Natural Hazards
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Lecture – 27
Introduction to Landslides

Welcome back. So, today we are going to start a new topic this is on landslides and related hazard. Briefly we had some discussion in the initial lectures where we talk about the landslides and which are the main locations where we can expect the landslides, and what are the reasons for that

Very briefly we discuss, but now we are going to discuss in detail about the landslides. Now this photograph was taken after the 2015 Gorkha earthquake in Nepal, where the landslide was triggered because of strong ground shaking

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Now in this topic we are going to also talk about the different type of landslides or we can say in total mass moment. This is another photograph from our the similarly reason for the landslide.

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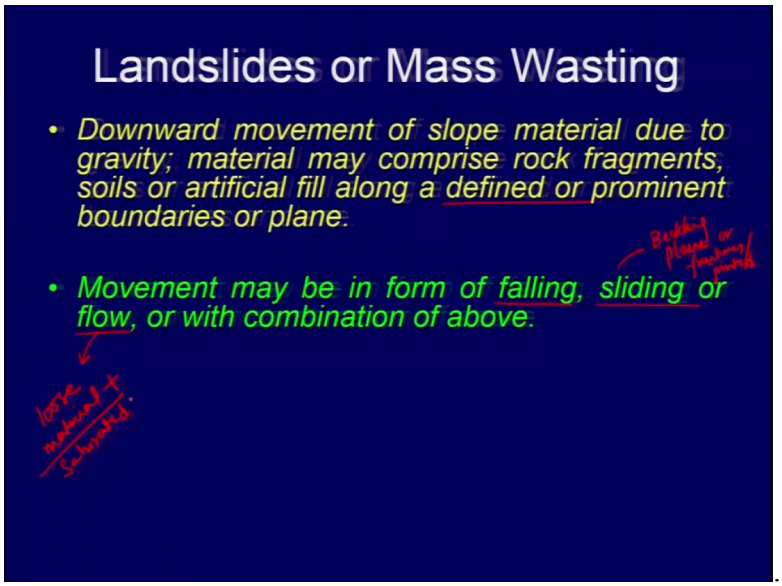

So, landslides or we can say mass wasting.

So, mainly what we see is the first photograph here, if you recall it clearly shows the downward movement of the material which is sitting on the slope. So, there are a few parameters which will be essential to trigger the landslide and as one is the slope and the material the type of material which is resting on this slope.

So, if the slope is higher or steeper and then the chances of having landslides is greater, but again it will depend on the material what type of material is available? If it is a loose material, then the area will be prone to landslide without adding much of the short of what I would say that ingredients like water if you have, because if you as soon as you make the slope material saturated it will lose the shear strength and it is most likely that it will trigger the land slip or mass wasting.

So, let us see what this means is. The downward movement of slope material due to gravity, material may comprise the rock fragments soil or artificial fill along a defined or prominent boundary or plane. So, the movement will occur along a defined plane moment may be in form of falling. So, this falling will be very typically seen if you are having rock strata. Sliding also can occur if you are having a strong rock strata, but we need to have either the rock strata or the succession is having joints; if they are jointed then they can slip along the joints.

So, movement can occur along this joint or the bedding planes we can say. So, joints will be either vertical, but that again will be very important because that will affect the shear strength of the material. So, either we say fractures or the joints in the succession or it may be in form of flow or with the combination of all three also. So, if you are having a fall then most of the areas where we are having in rock blocks which are setting loose then we may have fall, we may have slide as I told, if you are having even the bedding plane or the material is fractured or jointed. And flow itself it talks about that it will have and very loose material plus we can say that they are saturated.

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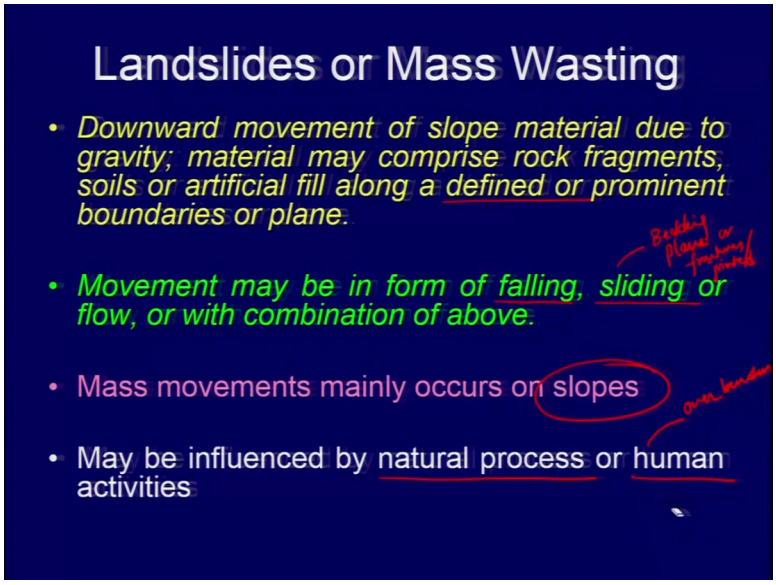

