Earth Sciences for Civil Engineering Part-2
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Landslide and subsidence (Part-2)
Module 4
Lecture No 16

Welcome back.

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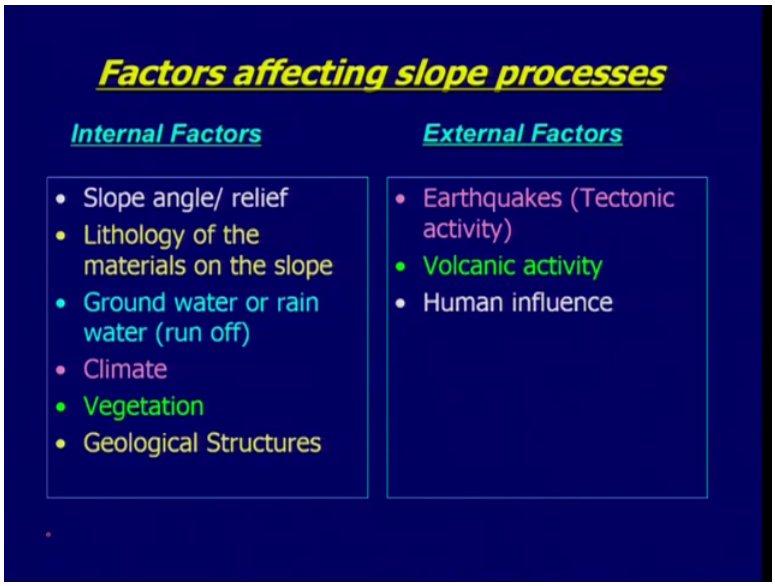

So uhh during last lecture, we were talking about the internal and external factors and we started talking about the lithology part. I will just briefly go back. Internal (fact) factors and the external factors which are extremely important to understand because these factors uhh results into the landslide in the most of regions like slope angle, lithology, groundwater, climate, vegetation, geological structures and external factors like earthquakes, volcanic activities and human uhh influence.

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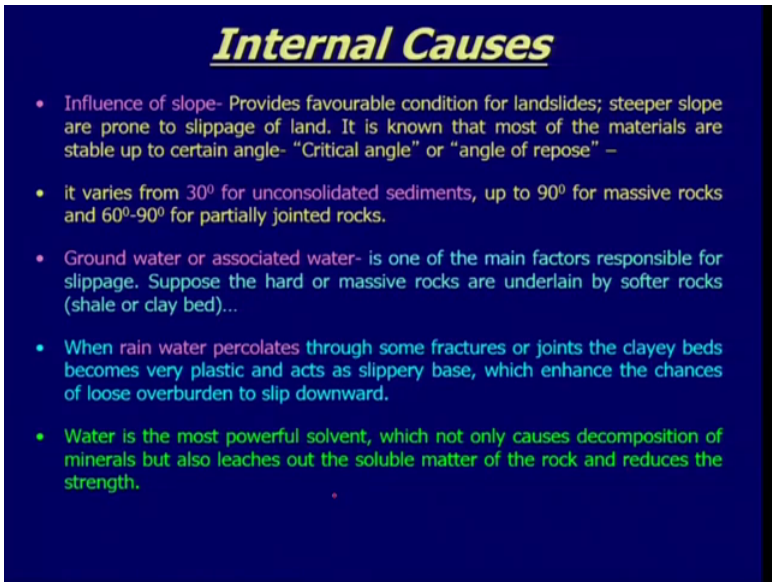

So one by one we will see uhh few of them like for example the internal causes we take the lithology factors okay so influence of uhh slope, it provides very favorable conditions for landslides. Steeper slopes are definitely prone for uhh slippage of land and it is common that most of the material as we were taking in the initial slides that slope angle is extremely important and that what we call the critical angle, angle of repose so each material or different material on the earth's surface has different critical angle.

For example, for unconsolidated sediments, it is around 30 degrees so it will remain stable until you have 30 degree of slope if you increase the slope, it will uhh slip down. Then coming to uhh the massive rocks, it has more uhh angle of repose, like 60 to 90 degrees for partially jointed rocks and for massive rocks it is around 90 degrees. Further uhh the another factor which is responsible for the uhh landslides or the slippage of the landmark groundwater (pan) associated water.

Now this one of the main factor responsible for the slippage because this reduces shear strength of the material so suppose if you have an harder rock sitting on the surface but subsurface or the uhh these uhh the below it you have some softer rocks because you will not have the complete succession comprised of uhh massive rocks okay or massive material or hard material. You have

softer and harder. Softer and harder succession you will see so suppose you have a clay and clay bed or shale.

This we have discussed when we were talking about uhh uhh the different type of rocks in the previous course, the part one. Now suppose you have an clay bed then when the water percolates through some of the fractures or joints, the clay beds becomes very plastic okay and this will act as an slippery base so even though you are having a very hard rock sitting on the surface but subsurface material is uhh softer, it may result into the slip.

Then coming to the uhh the water. As we all know that the water is the most powerful solvent which not only causes decomposition of the minerals because it has an capability of altering the minerals also but also leaches out the soluble matter of the rock and reduces the strength, this is what we were talking about the reducing the shear strength of the material. So water is uhh uhh everywhere it it creates problems on the slopes.

