Natural Hazards.
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology, Kanpur

Lecture –28
Types of Landslides and Related Hazards

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So, welcome back. So, as we were discussing in the previous lectures that the shear strength and the shear stress are the two very important components, which will play a key role in triggering the landslide. And not only the slope, but which we are talking here is the angle theta, is the slope and angle of slope on which the material is sitting. We also consider the weight, as well as we also consider the property of the material which is sitting on the slope. So, we have it, we take the cohesion, we take the internal angle of friction and the normal stress along with that ok.

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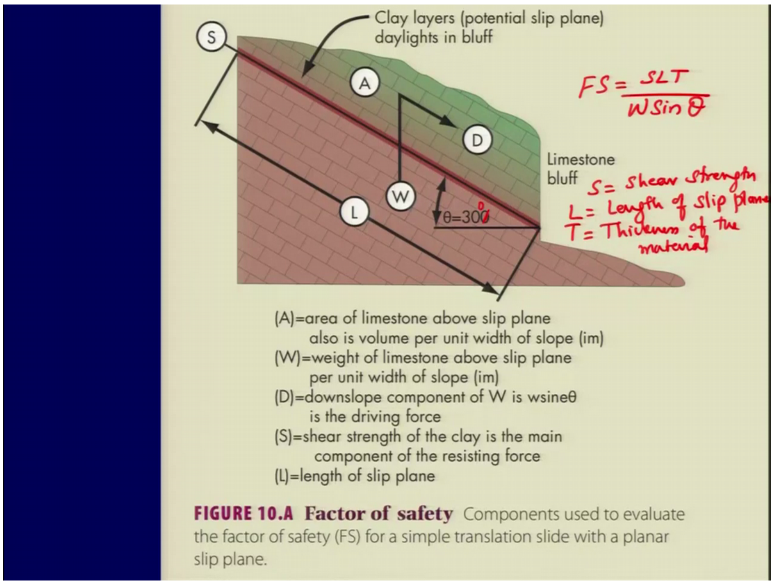

FIGURE 10.A Factor of safety Components used to evaluate the factor of safety (FS) for a simple translation slide with a planar slip plane.

Now, suppose if you have an material which is sitting on its slope, which is given as S; that is your slope. And you have suppose the material or sitting on the potential slip plane is your clay or a limestone. Then this material this is the this, this slope, that is the material with contact between the limestone here and the limestone pillows, so this is in potential slip plane, which is a clay layer. So, the shear strength or the property of this material, both the material will be different. So, if you have to talk about the factor of safety. Of course, you need to take into consideration what we were talking about the W sin theta; that is your, what we saw in the previous slide that is here shear stress.

And you have to take into consideration the sheer strength, and that will come from the property of the material. So, as I was talking that if, this is the degree, so you have the slope angle, you have the different material. Of course, the clay will have different property as compared to the limestone which is sitting on the top. So, factor of safety here, if we say if it will be given as FS factor of safety equal to S LT by W sin theta. So, sin theta is this one your angle here, and S LT is your, S is your shear strength, L is length of slip plane; that is your potential slip plane and T will be the thickness of the material.

So, what we are going to do is, we will formulate this small exercise on this which we will do in the next lecture, or maybe in coming one of the lectures which will help you in understanding the process and all that. So, usually based on the factor of safety, most of the landslides are classified.

