REMOTE SENSING FOR NATURAL HAZARD STUDIES

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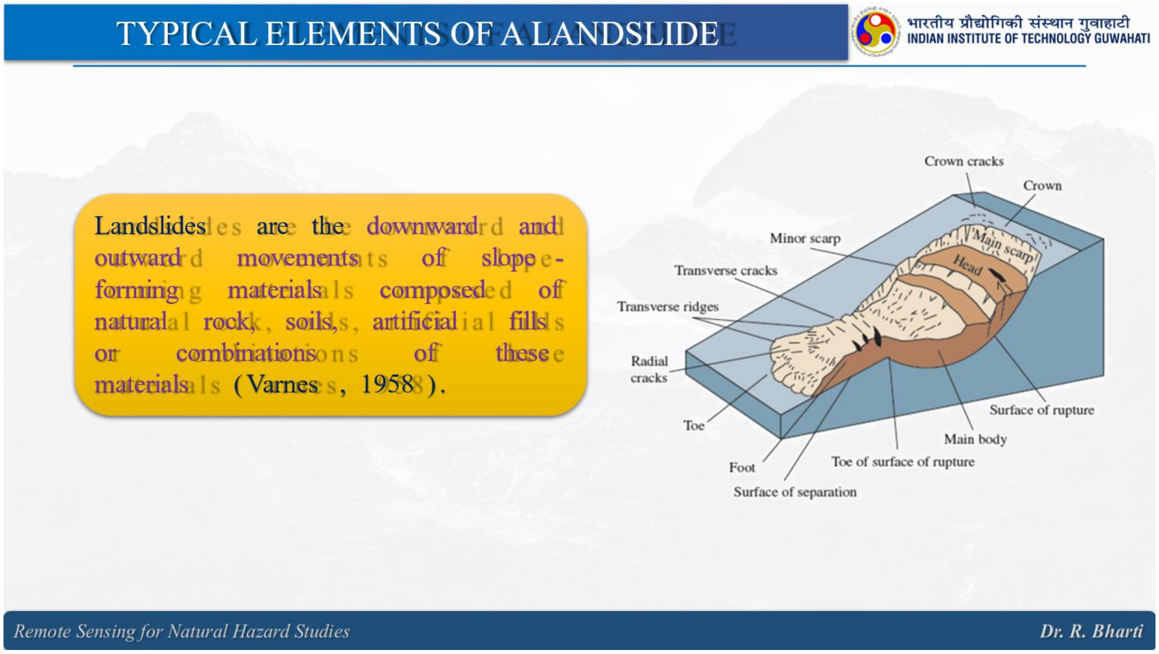
Lec 28a: Introduction to Landslides - Part A

Hello everyone, today we will start module 8, which is on landslides. So, this is lecture 28: Introduction to Landslides. So, many of you might have experienced the landslide, many of you might have seen the landslides, and probably you will be able to perceive how devastating it could be. So, in today's lecture, we will learn more about the landslide. This is an introduction to landslides; we will see different characteristics. So let us start this course.
So, here you can see this video of how devastating a landslide could be; just watch this video carefully to understand how devastating it could be. In another video here, you can see what the scale of this landslide is. So, it is not always that landslides are of this scale. This can be a smaller landslide; this can be a larger landslide.