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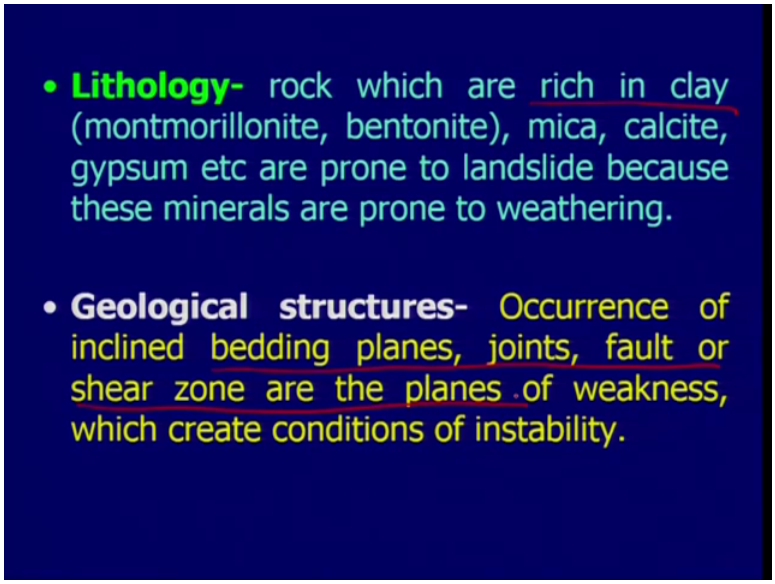

Then uhh the lithology part okay, as we understand that most of the rocks will have different minerals and if suppose those rocks are comprised of the minerals like montmorillonite or bentonite okay. It is one one of the examples which are taking up here or they comprise mica, calcite, gypsum etc, these minerals are prone to landslides okay because they will absorb water and they will reduce the shear strength of the material and as we know that these minerals are

commonly seen in most of the rocks okay so that those minerals are prone to the landslides okay and mainly the minerals which are rich in clay these are or rocks which are uhh rich in clay will result into the problems okay.

Geological structures is also another important uhh uhh part to be understood and if you are having the uhh sedimentary rocks which are rich in bedding planes, joints and they are faulted or fractured or having the shear zones okay. These are the plane, weak planes which will trigger uhh the landslides and (resu) resulting into the instability of the uhh the the slope okay. So um uhh in short uhh we are taking into consideration uhh the lithology part, we are taking into consideration the geological structures to understand that which are the the most uhh uhh triggering factors for this landslides and all that.

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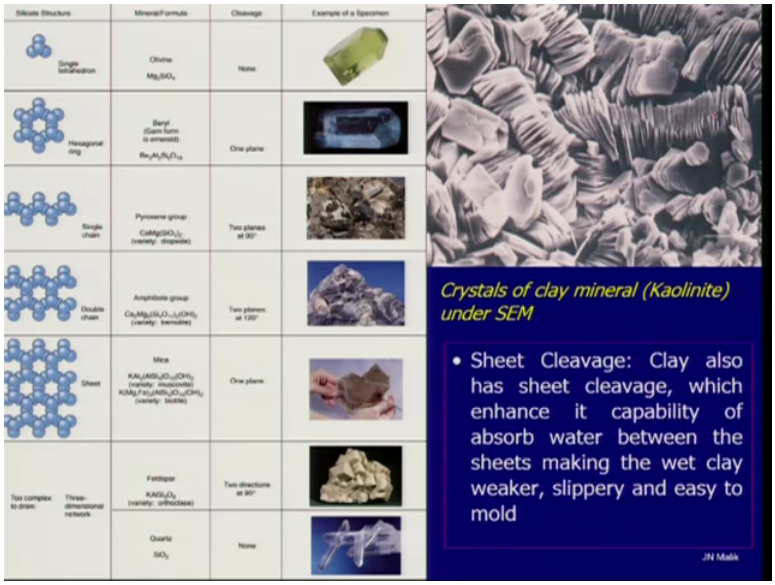

Now just to show this uhh I hope we have discussed this in the first part, the clay has an capability. For for example, the clay minerals like montmorillonite and all that. They have the capability of absorbing uhh water okay so they will absorb water and since they have uhh uhh the sheet like cleavage or the structures okay then uhh uhh this will enhance the capability of absorbing border between sheet planes okay making uhh the wet clay weaker, slippery and easy to mold. So if you are having more amount of water percolated between the surface and if you are having a clay bed then you may face the landslip okay because of this.

