomb Terzaghi equation which includes the importance of the internal friction of the material which includes the angle of the slope, so internal friction of the material will be affecting the shear strength. So for example if you are having gravel deposits and if you are having sand and if you are having clay, the internal friction will be different for different material.

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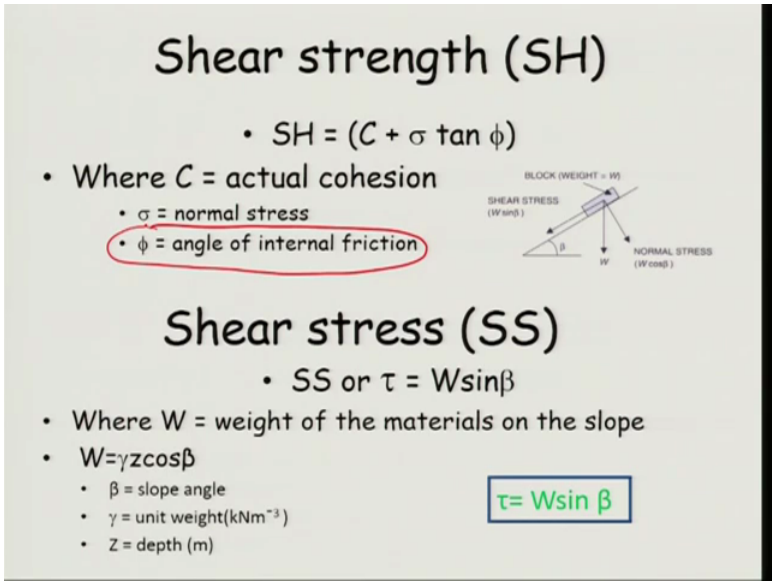

So shear strength either we say SH will be given this is Coulomb Terzaghi equation, where C is the actual cohesion of the material and phi is the angle of internal friction and the shear stress is given as the weight of the material and the slope angle so important part is hear that again, what we have been discussed that the the internal friction is extremely important and this can affect cohesion of the material, so here the water can play an important role in terms of changing the shear strength of the material.

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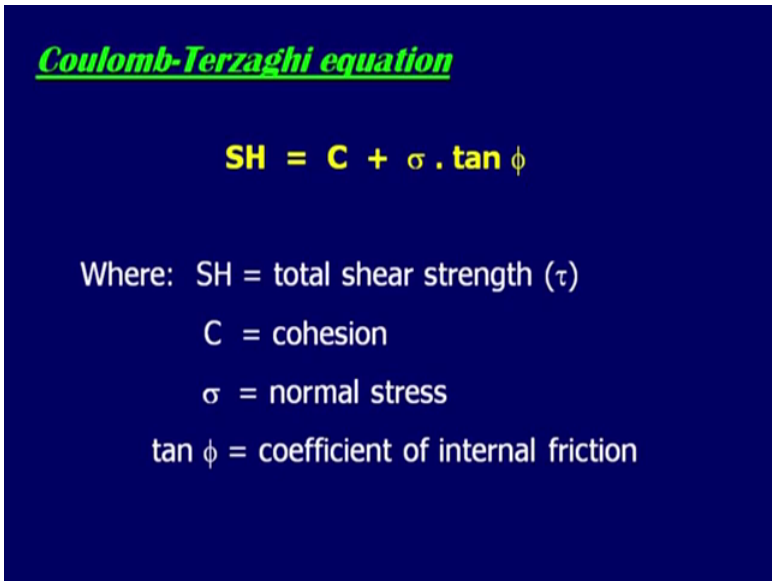

So Coulomb Terzaghi equation as discussed in the previous slide can be given as total shear strength tau okay, cohesion of the material, normal stress and phi is the coefficient of internal friction so if you have this information, you can talk about that what will be the shear strength of the material.

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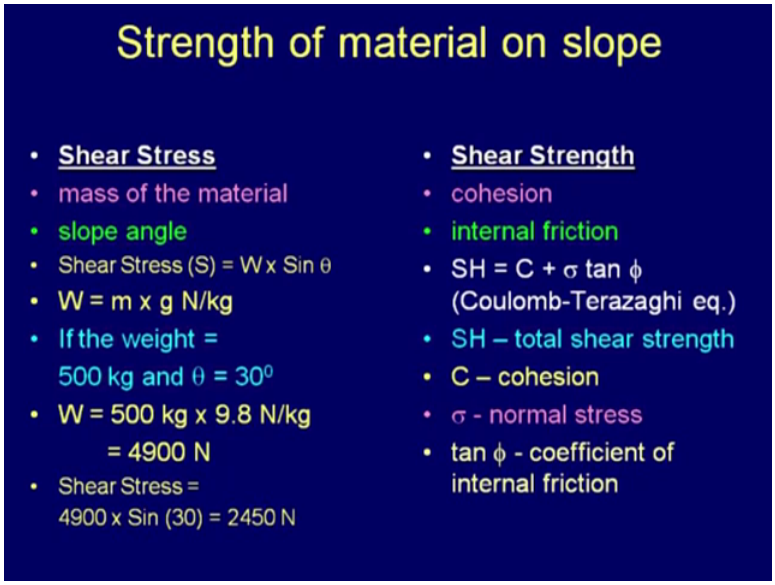