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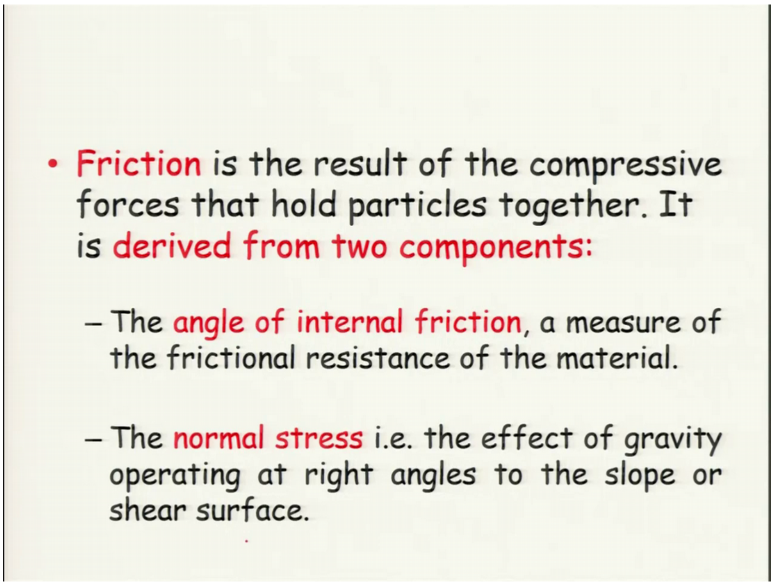

Now, the another important component which we will discuss here is that when you are having the ground shaking. So, friction what we were also discussing in the previous slide, is the result of two of the compressive forces that holds the particle together. It is derived from two components, so one is the angle of internal friction; that is a measure of the frictional resistance of the material, the normal stress. So, these are the two components which will eventually have the friction component.

So, normal stress that is the effect of gravity operating at right angle to the slope of the shear surface; that is your potential slip plane. Now as soon as you add like what we were talking about the water and all that this will change actually. The normal stress also will change and of course, the strength of the material will also change.

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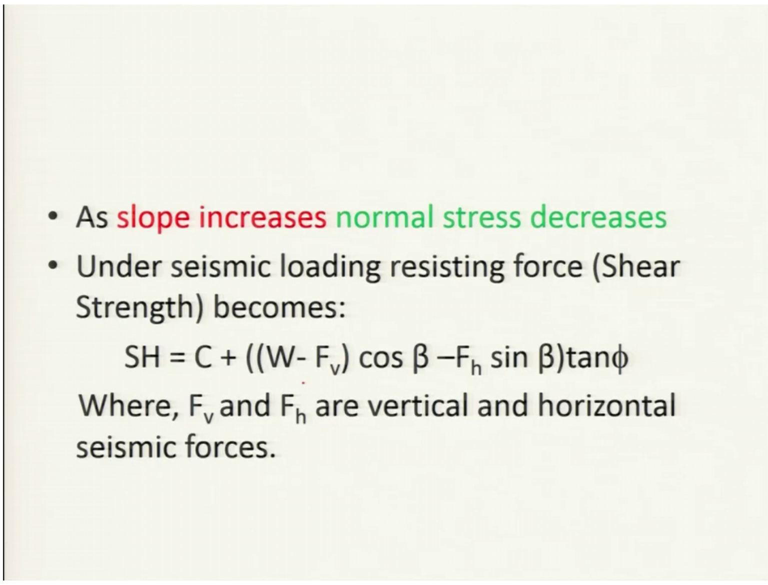

So, as slope increases normal stress decreases. Under seismic loading a resisting force that is your shear strength becomes as given below in this equation. So, what we are having this component, we are having another one that is a vertical force as well as the horizontal force, because in the seismic shaking you will have to and fro motion as well as vertical motion. So, you have this two component which have been added here, so we will have vertical component and you will have also an horizontal movement; so where Fv and Fh are vertical and horizontal seismic forces. So, this part you will have to take into consideration when you are talking about the seismic loading.