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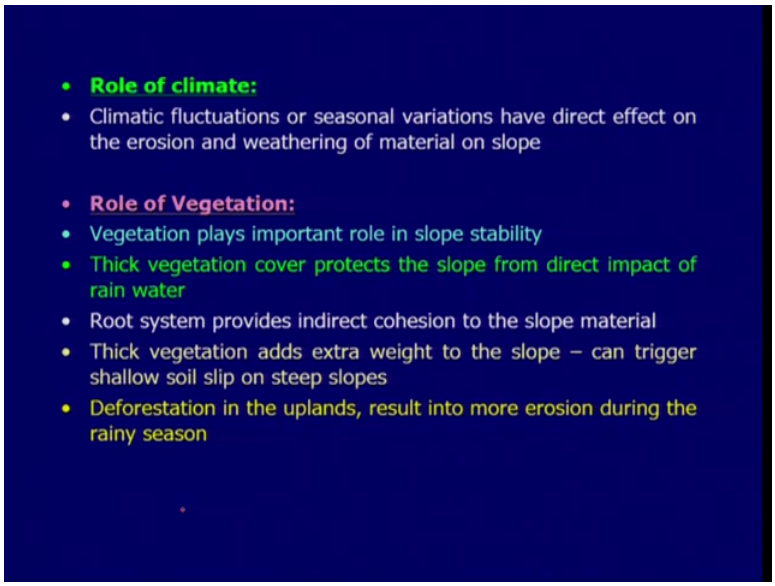

Now role of climate, climate fluctuations are seasonal and have direct effect on the erosion and weathering of the material on the slope. So for example role of material if we take, vegetation plays important role in slope stability, thick vegetation cover protects the slope from direct impact of rainwater. Because of you are having the barren area or barren land, you may have, the erosion will be very fast but to extent, the vegetation cover uhh will protect the uhh the slope surface. Root system provides indirect cohesion to the slope material so it will uhh hold the, the roots will hold the material on the slope and as we you might have seen in many places in the hill slopes, you you will see that uhh uhh to to have the slope stability lot of vegetation has been put okay but once you uhh remover that you should not put very uhh huge trees okay on the slope because that will increase again the uhh over burden on over the slopes.

A thick vegetation add extra weight. That is what I was talking about that if you have an thick vegetation, that will add an extra weight to the slope can also trigger shallow soil to slip on the steeper slopes. Deforestation in the uplands result into more erosion during rainy season and that can reduce the shear strength of the the uhh surficial material which can result into landslide.

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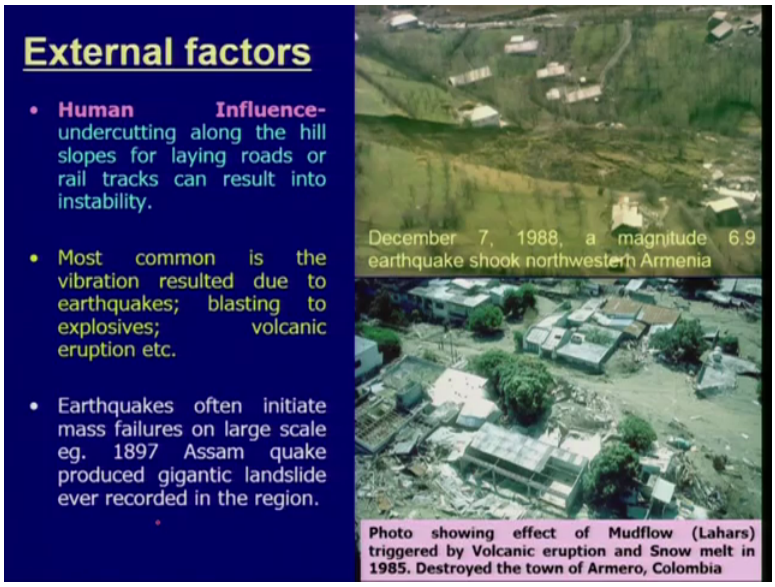

Coming to the external factors, as we were talking about that one is the human influence if you are you are doing the undercutting along hill slopes and for laying roads or rail tracks can result into instability of the upper part of the slope. It can result into landslip. Most common is the vibrations result due to earthquake blasting or volcanic eruptions. That can result into your uhh landslides also and volcanic eruptions it has been seen that this can result into the Lahar flows also and it can also trigger landslide closed to the coastal areas. Even the earthquakes can trigger landslide in hilly tracks uhh (no) not only along the uhh on the continent part but along the coastal regions also.

Earthquake often initiate mass failures on larger scale example 1897 Assam earthquake produced very huge landslide okay which was one of the largest one. These are some example from Armenia 1988. The magnitude was not so large but moderate magnitude resulted into landslide. Another this one is from again from Columbia, mudflow but this was what we have discussed the Lahar flow because this was triggered by the volcanic eruption and uhh (s) because of volcanic eruption melting the snow caps on the on the the cone so that is one of the reasons why we are say that volcanic eruptions can also trigger landslides.

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Then coming to the uhh other part, this is one example which has been given in from the same area, Columbia so the picture which shows on the left is before and this was after okay so the whole area was been swept away because of the Lahar flow which was triggered in 1985 in Columbia and this was because of the volcanic eruption and melting of snow on the volcanic cone.

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This is the landslide from 1999 Uttarkashi earthquake in India.