Now, strength of the material on slope, you can have one example here that if we have shear stress and we are talking about the shear strength okay then we are interested when we are talking about the shear strength of shear stress okay that is the mass of the material is extremely

important, slope angle and then you are talking about the shear stress okay. So where shear stress is given as W sin theta so W can be further classified as mass into gravity Newton per kg, so if the weight is for example 500 kilograms and the angle of slope is 30 degrees okay then weight that is 500 kg into the acceleration which G will give the mass as weight as 400 and 4900 Newton okay so shear stress will be your angle into the weight here.

That will be around 2450 Newton where the shear strength as we were talking about that this will depend on the cohesion okay internal friction that is SH where we talking about the cohesion and the internal friction of the material okay. Total shear strength, cohesion, normal stress and 10phi is the coefficient of internal friction. This parameter that is the shear strength and shear sorry shear stress and shear strength will be helpful extremely when we are talking about factor of safety of any material sitting on a slope.

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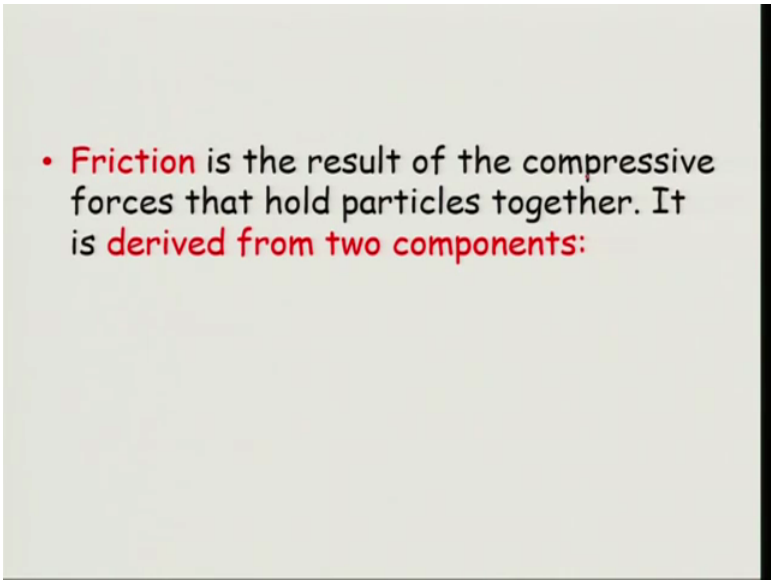

So friction is the result of compressive forces that holds the particle together. It is derived from 2 components that is angle of internal friction that is a measure of frictional resistance of the material. The normal stress that is the effect of gravity operating at right angle to the slope or shear surface okay so these are the 2 components.

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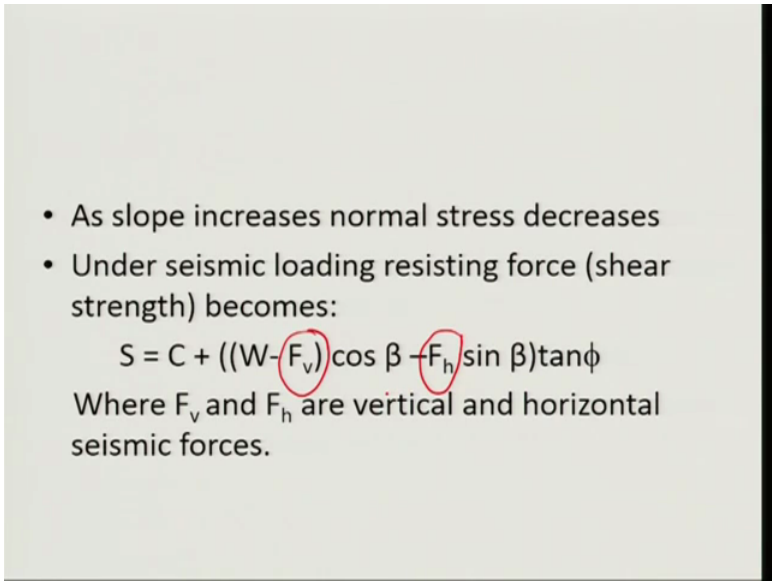