So, mass wasting how the mass movement mainly occurs on slope. So, this is a very important parameter which you will have to take into consideration, may be influenced by natural processes or human activities. So, natural processes could be your water if you are having a very high pouring down of rain then you may have the issues with the material sitting on the slope. If you are doing like lot of material has been post pour or been put on the slope that is an overburden. Then also that will trigger the land slip or you are having you are doing it down cutting. So, suppose you are having in slope like this and if you remove the material from below then this material can slip.

So, there are a few things which are very common and I would say the trivial, but they are very much important when it comes to the mass moment.

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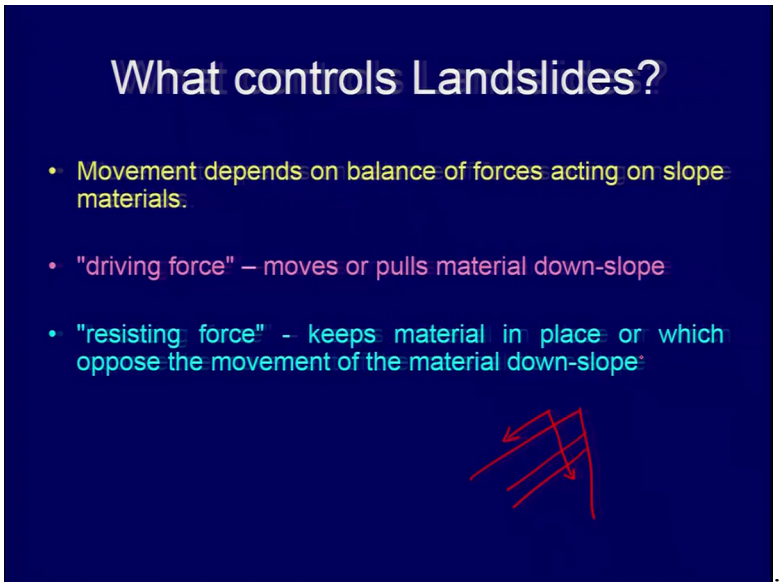

So, what controls landslide? This is the part the moment depends on balance of forces acting on slope. So, as we were talking about that moment will occur under gravity. So, these are the forces which will be acting on slope. So, one is your driving force; which will always tries to move or pull the material down slope.

So, if you are having the slope here. So, whatever the material is sitting on the on the slope, you will have one force acting here and then another one is the resisting force which will try to hold the material which is sitting on the slope. So, one is you this will be here driving force and another will be a normal stress we can say that we will discuss in the next slide. That will keep the material and does not allow the material to move down slope so, that is your resisting force.

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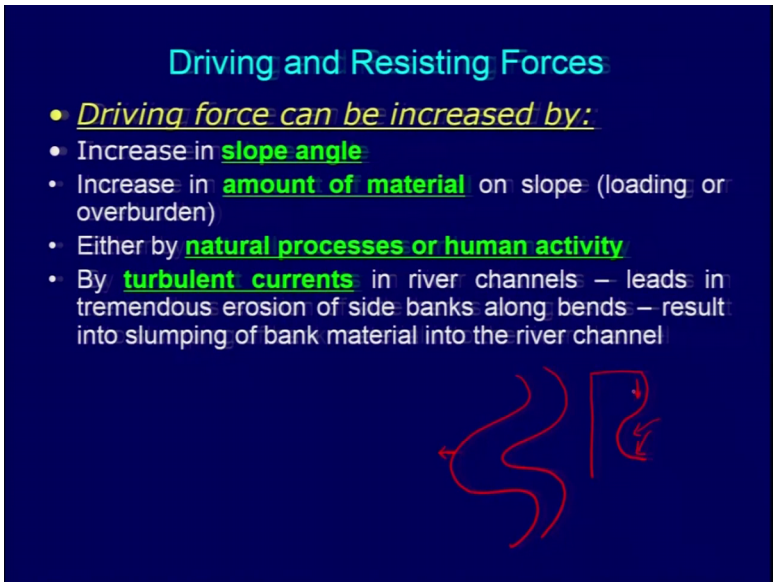

So, driving and resisting forces driving forces can be increased one if you increase the slope angle, second you increase the amount of material on slope that is loading or overburden either by natural process or by human activity. So, we should understand that if you are having the slope is could be an unstable slope you cannot keep on putting load or dumping the material on that, this overload or overburden could be also the civil structures. Then by turbulent currents in river channels, which will lead to tremendous erosion site on the side banks along the banks.

