**REMOTE SENSING FOR NATURAL HAZARD STUDIES**

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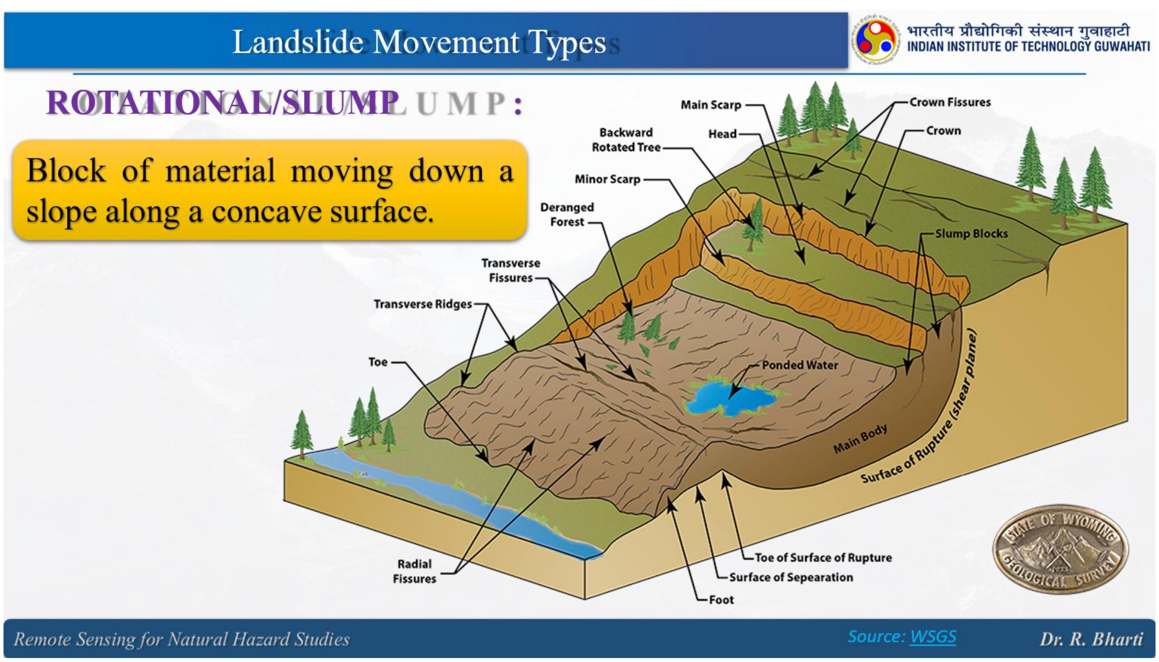
## Lec 28b: Introduction to Landslides - Part B

Hello everyone, welcome back to Lecture 28. So, we were discussing the landslide. So, this is part 2. So, we have discussed the landslide, what the different parameters are, and then we also discussed how we can classify the landslide based on the velocity and the mass movement. So, now we will continue this discussion and see what the different types of movement are. So, here the first one is the rotational landslide.

So, here you can see that this is the rotational landslide. The second one is the translational landslide that is here. So, you can just compare these two to see how they are different, then block slide. This is the block slide where the movement is like this, and this block is shifting, then you have rockfall.




So here is the rockfall, and the rocks are basically falling from a slope. Then you have toppled. So, one particular section is simply toppled, and you have the fragments here; then you have debris flow, which is coming with the flood. So, it is kind of a flood when your material is oversaturated. Then a debris avalanche occurs. This entire thing is coming down. Then you have Earth Flow. Here is the Earth Flow. So, here the velocity, if you remember, is based on the velocity we have characterized. So, this is slow; then you have creep. So, here is the simple, normal displacement you will see. And this is very difficult to identify in the field, but I have a few photographs that will help you realize how creep appears in the field. Then there is lateral spread; so here you have the lateral spread. So, let us start with the rotational, which is also called slump. So, here is the block of material moving down a slope along a concave surface.