So as slope increases, normal stress decreases so under seismic loading because we we are talking about the 2 factors, either we reduce the normal stress because of adding more water to the sloping surface or the material sitting on the slope or either because of the ground shaking. So underground seismic loading which is triggered by earthquake ground shaking, seismic loading resistance forces becomes something like this okay where you have the 2 components which are been added here. FV and FH okay because during ground shaking you will add on the vertical as well as horizontal forces so these parameters again has to be taken into consideration when we are talking about the the strength of the material.

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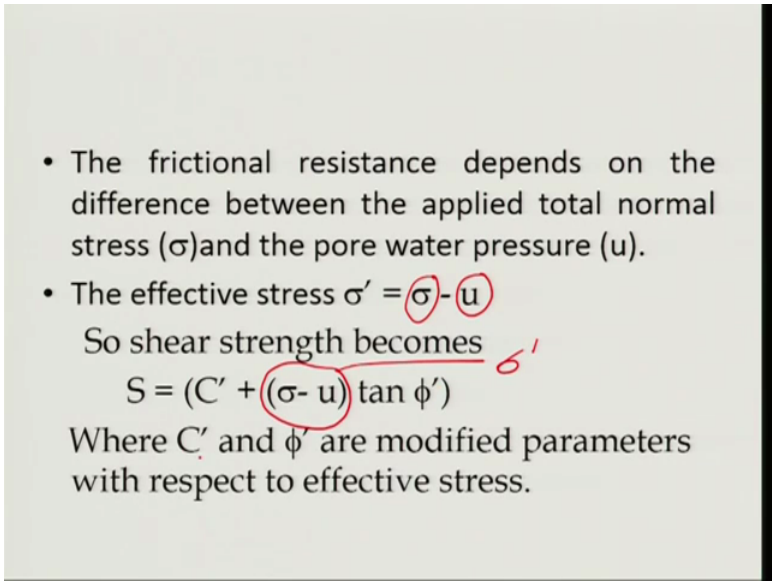

The frictional resistance depends on difference between the applied total normal stress and the pore water pressure that what we were talking in the one of the slide before okay and that will be your effective normal stress or effective stress, so this is your normal stress and this is a pore water pressure. So shear strength becomes when you are putting the component of the pore water pressure, this will be your sigma prime and of course the internal friction will also change so where C prime and phi prime are modified parameters with respect to the effective stress.

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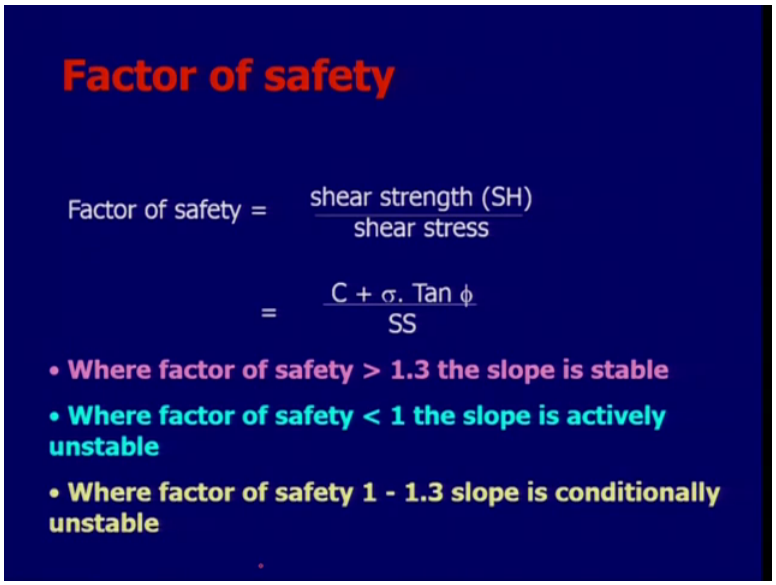

So this is important in terms of when we are talking about the factor of safety. Factor of safety is been given as shear strength by shear stress. So if you take the normal Coulomb Terzaghi equation we have this equation which will give us the factor of safety so where the factor of safety is greater than 1.3, the slope is stable. Where factor of safety is less than 1 then the slope is actively unstable. Where the factor of safety is between 1 to 1.3, the slope is conditionally unstable okay. So what is extremely important for us the parameters which we have discussed in the in the previous slides okay. That is the normal stress okay will be extremely important when we are talking about the material sitting on the slope and if they are getting saturated by water or if we are changing this parameter and this parameter because of seismic loading.