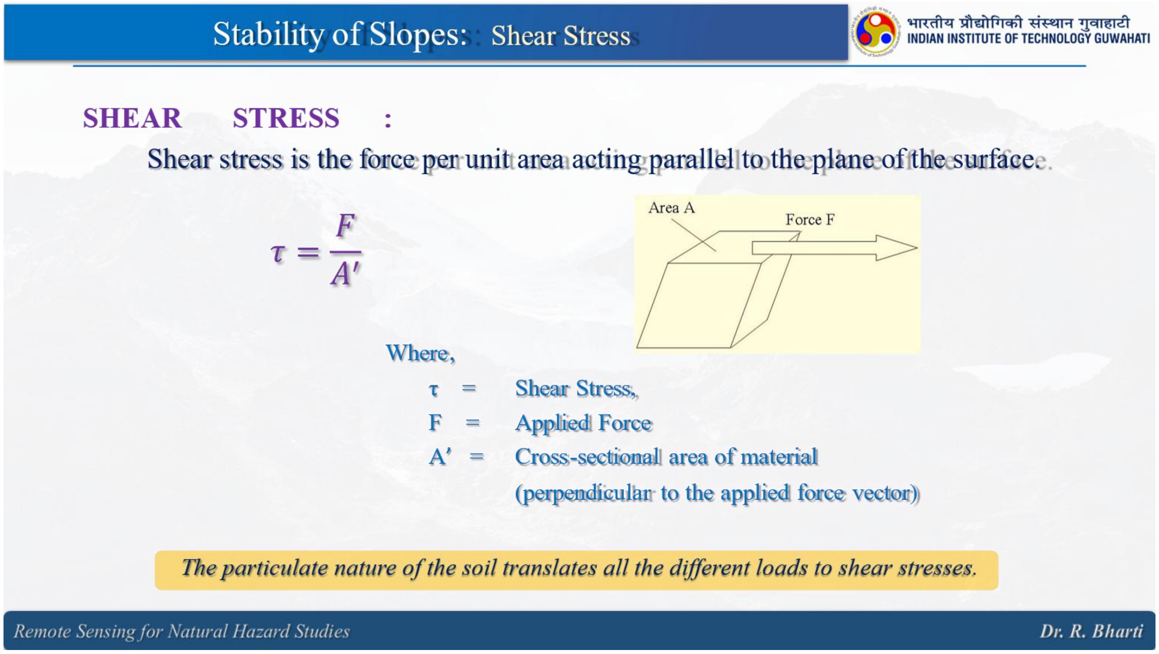
Landslides are the downward and outward movement of slope-forming materials composed of natural rocks. Soils, artificial fills, or combinations of these materials. You can see it here. So, these two videos are meant only to tell you how devastating a landslide could be. So, landslides are the downward and outward movements.



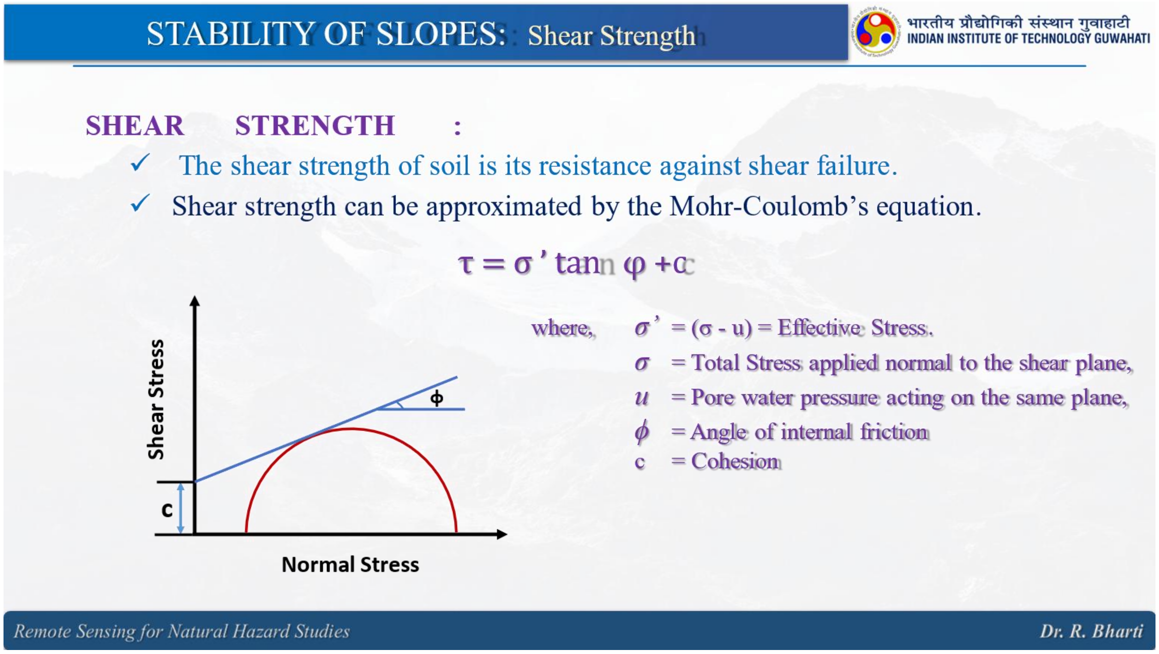
So, what are the properties here? So, here you can see the different components. So, this is the main scar, and this is basically your head, and this is the foot, and this we call a toe. Now, here you can see this is a crown crack, this is the crown, this is the surface of rupture, and this is the main body; this is the main body; this is the main mass of this landslide. Toe of the surface of rupture, so this is the toe because you see this is the surface of rupture here, and this is the toe of the surface of rupture. This is the minor scarp here; this is a transverse crack, a transverse ridge; these are the ridges; this is a radial crack. You can see here, and we have already seen this; this is the foot, and this is the surface of separation. So this is the surface of separation. So, these are the different components of a landslide. So typically, you will see all these features in a landslide.