So, you have the suppose you are having the sinus channel or (Refer Time: 08:53) channel then this portion will keep on eroding. So, if you are having a section like this suppose and the river is flowing if it keeps on eroding this I am putting the section. So, if it keeps on eroding this part, then this may collapse or it may result into the landslide. Then decrease resisting force can be because of saturating the slope material by water.

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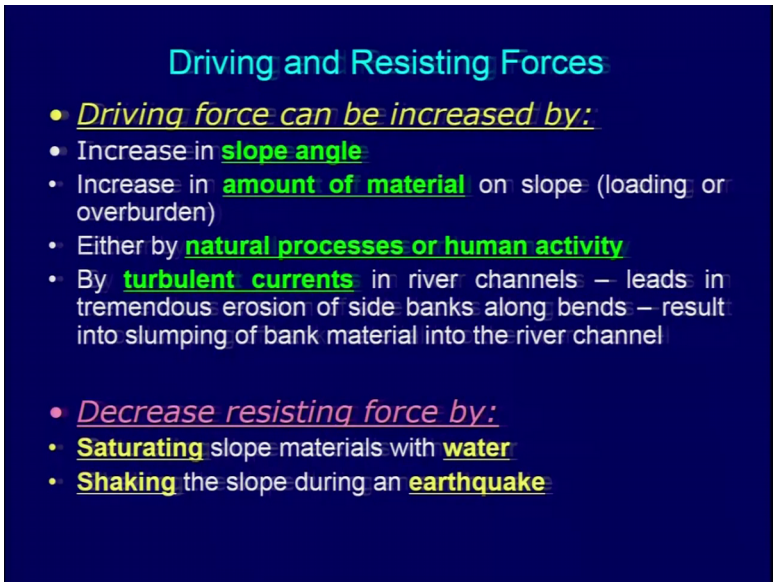

So, in most of the areas what has been done as that to; to allow the water flow as early as possible or flow out of the waters water should run off as early as possible then they try to construct the small waterways or the canals yes. So, that can be drained out as early as possible. And if you allow the water to percolate down then you may result the material getting oversaturated which will result in to decrease in resisting forces. Then another one is shaking of the slope material during an earthquake.

So, if you have an lose material sitting on the slope and if there is an earthquake and major ground shaking is there seismic shaking that may result into the landslide and that example we have seen in the first slide which was from 2015 Gorkha earthquake.

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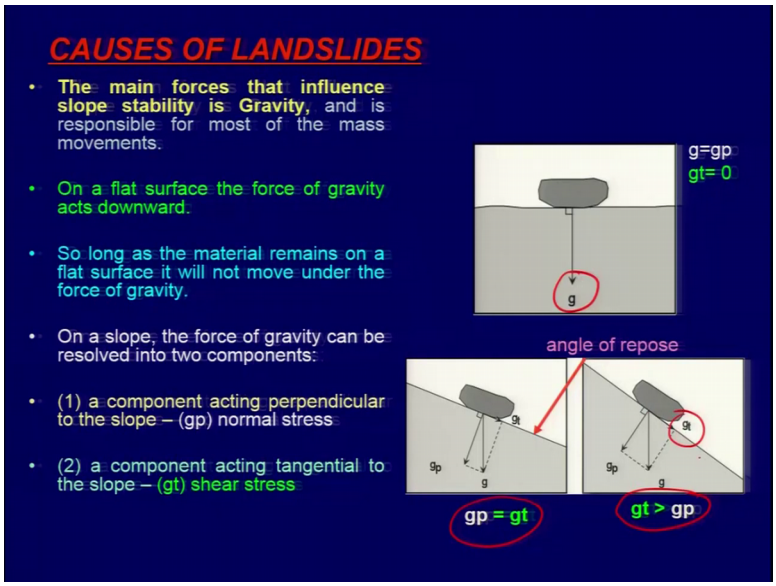

So, causes of landslide the main factor that influenced the slope stability is gravity and is responsible for most of the mass moment. On a flat surface the force of gravity acts downward that is your normal stress. So, if you are having a very flat surface whatever the material you have, you do not have any driving force over here.

So, the material will remain in stable condition, it will not move because this is very strong here. So, in this case the g is equal to g p whereas, the g t is almost 0. That is your shear stress or the driving force is almost 0 here. So, it will not allow the material to move. So, as long as the material remains on a flat surface it will not move under the force of gravity on a slope the force of gravity can be resolved in two components.