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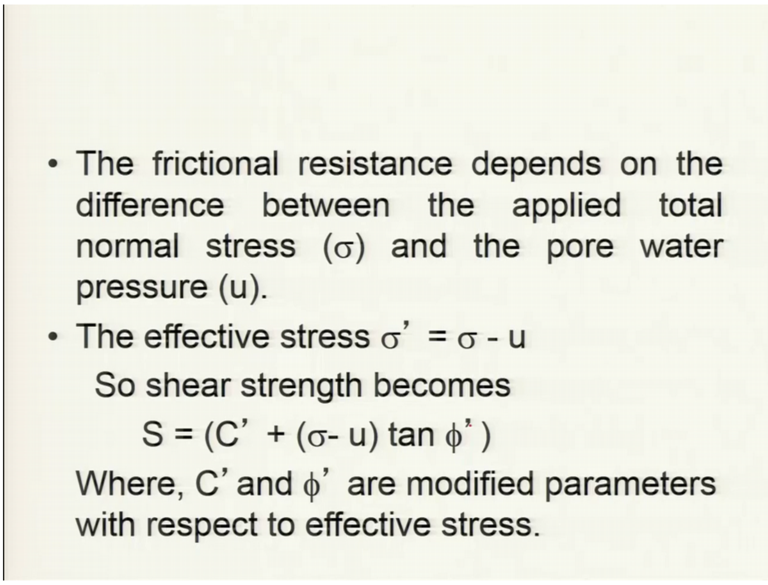

So, the frictional resistance depends on the difference between the applied total normal stress and the pore water pressure. The effective stress, or the effective normal stress will be, then normal stress minus the pore water pressure that is what we were talking about the Buoyancy effect, so the shear strength becomes this one.

So, this component comes in where you are having the sigma prime. And also this will affect, as I was talking the strength and internal friction. Angle of internal friction will also be affected, so you will have the phi prime. So, we the C, also the cohesion and sigma or phi prime are modified parameters with respect to the effective stress.

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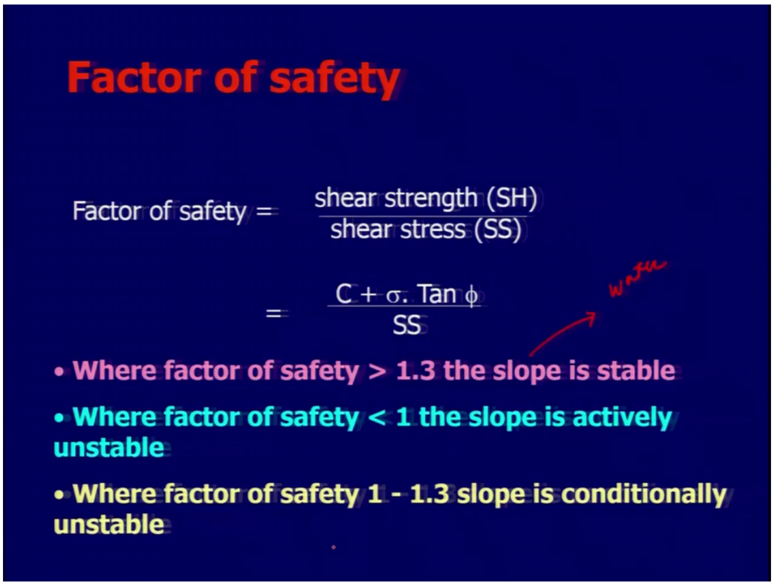

So, the factor of safety has been given as the shear strength by shear stress. Now if you get this ratio which is greater than 1.3, then the slope is considered as unstable slope. So, mass sitting on the slope will not move, but again keep in mind what we talked about, the that the water can complicate a simple picture. So, where the factor of safety is less than 1, then the slope is actively unstable and where factor of safety is between 1 to 1.3 slope is conditionally unstable. So, please keep this in mind and when we will give or solve the problems then you will be needing this information with you.