So, it is semantically very easy to demarcate the boundary of this, but naturally, when you see a landslide. It will not be so easy to demarcate the lines, and you will be able to say that this is the crown, this is a crown crack, a minor scarp, or the toe of the surface of rupture. So, you have to critically examine the features of a landslide. The factors leading to the failure of slopes can be classified into two categories. So, here you can see that this particular hill has failed.

So, this slope has failed, and the material is on this particular road. So, this is a typical landslide. Now, when we say "a landslide," it is basically the failure of the slope. So whatever material is there that is going to fail is going downward. So, this landslide can be classified, or the failure of the slope can be classified, into two major categories.



The first one is the factor that increases the shear stress, and the second one is the factor that reduces the shear strength of the soil. So, here you have a slope. So, either shear stress has increased or shear strength has decreased; this particular slope is going to fail, and then we will have this kind of landslide. I hope this is a clear increase in shear stresses. Because shear stress is playing a major role here. So, how are we going to evaluate what parameter is going to increase the shear stress of the material or what parameter is going to reduce the shear strength of the material? So, let us first see the increase in shear stresses. Increase in slope angle because of the change in the geomorphology or the change in some geological structure. So, let us say this is the slope we are targeting, and here this is in a stable condition. Now, there are two ways it can fail: either shear stress will increase, or shear strength will decrease. So, when we say shear stress will increase.



So, if I increase the slope, how will the slope change because of the weathering? So, probably there is erosion here, and now this slope is like this. So, as the angle is increased, the slope is increased. So, that is because of natural activities. So, natural processes are always acting on the surfaces, and because of that, you are having a change in the slope angle. Then next is the removal of lateral or underlying support because of erosion, previous slides, road cuts, or quarries.

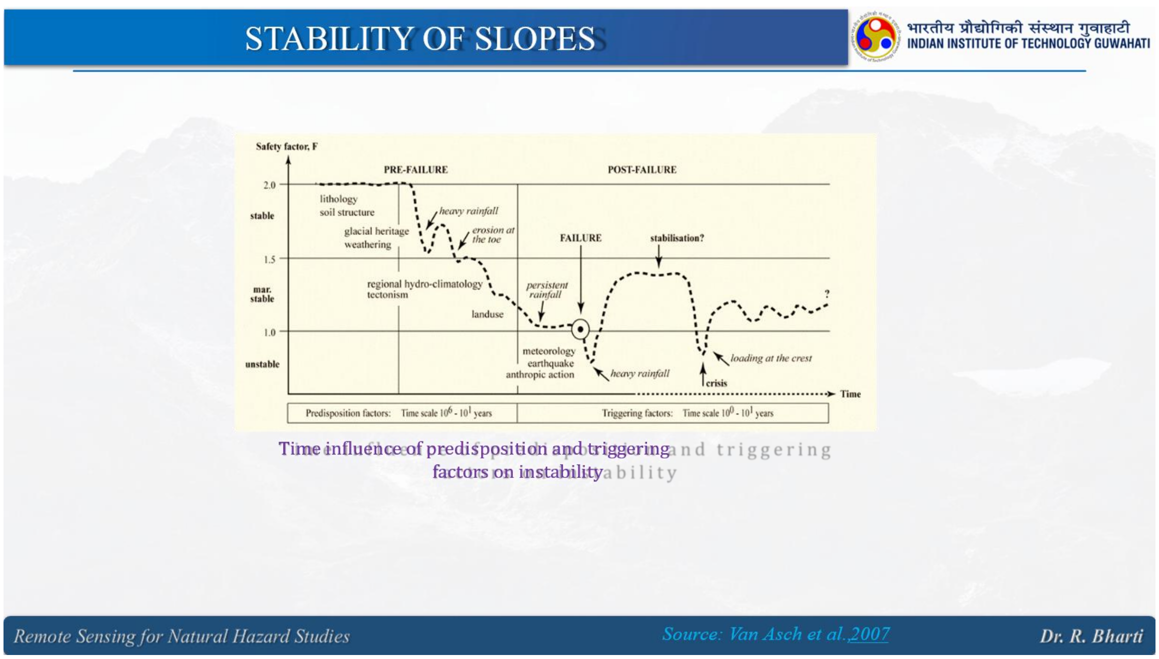
Now, suppose this is the slope, and it is actually in a stable condition because here you have something that is holding the material here. Right, but subsequently, what happened because of the change in the lateral or underlying support right from here, or maybe from here, is that this slope will start failing because the material will not hold here at this particular slope angle. Now, the next step is an increase in weights. Because of the rain or snow accumulation, the weight of the vegetation will increase. So, here, because of the growth of the vegetation, maybe the trees, the weight is increasing, or because of the rainfall, or maybe because of the snow accumulation, all this will change the weight of this particular surface.