So, one is your gt and another one is your gp. So, one a component acting perpendicular to the slope this one is your normal stress. So, what we were looking at here the g is equal to gp, that is your normal stress and another one is your shear stress which is acting tangentially to the slope. So, this is your driving force. So, if this becomes greater then you are allowing the material to slip or slide see if gt becomes greater that is your shear stress then gp will reduce.

So, if gt is greater than gp then you are preparing or creating an idle condition for the landslide. This is also termed as angle of repose. So, here in this case gp is almost equal to gt of course, it is here it has been shown that the with an arrow which is smaller, but if there is no slip is occurring here then in that situation you will have gp which is your

normal stress will equal to gt your stress shear stress, but in case here what you have done is the situation is that you have the gt that is your shear stress is greater than normal stress. And what difference you can see here is the material the mass which is sitting on this slope of failure is same.

But the angle has increased. So, if you are having greater angle then with the same land mass the gt will increase. So, your shear stress that is a driving force has increased which will result into the loss of shear strength of the material and eventually result into a landslide.

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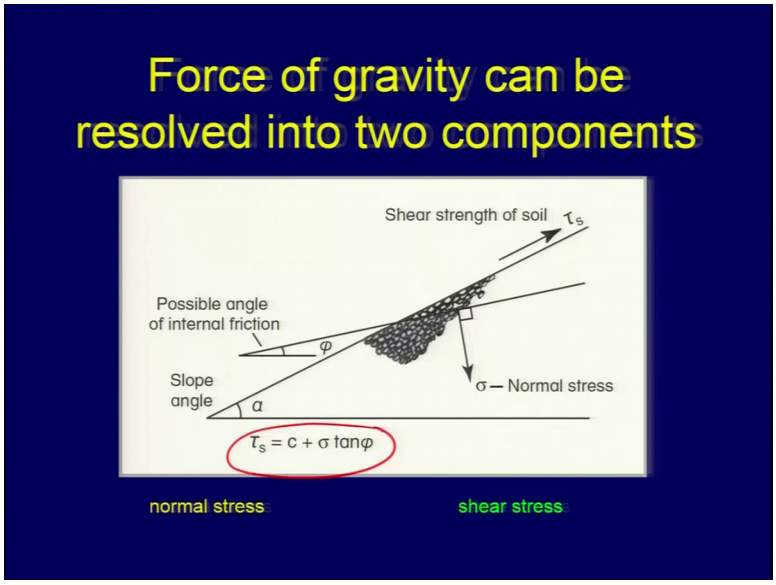

So, force of gravity can be resolved into two components that what we have discussed one is normal stress and shear stress. So, this diagram also explains the same this part will come later when we are talking about the factor of safety where we talk about the coefficient of friction and all that and the normal stress also, and then if you are having and water saturated material then we will have an effective normal stress.

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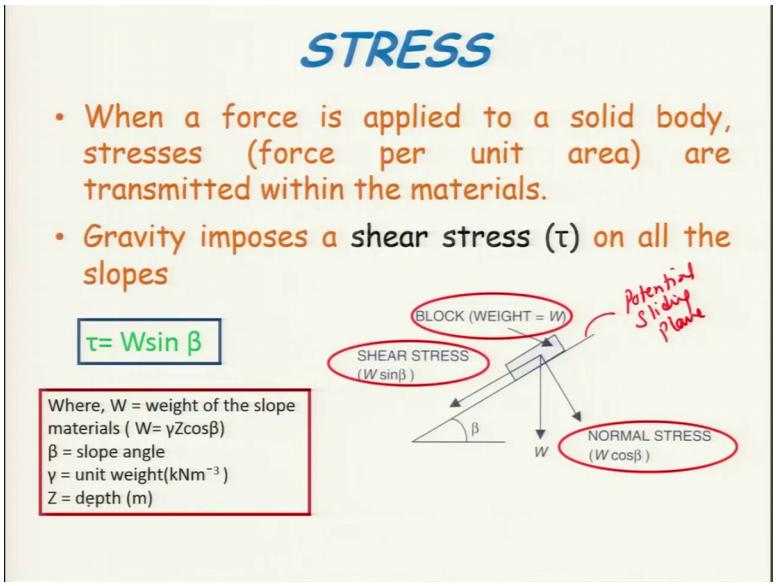

So, stress when a force is applied to a solid body stresses or forces per unit area, because we usually take a stress as an point where the force we are applying per unit area are transmitted within the material and if you take the gravity imposes a shear stress, that is your tau on all the slopes. So, tau is been given as w where w sin beta or you can say its w sin theta, that is an angle of slope and this will be your shear stress.

So, where w you take is your weight of this slope that is the material which is sitting on the slope and along the or above the potential sliding plain. So, beta is your slope angle gamma is the unit weight and said is your depth. So, if you have all this information you can easily talk about the factor of safety. So, where you have the material which has been given as normal stress and you take into consideration the weight and depth here.