So, here you can see that this is creating this concave surface. So, this is the main body, this is the surface of rupture, this is the slump block, and here you have radial fissures. Toe, transverse raises. Remember that what I discussed in the first slide is that everything is here. So, based on that, you can characterize a particular landslide.

This is another example from the field; here you can see how the rotational landslide appears, and here you can see how it is happening. This particular animation is here to help you understand how a rotational landslide occurs. The next one is the translational block of material moving downslope that occurs along a distinctive surface of weakness. It can be a soil horizon, bedding, or a fault parallel to the ground surface. So, here you can see that this is parallel to the ground surface.

So, this particular block has failed, and it is going down. Again, here I have a video that will help you see how translational landslides are happening, and here is the photograph from the field. So, here you can see how they appear. Then comes the block slide; it is under the translational. So, here is a translational slide in which the moving mass consists of a single unit or a few closely related units that move downslope as a relatively coherent mass; the sliding mass remains relatively intact.

So, here you can see how this is going. So, this is intact; this is what I meant. So, this is from the field: how this is happening. So, this is an example of a block slide. Now, we will see rock falls, an unexpected release of rocks or coarse material from a steep slope. So, here you can see these rocks or the fragments of this rock that are coming down. Separation occurs along discontinuities such as fractures, joints, and bedding planes, and movement occurs through free fall, bouncing, and rolling. So, what happens if there is, let's say, this block right here, and you have a small crack? So, what happens when water enters into this? And when the temperature is below the freezing point, is that this water will freeze, and that will exert pressure because the volume will change, and because of that, these two blocks will be pushed away from each other. This happens for quite a long time, and then slowly, this particular piece of rock will start falling. So, this can fall.

So, then you will have free fall, or maybe bouncing, or maybe rolling; this kind of activity happens right, influenced by gravity, weathering, and the presence of interstitial water. So, interstitial water means the water in the pores of these rocks, and because of the temperature, that will change the volume, and then slowly, that will generate the fracture, and then this rock will start falling. This is an example of rockfall here; you can see the video. So, this particular rock is falling, and this is how they appear in the field. So, this can be smaller in size, and this can be very large in size; then comes the topple, similar to falls and distinguished by the forward rotation.

So, this is similar to fall, but what happens here will be a toppling mass movement of rock or debris out of the slope; simply put, this particular chunk was here. And this has come down because of the gravity it has toward the forward rotation. So, this forward rotation is very, very important, caused by gravity and forces exerted by the adjacent unit or by fluid in the cracks. So, as I told you in the previous case, the water enters, and because of the change in temperature, this will be weakened, and then this particular rock will fall. Then comes the topple; here is the animation of the topple, where you can see how it appears, and in the field, how they appear. The next is the debris flow; here is a mass of loose, water-laden, or poorly sorted debris that flows down a slope. So here you can see that this particular material will flow down, triggered by heavy rainfall, rapid snowmelt, or other landslides.

Rapid mass movement contains fine material. Influenced by gravity, mechanical weathering, and the presence of interstitial water. So, here in the field, as you see this debris flow, this is the damage you can try to understand how devastating it could be. So, this is the animation you can see. So, you will be able to understand how it is happening because of the heavy rainfall. This is happening right now; you can see it again. Now, we will see the creep, which I told you has a very low velocity and is very hard to notice on the ground. So, a very slow downward movement of slope-forming soil or rock is caused by shear stress sufficient to produce permanent deformation, but too small to produce shear failure.

So, here this is permanent; the damage is permanent. So, the deformation is permanent, but it is too small to produce shear failure. So, seasonal creep, where movement is within the depth of soil affected by seasonal changes in soil moisture and soil temperature, is called seasonal creep. Now comes the continuous creep. Where shear stress continuously exceeds the strength of the material.