So, in such situations here stress will increase. Now, the next one is the transitory stresses; they are caused by the earthquake or vibrations due to heavy vehicle movements, and heavy machinery in a particular area, as well as the blasting; many times we use blasting to create roads. So, these will increase the shear stress. Now the next step is the reduction of shear strength due to an increase in pore water pressure. Weathering of a material changes in structure because of the failure plane, fracture, or unloading.

So, here the loading was also a reason, and unloading is also a reason. So, because of the change in the natural equilibrium, the slope can also fail, and the first one is the increase in pore water pressure. So, one thing is that a particular surface is receiving normal precipitation. So, here is the soil that is available in this particular area. So, there are different soil and rock layers. Because of this, rainfall or precipitation, what will happen is that this soil or the material will get saturated.

And because of the saturation, the pore water pressure will change. So, an increase in the pore water pressure will reduce the shear strength of the material, which is one of the very important parameters that change or shift the shear strength from a stable to unstable regime. When we talk about shear stress, it is because shear stress is one of the important parameters in slope failure. So, if you see, shear stress is the force per unit area acting parallel to the plane of the surface. So, here is the surface, and this is the force that is acting on it.

So, how do we calculate? We calculate using this formula; here, we use shear stress, which is tau. Then F is your applied force, and A dash is the cross-sectional area of the material, which is perpendicular to the applied force vector. The particular nature of the soil translates all the different loads into shear stresses. This is very, very important. So, here all the different loads are transferred, or they are translated to shear stresses when we talk about soil.



So, here, because of external forces, the forces will be converted into shear stresses. Now, we will talk about shear strength; the shear strength of soil is its resistance against shear failure. So, when we are talking about this particular slope, we are discussing how it is resisting failure. It is because of the sheer strength. So, the shear strength of soil is its resistance to shear failure. I hope this is simple and clear to you. Shear strength can be approximated by the equation that is here. Here, the tau is equal to effective stresses; you can see that here, you have the angle of internal friction, which is the tan of the angle of internal friction, and C is the cohesion. Now we will try to understand it with the help of this figure. This figure is basically normal stress versus shear stress.

So, this is the normal stress. Now, this particular area is basically your cohesion, and this is your angle of internal friction. So, how are we utilizing this information to calculate the tau, which is basically your shear strength, clear? Now we will try to understand the stability of the slope in terms of shear strength and shear stress. So when the condition is that shear strength is greater than shear stress, it is in a stable condition. So we call it a stable slope. Next, where shear stress is just above the shear stress, we call it a meta-stable slope. Very stable compared to this condition, but it is in the metastable state. Now, in the third one here, you can see that the shear strength is less than your shear stress; this is an unstable condition. So, the slope is in an unstable condition. So, here you can expect landslides. Now there are different causes; some of them are anthropogenic, and some of them are natural.

So, let us start with the natural causes. So, here you can see the heavy rainfall; this is one of the important parameters that is triggering your landslides. Then tectonic activity will cause vibrations, which will temporarily change the material properties, and this particular slope will fail. Then there is vegetation cover. If there is growth of the vegetation here, that will also change if there is a removal of existing vegetation under which it was stable; then it is going to fail.