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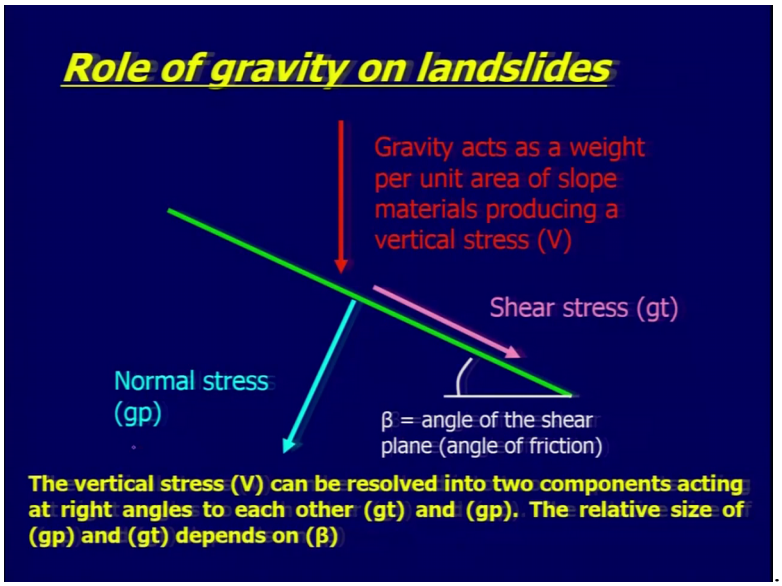

Now, role of gravity on landslides gravity acts as a weight per unit area of slope material producing a vertical stress say V. And we have this as a normal stress and this one is your shear stress and beta is the angle of shear plane along which the material can slip and that is your also will say angle of friction.

So, the vertical stress v can be resolved into two components acting at right angle to each other that is your gt, shear stress and gp normal stress. The relative size of gp and gt depends on the slope, this is what we have it we just discussed in the previous slide. So, this will depend on the slope angle. So, as soon as you vary this two components that is the gt shear stress and the normal stress gp will vary.

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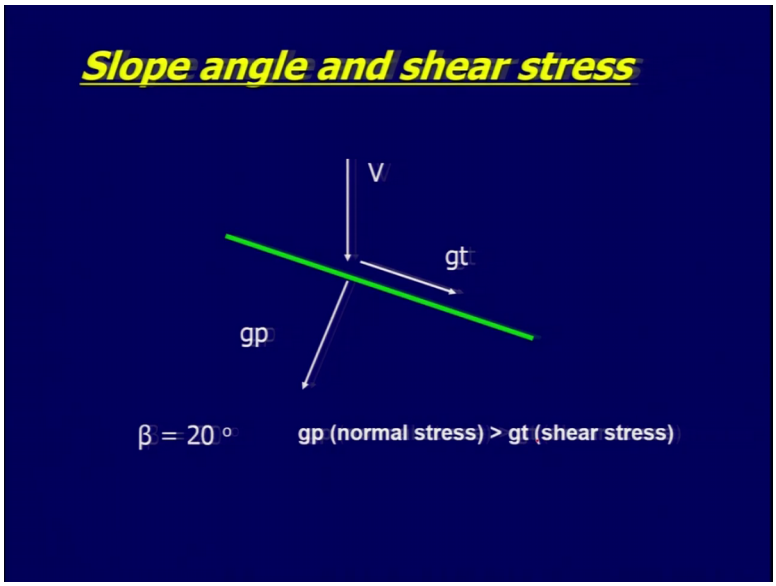

So, suppose you take randomly that beta is equal to 20. So, what is the. So, here the situation is that gp is greater than gt. So, you are resisting force is greater than the driving force here.

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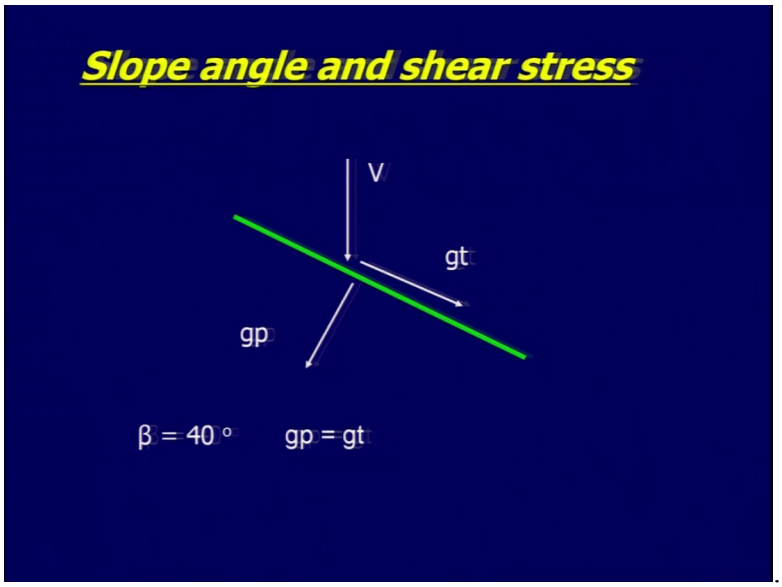