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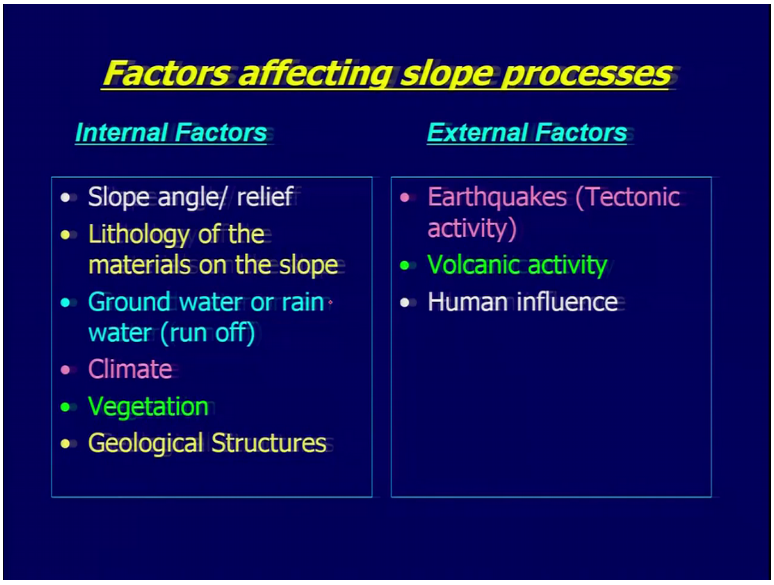

So, factor affecting slope processes or are internal as well as external. So, the internal are slope angle; that is relief. Lithology that is the type of material setting on the slope, groundwater condition or the rain water and runoff conditions in that area. Climate also will play an important role, because in humid region or sub humid regions you will have, the chances of landslide increases, also what type of vegetation is there on this slope will also play an important role, because vegetation can stabilize or hold the material and increases the shear strength to some extent. Of course, if you put in very heavy trees or the other trees which are with more weight, then it can result into the landslip, then we have in geological structures.

So, these are several factors which will affect the, the slope failure or which will help or creating an idle condition for the slope failure. External are your tectonic activities, earthquakes and volcanic activity. So, in the previous lecture where we were talking about the volcanism, we also learned that there was a recent landslide which was been triggered by Anak Krakatau volcanic eruption in Indonesia. And we also saw one example of earthquake triggered landslide from 2015 Gorkha earthquake, then we have another one is the human influence.

So, these are very important factors internal and external and you will learn when we are discussing some of the type of landslides or the mass fasting, where the geological structures for example, or the lithology or the slope has played an important role. The external factors will be and slow process in the sense they will not be occurring very frequently of course, but this are all present and if you are having the groundwater conditions and the rain, we have this seasonal effect. So, this we are going to face every year.

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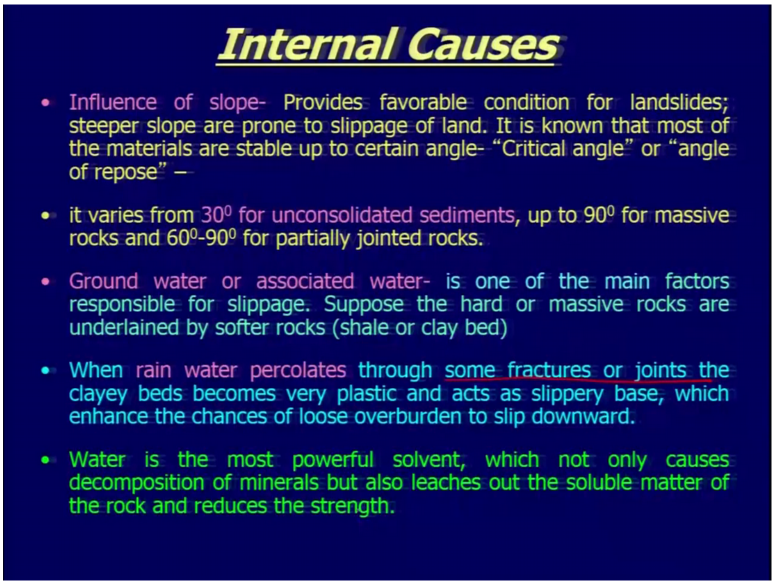

So, internal causes if we take then the influence of the slope, it provides favorable condition for landslides. Steeper slopes are prone to slippage of land, it is known that most of the material are stable at an critical angle; that is an angle of repose. So, it varies from for unconsummated material, we have the slope 30 degrees and if you are having this slope. So, until you have this slope then the unconcealed material will not move, but if you are having like slope greater than this one then there are chances of the land slip. And the angle of repose for massive rocks can range up to 90 degrees.