Then weathered material will have less strength than unweathered material. Then, seared, jointed, or fissured material surfaces, such as bedding, cysticity, faults, and unconformities, will also have less stability. Then other hazards like floods, volcanic activity, glacial movement, or erosion, etc., that will also trigger this landslide. Then, the last one is the natural loading on the slope or its crest that will also trigger or may also cause the landslides.
Now, we will talk about anthropogenic activities. The first one is the excavation of the slope or its toes. So, when there is a slope and we are trying to remove some material from here or from there, or when we are disturbing this slope, that will also cause it to fail. Then loading of the slope on its crest. So, there is extra loading because of some construction, or maybe big houses, or restaurants, or maybe hotels that will also bring an extra burden on this particular slope.

Then draw down the reservoirs. So let us say here this is a river, and here you have a slope. So, under normal conditions, the groundwater table and surface water are stable. But if there is a change in the water table or the surface water, what will happen? There will be a change in the moisture condition of this particular block. Because of that, these slopes can also fail. Then, irrigation, mining, and artificial vibration caused by heavy vehicle movement in this particular area will result in vibration.

Then, water discharge, if you are putting your discharge channel or the outlet through this, maybe this will change the stability. Then deforestation occurs, so here, if you have the vegetation, it is being removed. Because of some anthropogenic activities, the stability of this slope will also change. This particular table is from Selby, 1993. So, here you can see he has made a very nice table that includes natural causes, which are listed as geological, morphological, and hydrological, and then we have the anthropogenic causes. So, when we talk about the geological causes, here you have weathering, and structure is also taking place.

So, these geological causes are divided into two. So, here you have weathering and the structure, and the weathering can be physical, chemical, and biological weathering, and the structure, the stratification orientation, will also cause these landslides. Then, when we talk about these morphological causes. So, here you have topography because the surface is always being modified by natural agents. So, the topography is changing, then the surface covers slope inclination and the slope angles that are changing.

Then, because of the erosion, you have toe erosion, gully erosion, and subterranean erosion. Then you have deposition on slope faces on the crest on both if there is deposition. So, that will also change the stability; then you have tectonic activities. So, because of the uplift, there is a change in the angle. Now, when we talk about these hydrological causes, such as rainfall, infiltration, seepage of pore water, and the rise in groundwater level, that will change the stability of this slope.

Now, these anthropogenic activities, such as encroachment, deforestation, unscientific cutting of hill slopes, and unplanned infrastructure development, all play a major role; that is why we are calling it a causative factor. So, these are causing the landslides. If you see this particular graph, it shows the time influence of predeposition and triggering factors on instability. So, here is a self-explanatory graph; here you can see this is the pre-failure, this is the post-failure, and here is how it is changing. So, here you can see that this is because of the heavy rainfall; this point is here, and this is unstable; this is stable.

So, this is metastable. Now, here you can see that because of the high rainfall, this unstable zone is approaching. Here you can see the land use, then hydroclimatological tectonism, lithology, soil structure, glacial heritage, weathering, heavy rainfall, and erosion at the toe. So, all these have a major role in the stability of the slope, and the x-axis is basically your time. So, the predisposition factor and the time scale are given as triggering factors; here, you have the time scale. So, let us see; I have a few images so that you will understand the scale of the disaster when we talk about the landslide and the different causes that are playing a role in triggering this landslide.

So, when we say heavy rainfall, you can see here that this particular landslide occurred because of the heavy rainfall. So, how it is on the surface is because of the water level change along the coastline. So, there is a change in the coastline. So, the water level has changed. So, because of that, stability will be different, and this kind of landslide is very common along these coastal regions.

Here, this is because of the flood; you can see that due to the flood, the stability will be lost, and then you will have landslides. This is because of the lahar, which is caused by a volcanic eruption. So, what happens during the volcanic eruption is that this material will start flowing, which will also cause a change in the stability of this slope, and then you will have landslides. This is very easy to understand; you can see that all this material is because of the failure of this particular hill.

So, it is due to the earthquake. So, when we talk about the criteria, let us now understand how we can classify the landslides. So, a phenomenon involving such a multitude of combinations between the material and disturbing agents opens unlimited vistas for classification. So, based on that, you can have many criteria to classify these landslides. So, let us understand it one by one. So, the criteria for the identification and classification of the landslides.