Now, again we increase the slope by about 20 degrees. So, the vertical stress again we are having the two components gp and gt. So, here also we have gp is equal to gt.

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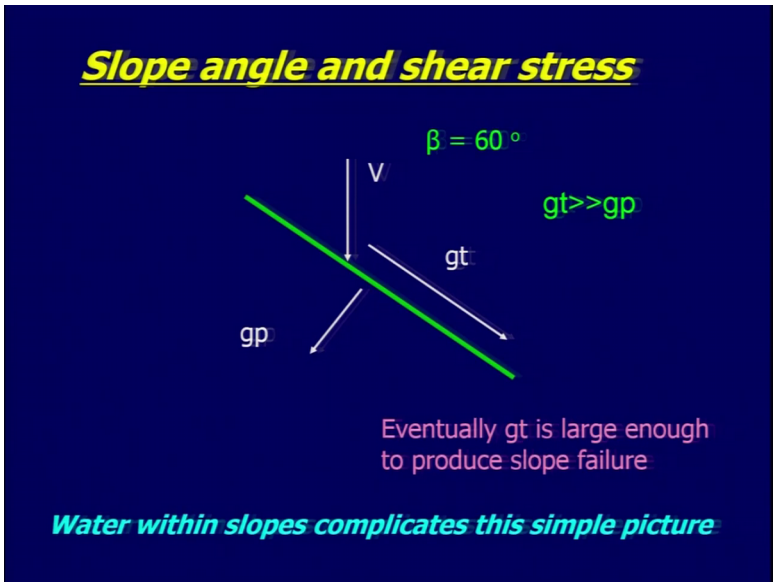

Further if you increase the slope say sixty degrees then you are reducing the gp and you are increasing the. So, you have increased the shear stress, you have reduced the normal stress here. Now in this condition you will have a landslide.

So, eventually gt is larger enough or large enough to produce slow failure. So, this we have in this is the result of the increase in slope. So, water within slope will eventually complicates the simple picture watch, we are trying to understand. So, it is not only the slope of course, the slope is important, but not only the slope will play and crucial role. But if you have water saturated material, then this will complicate the whole scenario.

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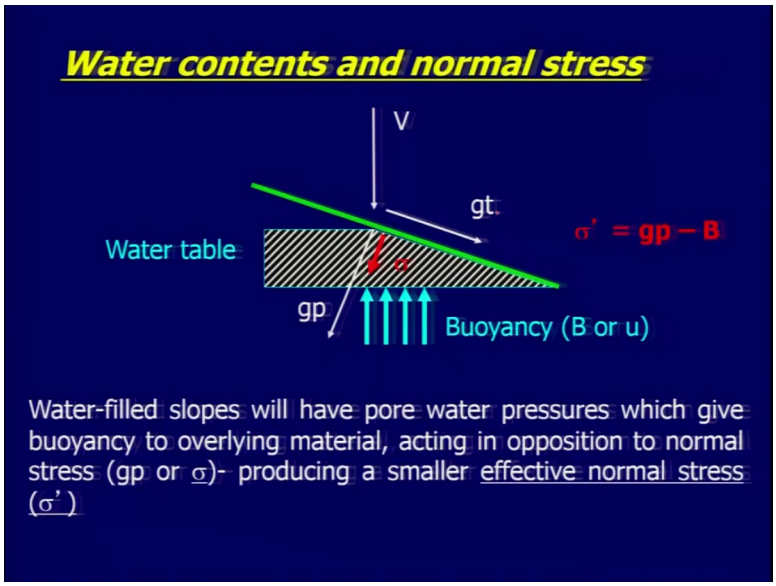

So, water content and normal stress if you take then we have the gp here and if we are having the sigma that is your pore water pressure now the pore water pressure will have some shot o f an buoyancy effect. And that will result into your what has been produced a smaller effective normal stress. So, sigma prime will be your gp what is a normal stress the buoyancy what you are going to do.

So, that will again even if you are having an very gentle slope or maybe say around twenty degree or forty degrees where in the previous case it was not moving , but as soon as you have the water in it water content, that will have the effect of buoyancy resulting into the effective stress or now effective normal stress which will be lesser than the gtn result into the slow failure.