So, even if you are having and 90 degrees or 60 to 90 degree for partially jointed rocks. But as I told that groundwater or the rain can affect this angle and can change the scenario. Groundwater or associated water is one of the main factor responsible for the slippage. Suppose the hard and massive rocks are underlined by soft rocks, shale or clay bed. So, the previous one of the slide we were talking about that we are having in potential slip plane is your clay and the mass which is sitting on the top is your limestone; so such situations will have.

So, this is what we were looking in the previous one, so this is limestone and this one is your potential clay, the potential slip plane. So, if you are having this plane in between, because in sedimentary situations you will come across such scenario where the lithology will vary, so you are having a hard dog soft rock hard rock soft rock sequence. In that case the softer rocks will be your potential slip planes. So, when rain water percolates through some fractures. So, again there is an geological structures, so if you are having a massive rock then whatever the water which is coming in will not percolate, but if you are having it fractured rocks, then the chances of percolation of the water increases and this will eventually reduce is your shear strength.

So, when the rain water percolates through small some fractures or joints, the clay bed or if you are having even the rocky succession, they will lose the shear strength, but in case of the clay it will become plastic and act the as in slippery base. So, even though if you are having the hard rock which is sitting at the top. So, if you see just the surface you will feel that you are safe, nothing will happen, but if you, are having the clay bed as well, just put very quickly if you are having this mass here and then this is a clay bed.

So, even if you are having the overlying rock is harder, but you are having this plane which is likely to slip, because as soon as you have the water getting in this will changes its property and you have the, it will act as an plastic an accident cp slippery base, which enhances the chances of loose overburden or even the harder rocks sitting on the top of it to slip down. So, water is the most powerful solvent which not only causes decomposition of the minerals, but also leaches out soluble matter of rock and reduces the strength. So, this is an another important parameter which we should keep in mind, because this can result in to the reduction of shear strength.

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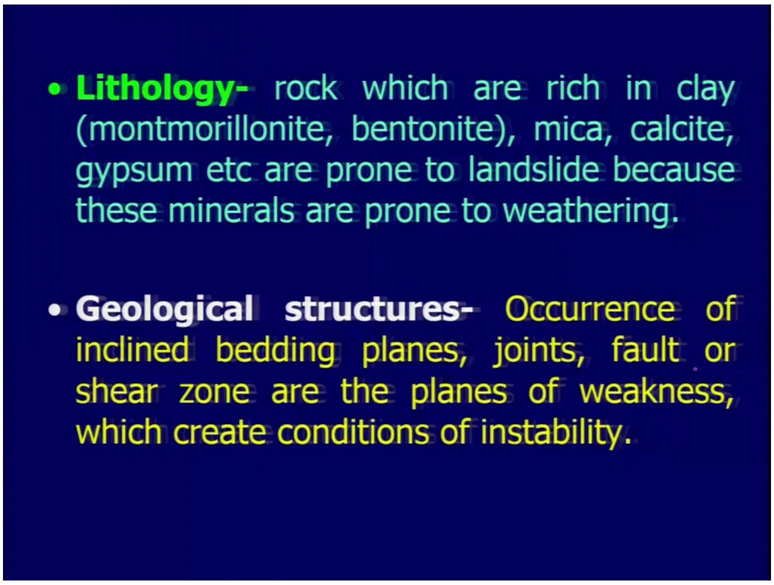

Now, for example, you take the lithology rocks or the rock which are rich in clay, the mineral like montmorillonite or bentonite and if you are having mica, calcite, gypsum etcetera are prone to landslides, because this minerals are prone to weathering. And the geological structures if you are having the inclined bedding planes, joints, falls or shear zones are the potential weakness or potential plane of weakness which creates the conditional instability in the area.