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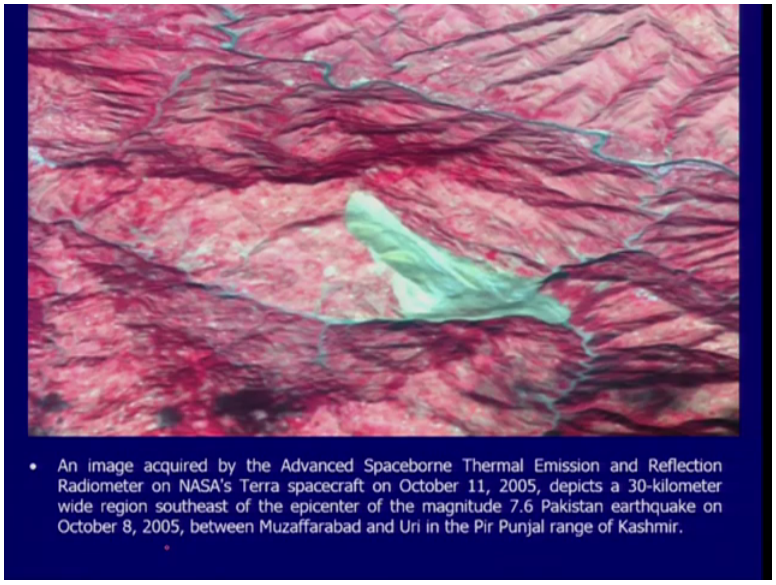

This was from 2005 Muzzaffarabad earthquake. The satellite picture shows the the major landslide which occurred over here and it also choked to some extent the the river valley here okay. So this type of landslide can also result into the natural damming in the hilly tracks okay.

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This is the same photograph, Ariel photograph which shows the landslide due to 2005 Muzzaffarabad earthquake.

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Again the same photograph showing the landslide over here.

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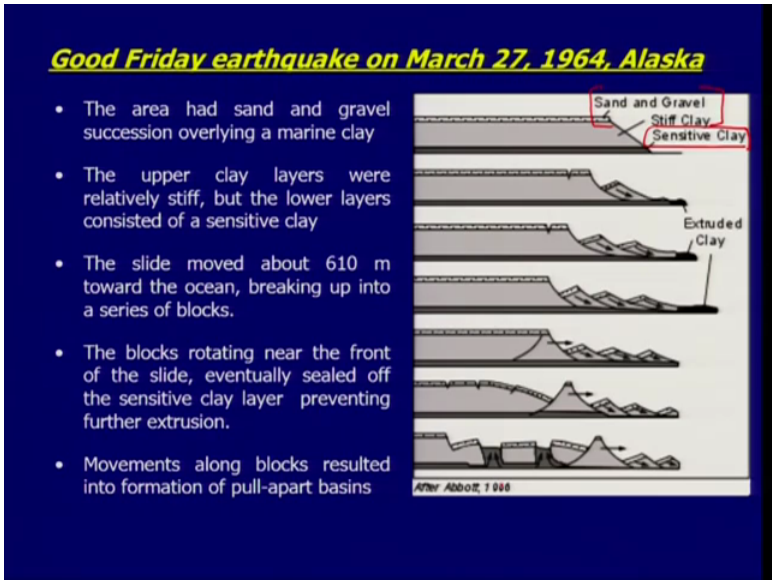

Now this is another uhh uhh very good example uhh which talks about that even if you are having the uhh harder material or stiffer material sitting on the surface but having the softer one

below can result into landslide. Now this area they had uhh sand travel succession overlying marine clay. So what people uhh, they had the uhh the houses sitting on the top of this layer here which is comprised of sand and gravel and below that they had an stiff uhh clay bed and further down an sensitive clay bed okay. Now this sensitive clay bed was extremely and which slipped at the time of uhh the Alaskan earthquake of 1964. So as we were discussing that if we are the (sti) uhh uhh stiff or uhh harder material sitting on the surface, we rest assure that nothing will happen okay likewise in this case here.

But if you are not having the understanding of the subsurface material, what is sitting below which may slip okay that is extremely dangerous. So this material the upper clay uhh layers relatively stiff but the lower layer consisted (ka) of a sensitive clay. The slide moved about 110 meters towards the ocean breaking up into (s) series of blocks and those blocks rotated actually okay so they had an massive landslide or landslide or landslip okay which resulted into the rotational uhh sliding. So this is uhh like the example which can be taken into consideration that it is extremely important to know that what exactly is sitting deeper at the deeper part of the succession, not only in the upper layers okay.

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Another example of the landslide so we are never bothered about that we are sitting very close to the the hill slope okay and we keep on constructing our houses close to that but the landslides

can result into this (whu) this whole area got affected during the landslide which was triggered in Salvador okay in uhh 2001 earthquake.

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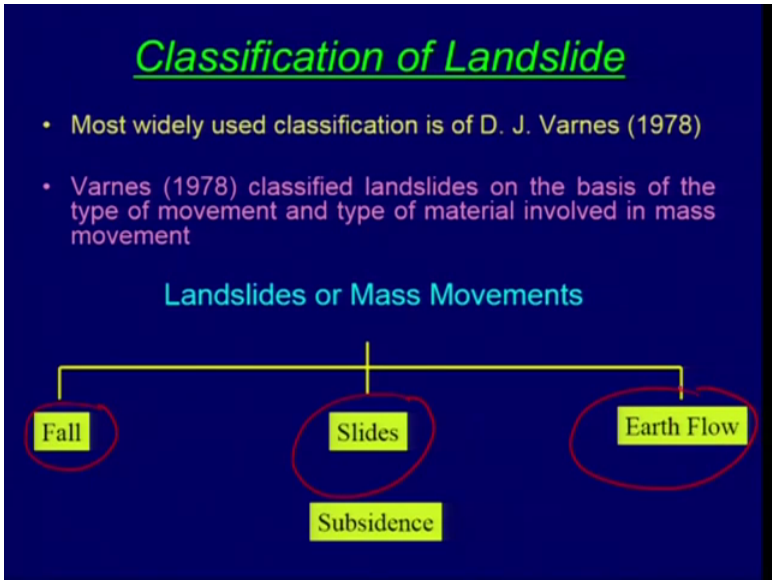