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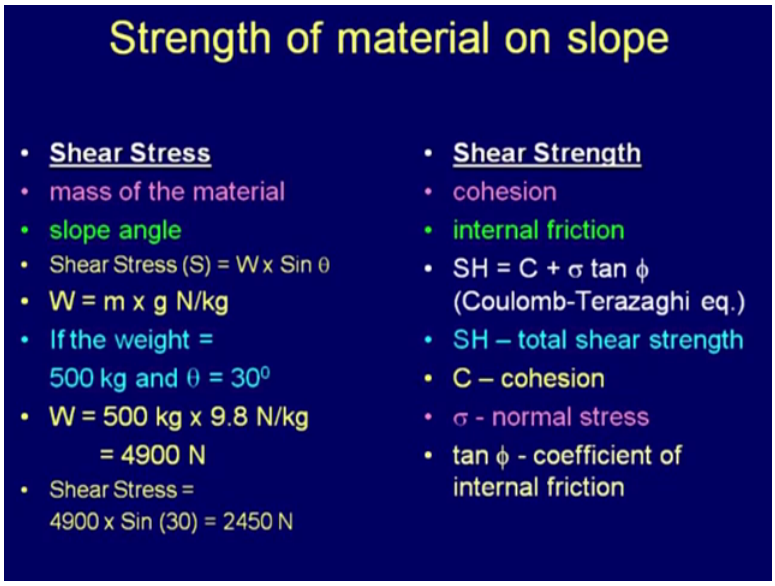

And this will depend upon the so shear stress will be will depend upon so shear will talk will depend upon the weight and the slope angle whereas here we are talking about the stress so again where we talk. We (in) incorporate the cohesion, then we incorporate the internal friction of the material and the normal stress okay. So this is this one has to keep in mind when we are talking about the factor of safety.

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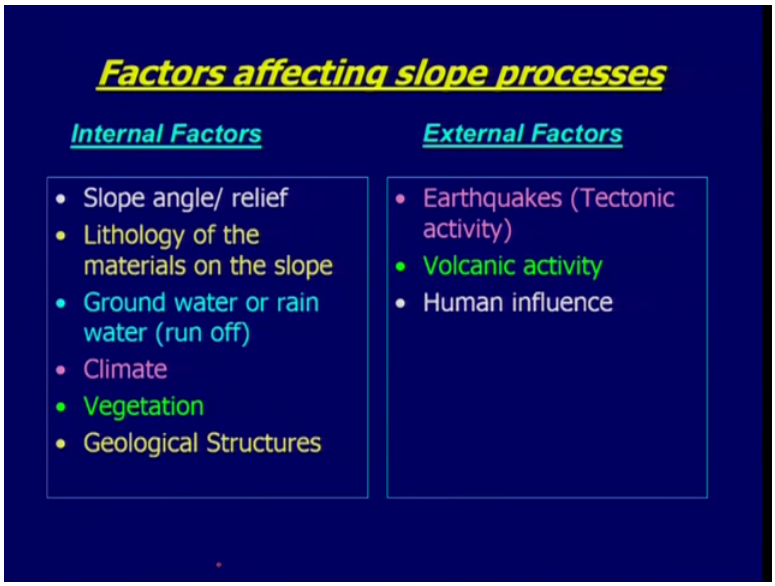

Factors affecting the slope processes, internal factors, internal factors and external factors okay. A slope angle or relief, lithology of the material on the slope, ground water and rain water that is what we are talking about the run off, then climate in which area the slope is present okay and what type of material is there then of course the vegetation then geological structures. Then external forces, earthquakes, tectonic activities in the areas, volcanic activities, human influence which will destabilize the slopes okay so these are all factors okay so it is not the one single one which will act upon or affect the the landslides but there are several okay so please keep in mind what parameters we talked about in terms of the shear strength and shear stress okay which includes all that is we are talking about the slope angle, we are talking about the internal friction of the material. We are talking about the groundwater which will affect here, normal stress and of course the climate because this will be extremely important when we are talking about in terms of the precipitation.

Vegetation to some extent will hold the the slope and then geological structures so if you are having faults and fractures, that eventually will affect the shear strength of the material. Earthquake will result into seismic loading okay because of the strong ground shaking, volcanic activities as we were talking in the introductory lecture that it can result into the landslide and the human influence if we reduce the or we we excavate the material from the slope or we are over

burdening the others the the weight on the slope (re) increasing the slope of slope angle can result into the landslide so these are 2 factors okay, internal and external factors which will also affect the slope processes.