Then comes the progressive creep, where slopes are reaching the point of failure like other types of mass movements, and the creep is indicated by a curved tree. Trunks bend fences. So, as I told you, the velocity is very low, and it will be very hard to notice, but there are a few indicators. So, creep is indicated by curved tree trunks, bent fences, or retaining walls. Tilted poles or fences and small soil ripples or rises in the field.

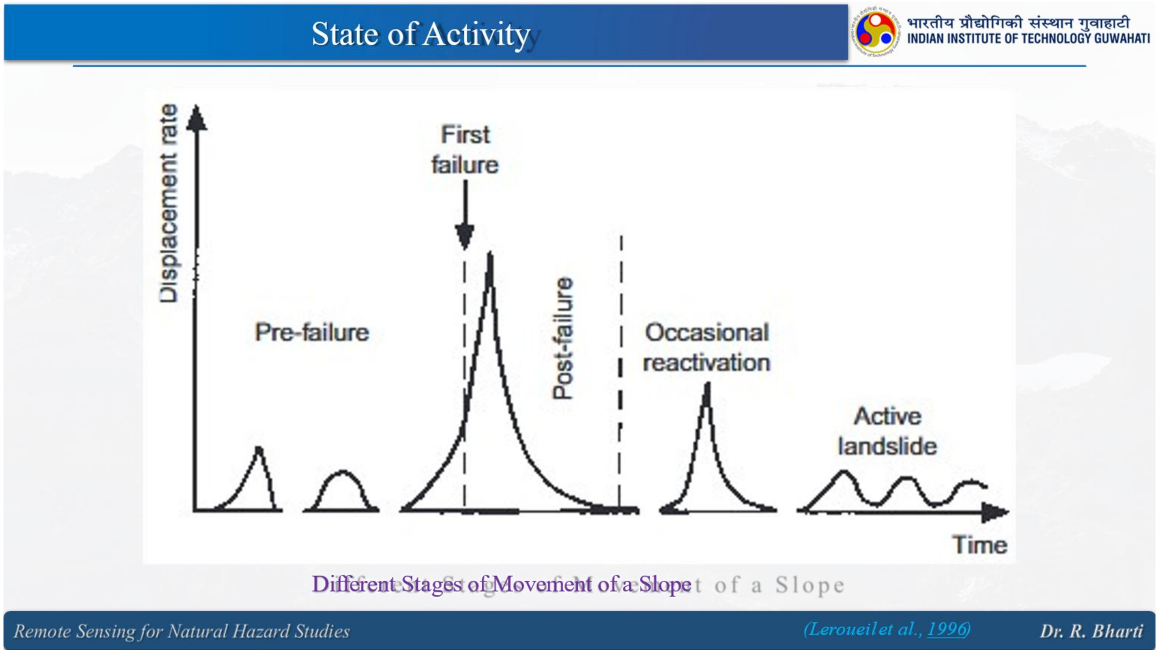
So, you will understand by looking at this particular diagram. Here, you can see that there is a change in the orientation. I hope you are able to see these angles in the field. You can see that this kind of ripple mark can be seen; this is because of the creep landslide. Here you can see the video. I will try to watch this video here; you can see how the creep is taking place. Now we will talk about the Earth's flow. So, this animation will also help you. So, an earth flow is a type of mass wasting where fine-grained soil, clay, or silt moves downslope in a fluid-like motion due to gravity. It is slower than debris flows but can still cause significant damage; heavy precipitation, deforestation, and earthquakes, etcetera, contribute to this, and it has a tongue-shaped form with a steep slope at the head.

So, here in the field, you will see this kind of feature when we talk about the Earth's flow. Then comes the debris avalanche. So, this is an extremely large and fast-moving debris flow. A rapid, extremely fast-moving mass of rock, soil, and debris detaches from a steep slope and flows downslope in a turbulent manner. Often triggered by volcanic activity, earthquakes, or heavy rainfall, it is very fast.