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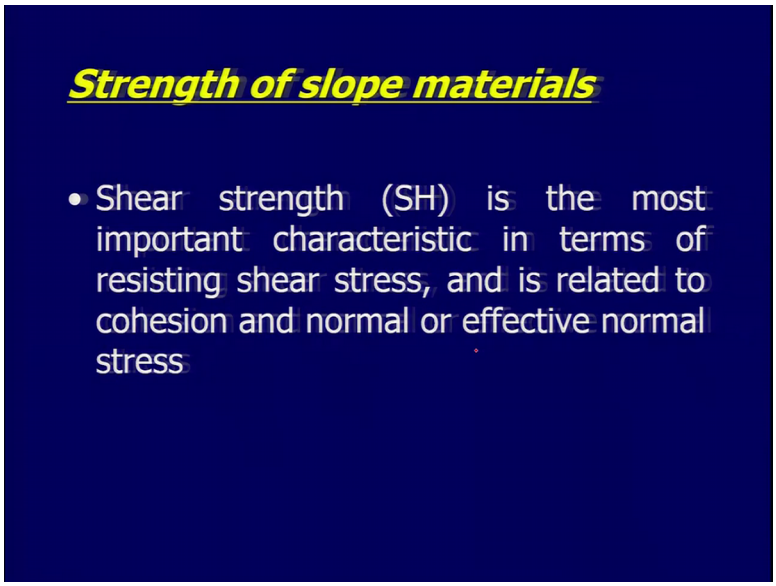

So, if you are having the material; type of material which is porous can hold the water very easily or get saturated that can be dangerous.

So, shear strength of slope material is the most important characteristic in terms of resisting shear stress and its related to cohesion because sand is cohesion less ok. So, it will depend on the cohesion it is related to cohesion and the normal or the effective stress will also get affected.

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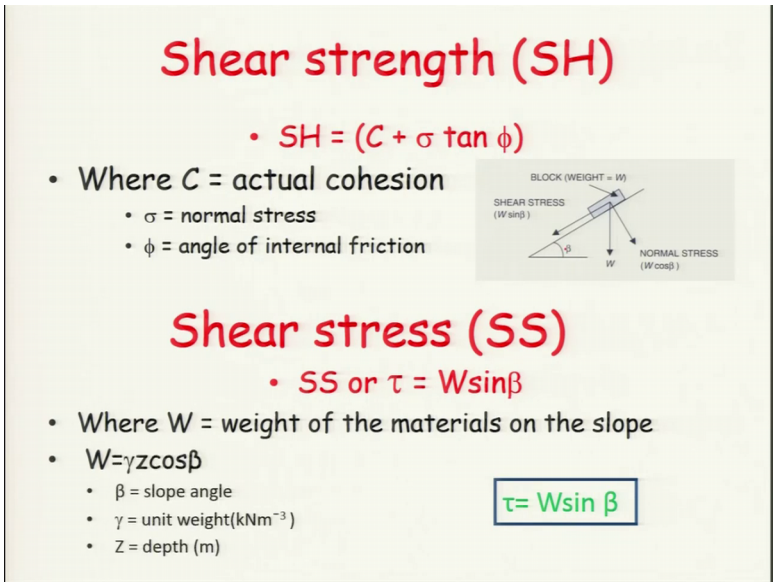

Now, if we take shear strength of the material that can be resolved as C plus sigma tan phi. Tan phi is your internal friction of coefficient and C is your actual cohesion. So, as I was talking that if you are having sand, sand will have this cohesion less.

So, the internal friction of coefficient or angle of internal friction will be different then the other saw material like if you are having silt or clay. Then comes to the shear stress we have already discussed about this that is tau and its given as w sin beta where W is the mass of the material that is the weight of the material on the slope and beta is your angle of slope here.

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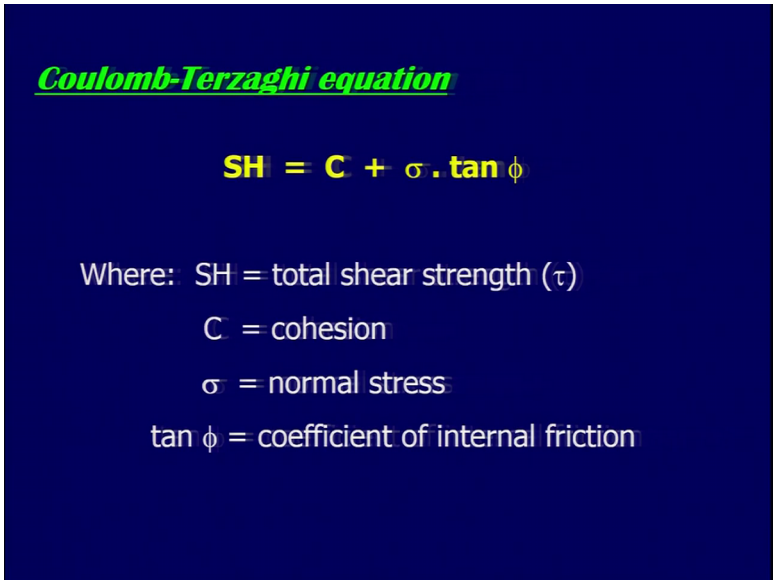