Now classification of landslide further if we take okay, most widely used classification was been given Varnes in 1978 and the classification of the landslide was on the basis of the type of movements and the type of material involved in mass movements because we have like uhh coarser material, we have finer materials okay so landslides or we can generally call that as an mass movements, we can classify as falls, slides and earth flows. And this all has this this will have coarser material, this will have the combination of coarser and finers and this will have mostly the finers one okay. And then coming to the land subsidence okay.

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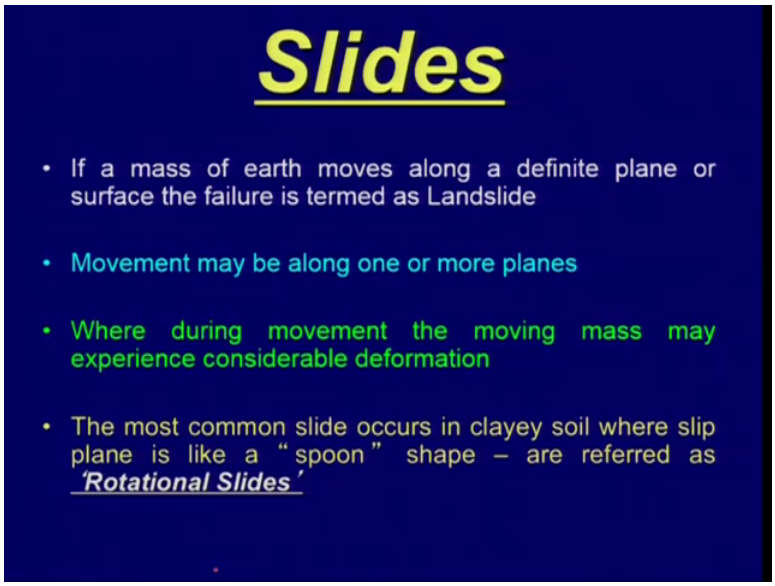

Now slides as we call again it may be faster or it may be slow also okay. So slides if a mass of the earth moves along a definite plane or surface, the failure is termed as landslide. Movement may be along 1 or multiple planes where during movement, the moving mass may experience considerable deformation so this deformation is nothing to do with the tectonic deformation but because of the slip, it will experience some deformation, internal deformation so this is nothing to do with the tectonic deformation we are talking about but the deformation may be very much similar to what we see in the tectonic deformation. The most common slide occurs in clay soil where slip plane is like a spoon shape and they are referred as rotational slides. You will be able to see uhh the slip plane at some in some of the land slides of this type okay.

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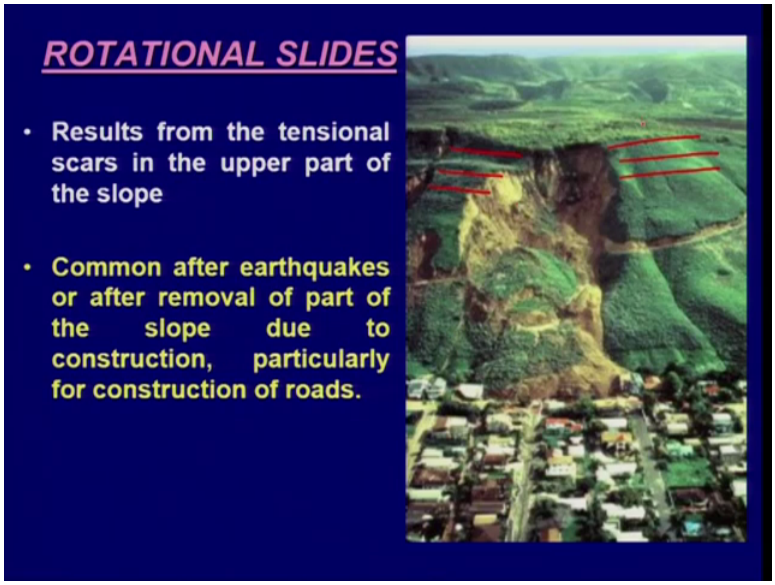

So rotational slides, these are again. This is an example of the rotational slide where you can see the this feature is like spoon shape and the the portion which has moved down here, this one will experience or will have the deformation within that because it has moved down and because of the the movement, it will have some deformation. We will see that uhh uhh in coming slide okay, how that deformation looks like okay.

So results from the tensional, this type of deformation or sorry the the rotational landslide will result from the tensional scarps in the upper part of the slope, common after earthquakes okay so you have for example some tensional scarps some tensional scarps on the surface here or may be the extensional cracks which are developed over the time on the slope here so at the time of the earthquake or ground shaking, this may result into the landslide or if you are having the the groundwater going in okay then also it can result into the landslip. So it is extremely important that such slopes are monitored constantly to know that whether this area will slip or not okay.