So, the velocity is very high; the rate of movement is very high. Moves chaotically, often in a widening path. Debris avalanche; here you can see the example of the debris avalanche and how the material is coming down the slope. Then comes the lateral spread, so when surface material extends or spreads on a gentle slope, this type of ground deformation is often associated with earthquake shaking. So, because of the seismic activity, this lateral spreading is occurring.

You can see ground failure here when cohesionless soil moves horizontally over a weaker underlying layer, often due to liquefaction. occurs in areas with weak subsurface layers like soft clay or liquefiable sand. I will be covering this liquefaction in the next module, module 9, but here, for the time being, you can consider that when we talk about liquefaction or liquefiable sand or soil, it means that temporarily, it is losing its stability. So, displacement is horizontal rather than rotational. So, here in the field, you can see this is the horizontal displacement.

So, when we talk about the lateral spread, the displacement is horizontal rather than rotational. It commonly occurred on gentle slopes or in areas with weak subsurface layers. So, this is how they appear in the field: right lateral spread. Now, we will talk about the state of activity, where we will discuss the stages of movement of a slope. So, the pre-failure stage includes all the deformation processes leading to failure.




The onset of failure is characterized by the formation of continuous shear surfaces throughout the entire soil mass. The post-failure stage includes the movement of the soil mass involved in the landslide from just after failure until it essentially stops. The reactivation stage occurs when a soil mass slides along one or several pre-existing shear surfaces. So, this particular graph will show you the different stages of movement of a slope. So, this is the pre-failure, this is the first failure, this is the post-failure, this is occasional reactivation, and this is active landslides.

So, here is the time, and this is the displacement rate. So, I hope you are able to understand this when we talk about the state of activity. So, here you have active, suspended, reactivated, dormant, abundant, stabilized, and relaxed. And so we will see one by one how they appear, what they mean, and how we will be able to identify them in the field. So, this is when we talk about the active landslides.

So, currently, movement can be slow or rapid depending on the material and triggering conditions in the figure. Two erosion causes a block to topple. So, basically, there was erosion here that caused this particular block to topple. Then comes the suspended move in the last 12 months, and here it is suspended. So, you can see that some amount of deposition is taking place, not actively currently in the figure.

Local cracking can be seen near the crown. So, here you can see some cracking when we talk about reactivation. So, this is the first block; then we had some deposition because weathering is taking place. This particular block is now failing. So, it is failing from here to there. So previously inactive, activated currently in the figure; another block topples, disrupting the previously displaced material.

So now this will come on this particular block, then inactive, not moved in 12 months; then it is divided into dormant. Abundant, stabilized, and relict. So, here slowly what will happen. It is dormant. So, when we say it is inactive, it can be classified into all four of these categories. So, when we say dormant, it is basically inactive and can be reactivated by original or other causes.

In the figure, you can see that the displaced mass regains the vegetation cover and scarps modified by weathering. So, here the vegetation growth is taking place. This is the original one, which is coming from here, and the vegetation has started growing here. When it is abundant, it is again inactive, no longer affected by original causes, because it has gained its stability on this particular slope. In the figure, you can see that the fluvial deposition has protected the toe, and this calf has regained its vegetation cover.

Then comes the stabilization. So, either it will be naturally stabilized, or it will be stabilized by some mechanism. So, when we say stabilized, it is inactive and protected from its original causes by remedial measures. And here you can see that a retaining wall is provided at the toe, and soil nailing is done on the slope faces. So, you can see here, because of that, it is getting stabilized. Now, the relict will make it very hard to identify whether any landslide occurred at this particular slope, because there will be no traces here.

So, this is currently inactive; climatic and geomorphological conditions are considerably different from when it was formed, and here you can see a uniform vegetation cover established. So, it will be very hard even to notice that there were a few landslides in this particular region. These are some of the references you can refer to if you are interested in knowing more about any one of them; you will be able to get the details from all these references.

Thank you very much.