Now, coming to this equation coulomb terzaghi equation is usually been taken into consideration when we are talking about the shear strength.

So, whereas, sh is the total shear strength either you say tau C is the cohesion normal stress and t phi is your coefficient of internal friction.

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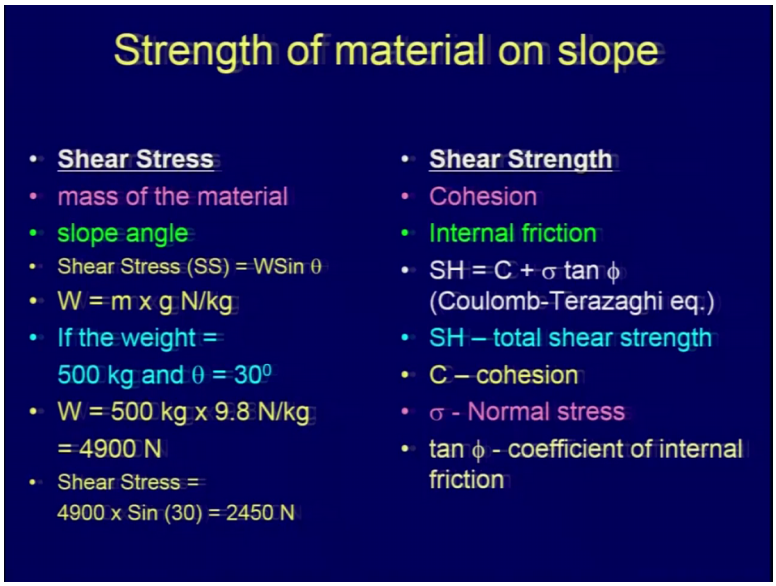

And the shear strength of the material on slope if you take suppose you are having the shear stress, and shear strength then mass of the material need to be taken into consideration slope angle, shear stress, that is your w sin theta vary w is your mass and gravity here Newton per kg now if the weight is say around 500 kg and your theta is around 30 degrees then you have w is equal to your 500 kg into 9.8 Newton per kilogram.

So, this will give you four thousand nine hundred Newton of weight or the force and the shear stress will be we have to take this one here. So, shear stress will be your 4990 into sin 30. So, finally, the shear stress of the material which is sitting on this slope will 2450 Newton. And the cohesion if we take above for the shear strength cohesion we need to take internal friction of coefficient.

So, you have the shear strength which we have we were talking about the coulomb terzaghi equation. So, where sees the strength normal stress, and phi yet taking the coefficient of internal friction.

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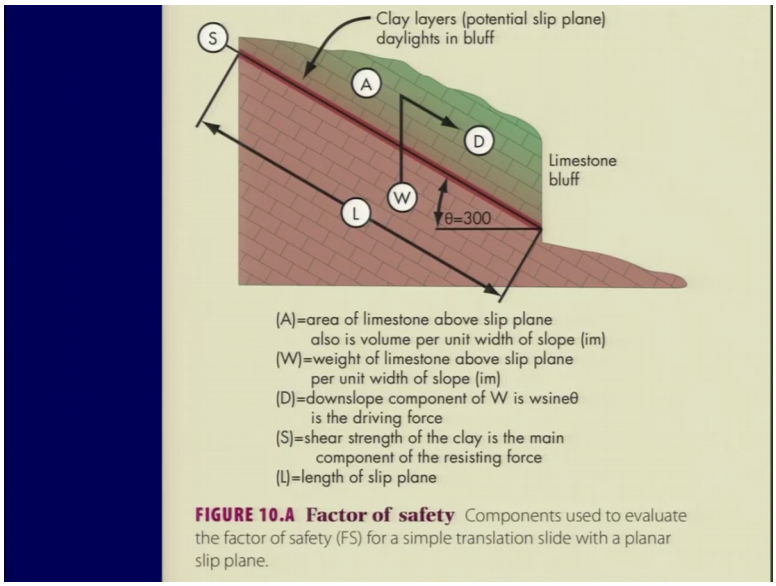

So, we will stop here and we will continue in the next lecture.

Thank you so much.