So, the first one is the type of movement, how the material is moving; then comes the kind of material. What kind of material do we have, then What is the rate of movement, and at what velocity is it moving? the geometry of the area of failure, and the resulting deposits, then what is the age, and what are the causes? So, based on the causes, you can also classify the landslides. The degree of disruption of the displaced mass. Then comes the relationship, or lack of relationship, between slide geometry and geological structure, degree of development, geographic location of type examples, and state of activity. So, all these have been used by various researchers to classify the landslides.

So, let us understand them one by one. So, based on the velocity scale. Here you can see the types of movement: the falls, topples, slides, which can be rotational or translational, lateral spreads, flows, and complex movements. So, when we talk about the type of material here, we have bedrock and soils. So, when we talk about the soil, you have predominantly coarse and fine material. Then, based on these rocks and soil, we have categorized them into different categories.

So, the falls will be called rock fall, and the coarse soil will be called debris fall. Or earth will fall, then rocks will topple, debris will topple, or earth will topple. Then you have rock slides, debris slides, earth slides, rock spreads, debris spreads, earth spreads, rock flows, debris flows, and earth flows. Then you have flows in the next category, Deep Creek, and then in the complex, you have a combination of two or more principal types of movement.

So, this is also very evident in the field. So, you can have multiple landslides of different nature, and those will be categorized as complex. Now, we will see the classification of landslides based on the type of material. So, here you can see the type of material is of 2 types. So, the bedrock and the soils are categorized into coarse and fine. Now, here are the types of movement we have: fall, topple; then you have slides, which are classified into rotational and translational; then you have lateral spread; then you have flows; and finally, complex, which is the combination of one, two, or three different types of landslides.

When we talk about this first category of falls, we have bedrock, which is called rock fall; coarse soil is debris fall, and fine soil is earth fall. Then for the topple, you have rock topple, debris topple, and earth topple. Then you have rockslides, debris slides, and earth slides. Then rock spread, debris spread, and earth spread. Then, for the flows, you have rock flows and deep creep, then debris flow, earth flow, and for the soil, you have soil creep.

And the complex, as I mentioned before, will be the combination of two or more principal types of movement. So, based on the type of material, this landslide can be categorized as one of them, or it can be complex in nature. When we talk about velocity, we can characterize or classify these landslides based on the rate of movement. So, you can see that the velocity is given here. So, when we talk about the first extremely slow, it is less than this velocity; then you have this and less than this and greater than this that will be your very slow; then you have slow, moderate, rapid, very rapid, and extremely rapid.

And here, probable destructive significance, major catastrophe, escape unlikely, velocity too great to permit total evacuation; escape evacuation is possible. So, below this escape is possible. Then the structure can be maintained with frequent maintenance. So, here less than this.

Then you have instrument construction possible with precautions. So, here this is a safe one because we are talking about the extremely slow. So, we will see them one by one when we talk about the types of landslides. So, here this is the description, and this is the velocity; here you have the significance. This particular graph nicely represents the different landslides and their velocities.

So, here you can see the rock avalanche that is having the highest velocity, it is here. When we talk about the debris avalanche, it is here; mud flow, it is here. Debris flow that is again on the higher side, then earth flow that could be very low to moderate, then clay flow slide that is again high, then sand slide debris flow slide that is again high. When we talk about this earth flow that is only having a moderate velocity, others have very high velocity, or the rate of movement is very, very high. So, in this slide, I am trying to tell you about the multidisciplinary nature of landslide studies.

So, geography, geoinformatics, geology, geomorphology, geomechanics, hydrology, hydraulics, hydrogeology, structural engineering, statistics, and artificial intelligence can all be used or studied from any of these perspectives. But the best way to resolve or characterize a particular landslide is to have people from all these domains together, which will give you better and more fruitful results. So, once you incorporate all these aspects, your work will be very nice. When you involve the different aspects that are discussed here, landslides have a multidisciplinary nature. So, it is always suggested to have the different aspects that are discussed here when you are going for the landslide studies.

So, with this, I will end part 1 of this lecture. We will continue this introduction to landslides in part 2.

Thank you. Thank you very much.