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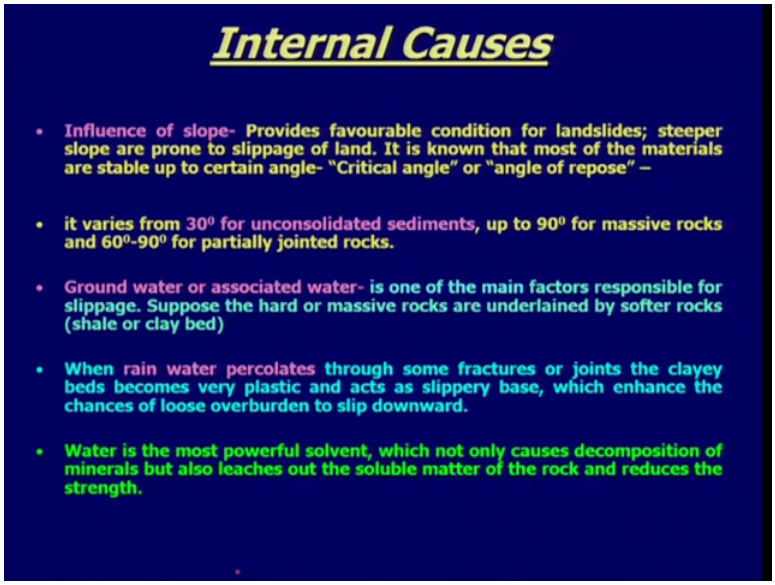

So internal causes, influence of slope provides favorable condition for landslide. Steeper slope are prone to slippage of land. It is known as known that most of the materials are stable up to a critical angle that is what we were talking about, the angle of repose. For example, it varies from 30 degrees for unconsulated sediments so if you are having loose sediments, it will remain stable until 30 degrees. Up to 90 degrees for massive rocks and for jointed rocks, it is up to 60 to 90 degrees, so ground water or associated water is one of the main factor responsible for the slippage.

Suppose the hard or massive rocks are underlain by softer rocks like shell or clay beds okay so they have different shear strength so if you are having the massive rock sitting on the surface that doesn't mean that area will not slip okay because you are having a softer material which is having comparatively less shear strength and will eventually decrease the the normal stress okay when you are pouring more water on the slope okay and if it becomes over saturated, it will result into the mass movement. So when rain percolates through some fractures or jointed areas, jointed regions okay, the clay beds become very plastic and acts as an slippery base which

enhances the chances of loose over burden to slip downward so you have affected here the normal stress of the material on the slope so the holding forces which were acting before the percolation of the water okay is changed.

So water is the most powerful solvent which not only causes the composition of the minerals but also leaches out the soluble material of rock and reduces the strength okay, so this will reduce the shear strength of the material so along with the slope, the angle of the slope, what type of material is on a surface is important.

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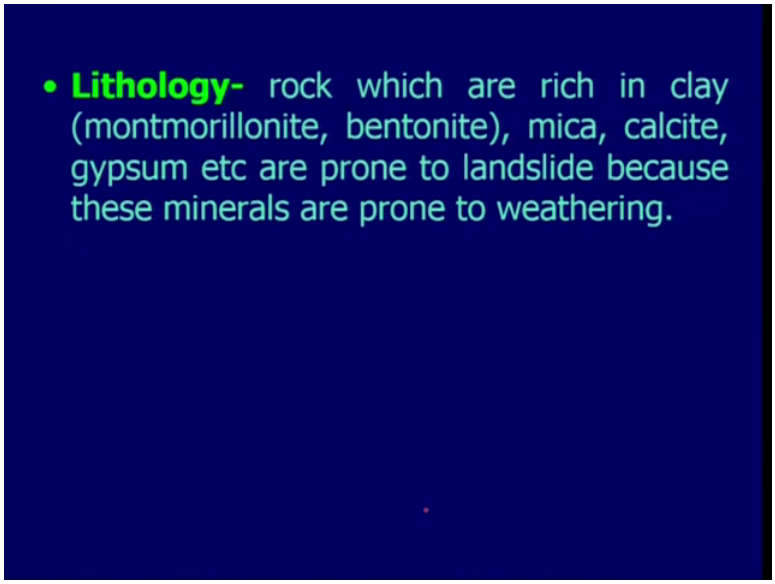

So for example, lithology, if we take into consideration, rock which rocks which are rich in clay, Montmorillonite, bentonite, mica, calcite, gypsum etc are (pron) prone to landslide because these minerals are prone to weathering so will discuss this part again and in the next lecture, thank you very much.