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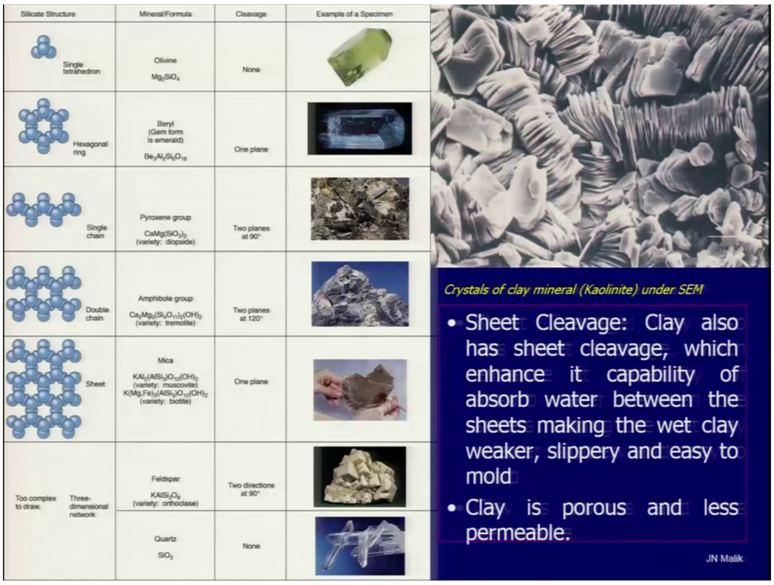

So, this is an typical property of the clay. So, it has not sheety sheet cleavage, clay also has not hit cleavage which enhances its capability of absorbing water between the sheets making the wet clay weaker, slippery and easy to mold. So, clay is porous and less permeable; so it will hold water. So, when in some areas, when there is an and then heavy rainfall it may hold water, resulting in to the making the clay, bed weaker in terms of a shear strength and it will be the week zone which will slip the over lighting material.

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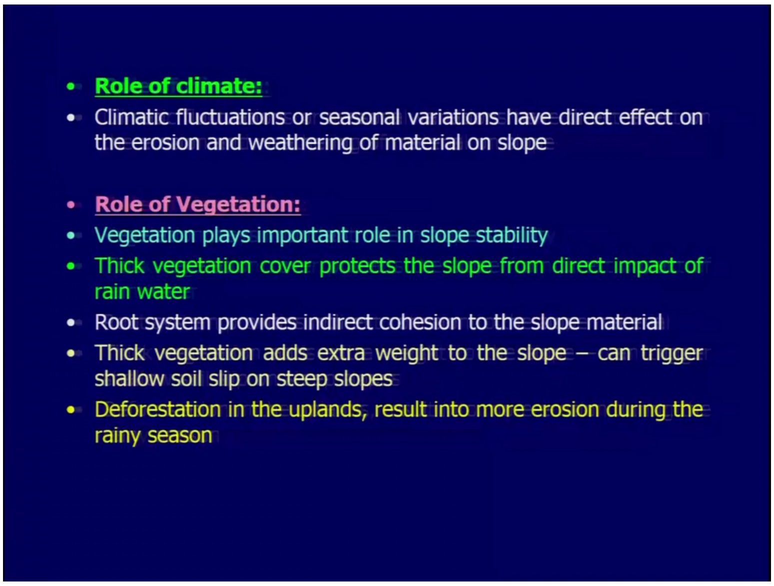

And the role of climate, if we take the climatic fluctuations or the seasonal variations have direct effect on the erosion and weathering of the material on the slope; as we were talking in the previous one that even the clay has an capability of shrinking and swelling that can also trigger the landslide or the land slip.