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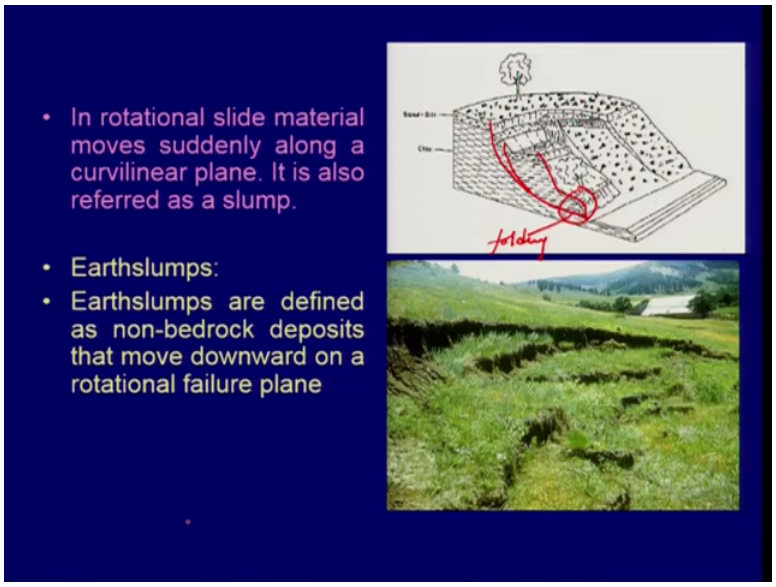

So rotational slides okay. In rotational slide, material moves slightly, suddenly along a curvilinear plane okay so plane will be curvilinear here and if you see this part here, this part has moved along multiple planes and then this area is having like pulse like here okay. So this portion will experience some sort of a deformation very much similar to the folding part okay so this will have folding within it. So these are termed as slumps and earth slumps are defined as non bedrock deposits that moves downward on a rotational failure plane. So here if you see from the side view, you will be able to see that this is one crack, this is another one. This is another one here and so on. It is having the extensional cracks and the the the slope along which uhh the movement occurred are all these curvilinear planes here okay, so it has occurred along the multiple curvilinear planes.

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Again similar uhh example where you can see clearly the scarp and multiple extensional cracks here.

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Another example of the same area.

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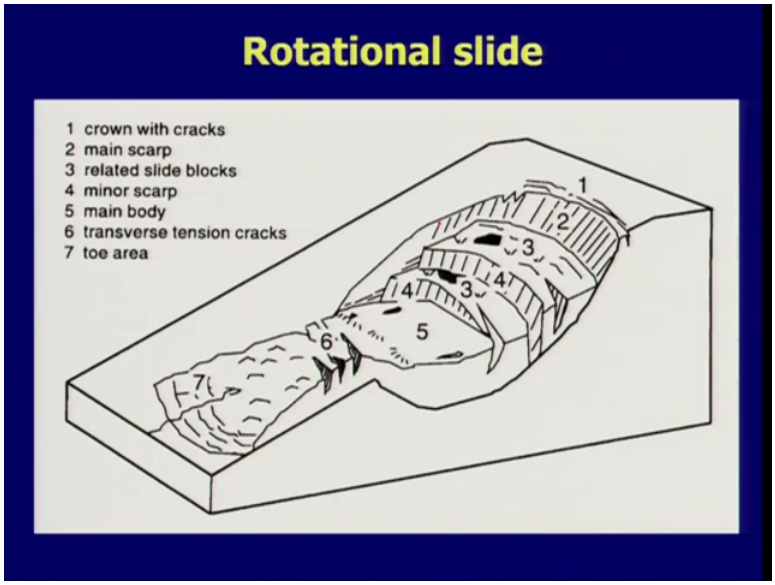

Rotational slide again so what you will be able to see is that you will have the ground with cracks which is given here. You will have the extensional cracks on the upper part. Then you will be having, you will be having the main scarp that what you see like a spoon here. This one is the main scarp here which you can see this part and then you are having related slide blocks okay so these are the blocks which are moved along with the same plane and this is the main plane actually.

This is a main plane and then you are having minor scarp, scarps which are minor scarps which are minor scarps as (mark) marked by this ones. These you are having the scarps here which you were able to see over here okay. These are all the minor scarps and you may be having the external cracks on the top and this is the main scar. Then you are having the transverse tensional cracks okay which are seen over here on the bed and this lobe or the toe part will have the deformation will experience the deformation.

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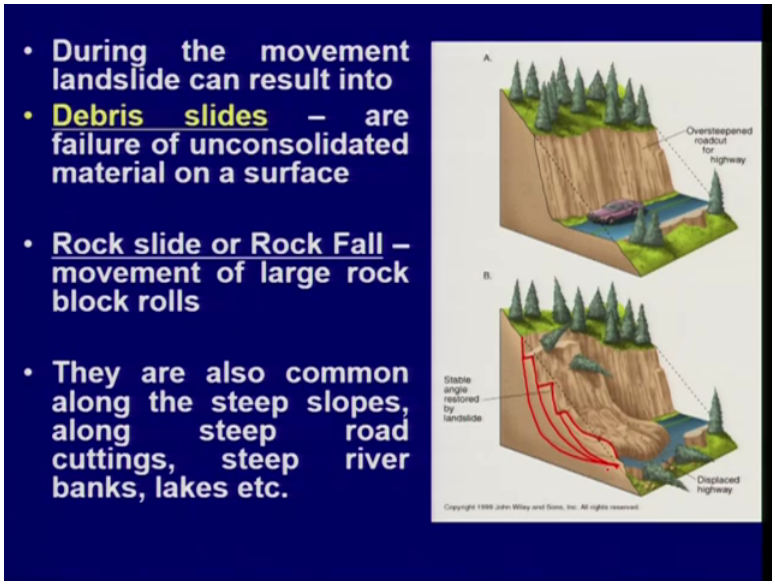

Similar example which has been shown that on the on the surface you may see multiple uhh scarps here okay and then you are having a lobe here. This movement in if you see, you will be able to see something like steps like this okay. These are all connected with the (maiz) main failure plane and then you are having another minor one okay so you are having multiple planes along which this movement has occurred. Now during this type of uhh uhh slide okay, you may have uhh the landslide comprised of uhh unconsolidated material which we termed as an in debris slow.

So it has it may have uhh the uhh gravels and along with the sandy matrix or it may have gravels or along with the the sandy or clay material okay. You may have the rock slide or the rock fall also which will comprise the larger blocks. They are common along the steep slopes, along steep road cuttings as has been shown in this figure okay. Okay or along the river banks also.

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Now this is an example from uhh India uhh near Chandigarh where we looked at the landslide which occurred along an hidden slip plane and we identified this as an rotational landslide okay. Now if you carefully see, you are having an riverbank here. The river is uhh flowing, this is an Ghaggar which flows in this direction down, there is a river channel. If you see this part here, this is the river channel here and then this, you are having the the huge cliff, of course it is cutting the Shivaliks. The young succession of the Himalaya. Now if you carefully look at what we were able to notice that nothing was been seen here much okay.

Few cracks like this okay but this portion. If you carefully see, I will show the close-up okay of this one. This is slightly warped okay so you have an elevation change here so this was an very interesting to understand that what exactly happened here. People talked about that this was an uhh surface rupture because of the 2001 Bhuj earthquake so it was but impossible for us to understand that why so far from uhh which is sitting almost like more than 1000 kilometers, the surface rupture will occur here okay. Then we visited the site and we looked at that what exactly happened okay.

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Now this is the example of the warped lobe or the toe part of the the landslide okay. So we can see this area here. So this portion moved over the surface.

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Another close up of that okay. So this is the lobe of the landslide okay. So if you if I I put the cross section then what I will be able to see is that this was initially this was this flat surface here, riverbed or the flood plain area then because of they push from here along the slope, the

material came down and then this moved over the top of this okay or you can say that this wasn't pushed and this was been. Yeah so if I if I see the section, I will able to see something like this okay so this area, it moved okay.

So this will definitely show folding here so it will show the internal deformation so this was moved along the plane. This is the plane coming from the (surf) from the the stiffer part. Now the interesting part which we uhh were worried about here was that this similar type of slip can occur in future also here okay and since this area has been already uhh like occupied.

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I am unable to show the uhh but there are some small uhh white blocks which are been put here so what does this indicate is that this area is already marked or plotted for new houses coming up here okay. So they they have the uhh the plotting is been done and this area will be quickly occupied and might have been occupied by the by the residential colony here okay. So this type of slip will occur again in future also and it will result into the severe damage to those houses okay, so one has to be uhh careful about choosing the locations for construction.

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Now and what we did was we uhh again we understood that this is the landslide and uhh but we wanted to know that whether it shows some extensional cracks on the (surfa) on the hilly part or not so we (visi) visited on the top and we found the (reve) so these are the scarps here, this is one scarp here, that is another one here and then we have the extensional cracks which are developed on surface. So this extension on the (hee) uhh the hilly portion or the stiffer part resulted into the movement of the the mass along the the rotational or the curvilinear uhh plane okay so this we classified as an rotational slide which we observed close to Chandigarh.

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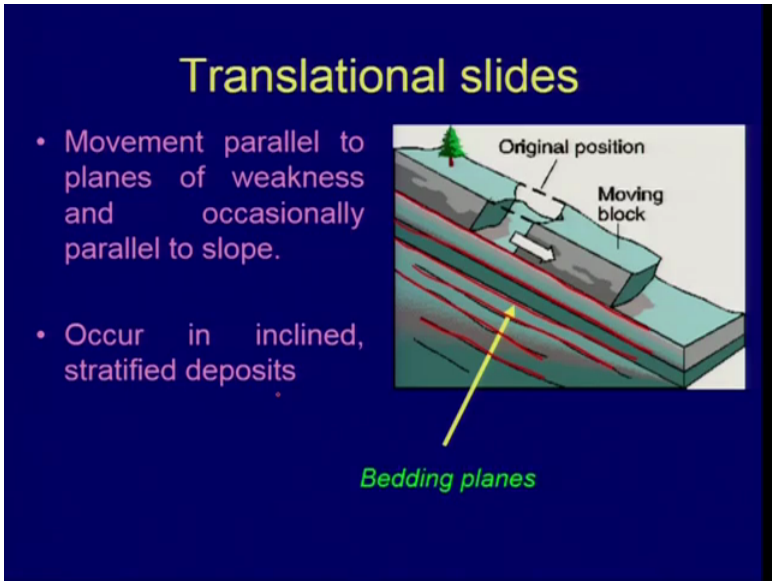