Role of vegetation, its plays an important role in giving the stability to the slope, thick vegetation cover protect the slope from direct impact of rain water, it will not allow the water to percolate down route system provides indirect cohesion of the slope material. Thick vegetation; however, will add extra weight to the slope and this can trigger the slip in the shallow soils. Deforestation in the uplands can result in to more erosion during the rainy season and that can also trigger the land slip. So, these are a few very important points which we feel are trivial, but can be dangerous.

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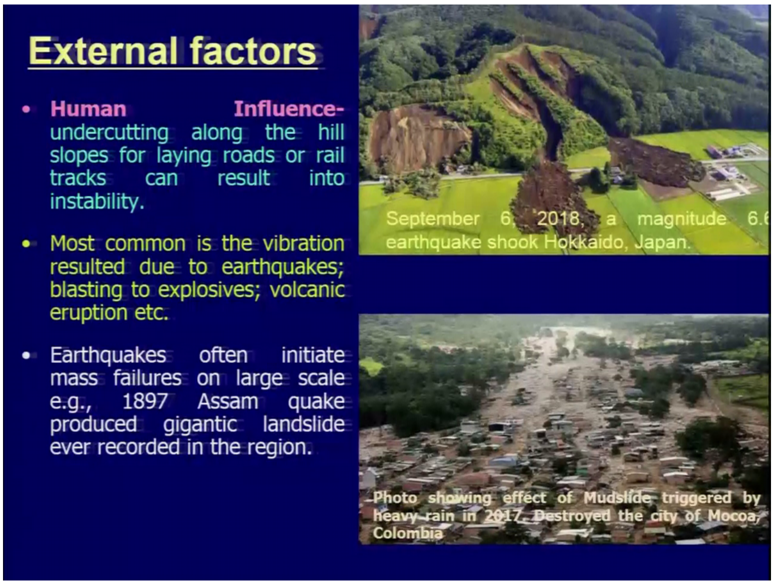

External factors; human influence mainly what we do is undercutting along the hill slopes can result into the land slip, wherever we are putting the roads or the rail tracks we try to dig out the material and result that can result into the; so if you are having the slope like this, for example, and if you remove this material here and you are triggering, going to trigger the instability to the slope, so that can result into here or idle condition for the landslip. Then we have the most common is the vibrations resulted due to the earthquakes. So, this is one another external factor or blasting to explosives, volcanic eruptions, earthquake often initiate mass failure on large scale.

So, this was again experienced, this is an example from the 1897 Assam earthquake, but we have experienced this in most of the recent earthquakes on borders ok. So, this is from recent Hokkaido earthquake of Japan, where massive landslide was been triggered. So, this earthquake was triggered on 6th September 2018, magnitude was 6.6 and the landslide which was triggered was quite massive. So, probably we have shown you one more picture in the previous slide or maybe in previous lecture, where there was not massive landslides in most of the areas.

And that was because there was an typhoon, just because before the earthquake, and heavy pouring of rain or the water, because of the typhoon oversaturated the slope material over here and just having as a moderate magnitude earthquake 6.6, it triggered a landslide. And there is another picture of the massive landslide which shows the mudslide triggered by heavy rainfall in 2017 in Colombia. So, these are the two examples of one is external factor and another one is the landslide or the mud flow which was been triggered, because of the heavy rainfall.

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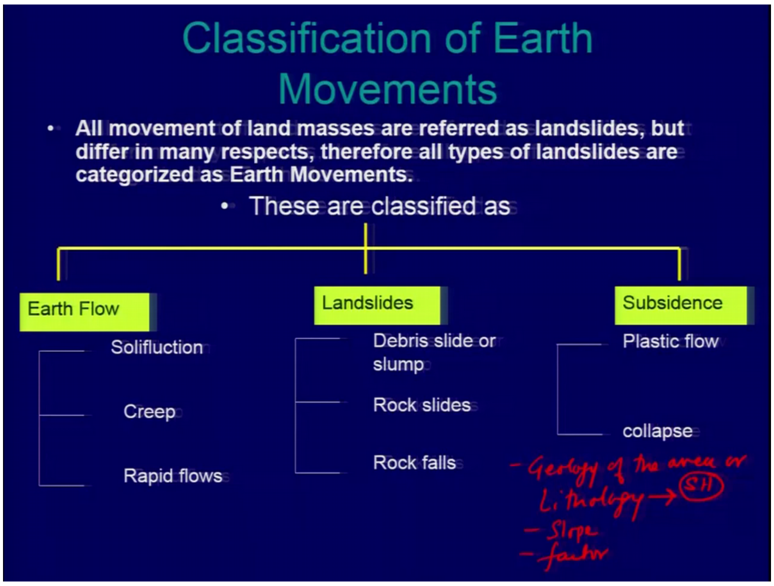

Now, classification of earth moment if we take, then all moment of land masses are referred as landslides, but differ in many respects. Therefore, all type of landslides are categorized as earths or earth moments. These are classified as one earth flow where we have solid faction creeping a rapid flows.

So, this again depends what, at what velocity or the speed they will move and where this type of movement will occur the earth flow. And then coming to the landslide then we have debris slide or slump, rock slide, rock falls, subsidence then we have plastic flow and collapse. Now all in all this three classification if you take the lithology; that is the geology of the site or the site condition will play extremely important role of course, along with the slope ok. So, when we say the geology of the area or we say lithology, then we talk about the shear strength of the material.

So, this will play an important role of course, along with this we also talk about the slope on which the material is sitting and then the factor. So, again the geological factor or internal or external will play an important role in triggering the earth movements.

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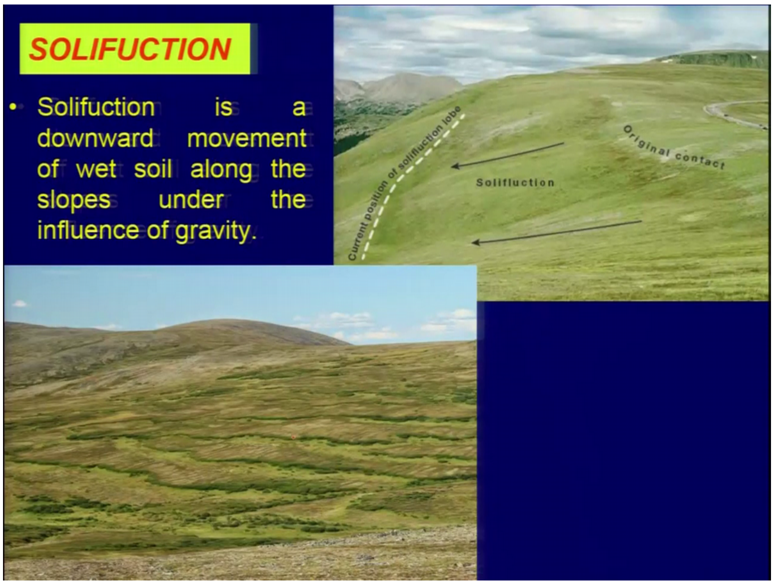

Now, solifuction if we take, is a downward movement of wet soil along the slope under the influence of gravity. Now this will be mostly seen in the area where we are having the snow cover or in the area where we having the glacial landforms. So, what you see here is this same picture here.

The original contact here, whereas the slow movement of the soil has been seen, the topmost soil has been moving downward. And this is mainly because of the top surface which is getting saturated, because of the melting of the; this snow of the ice which will result into the movement, slow movement under the gravity our under the influence of the gravity.

So, you have slope and you have the uppermost soil which is getting saturated, because of the melting of ice or snow which will result into your slow movement. The solid fluxion is usually seen in the areas where you have a thick snowfall. So, we will stop here and we will continue in the next lecture.