Now, translational slides okay. There are the those we were talking about the rotational one. These are translational slides so movement parallel to the planes of weakness and occasionally parallel to the slope. So on the slope mostly what we see is that if suppose you are having a stratified rock okay and we are having the bedding planes. These are all the bedding planes which are been shown here okay. Now they are dipping towards the, along the slope okay so these are the weak planes which may result into the the slip okay in future. So occurs uhh in inclined stratified deposits bedding planes.

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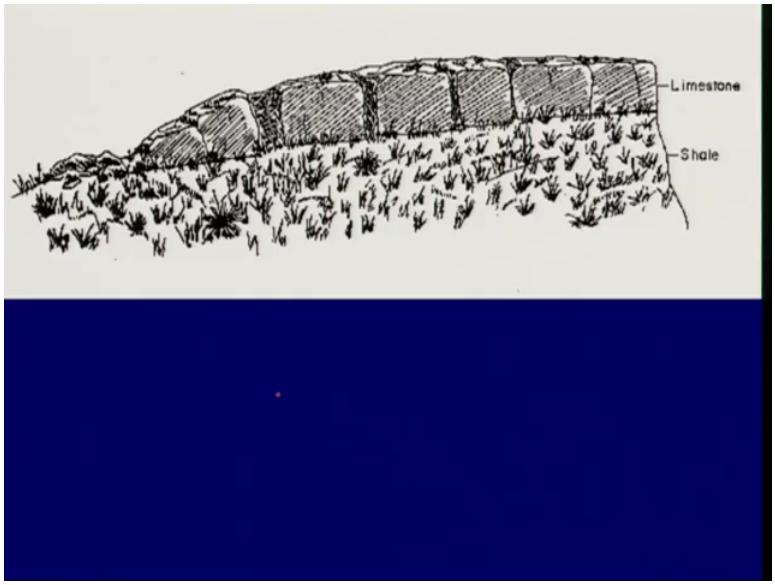

Then this is another example of again we are having shale and limestone okay. And this type of uhh landslip, we term this as an rock spread okay are defined as blocks or the slabs of bedrocks so you are having a bedrock here and you are having of course a shale again and they both are lime uhh limestone and shale are sedimentary rocks but shale is again the comprised of finer material okay so this may result into the lateral spreading okay. So lateral spreading may develop in finer unconsolidated sediment like clay, silt and sand. It is mainly due to increase in pore water pressure at relatively shallow depth and increase in pore water pressure can be resulted because of ground shaking also. That is uhh because of the seismic events.

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Commonly seen examples during earthquake. This is uhh example of lateral spread. During 2001 Bhuj earthquake which happened and if you see this the ground, it is almost flat okay so the the slope is very gentle but even then this phenomena occurred because of the uhh the very soft material sitting below these sandy units okay. So this is an agricultural field which had an very gentle slope of hardly 2 degrees okay.

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This is another photograph from 2001 Bhuj earthquake, lateral spread. So slope is very gentle. If you can see this here. The car standing here and the person standing here. Slope is very gentle. Then also It occurred okay because it had very soft material sitting below the sandy units on the surface.

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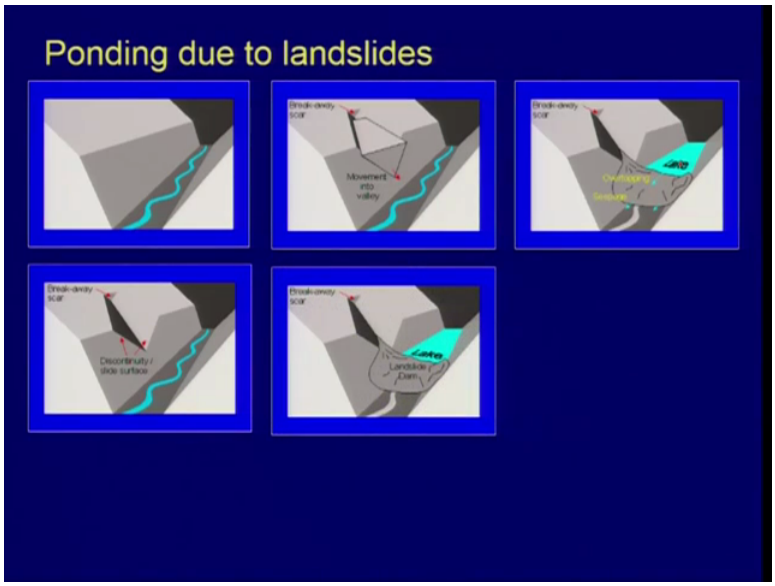

Ponding due to landslide as I was talking about that if you are having uhh uhh the landslide close to the river valley, it may choke or blog the the river channel and will result into the natural damming or natural dam okay and this is uhh very commonly seen in Himalayan region where scientist have identified that that the lake deposits okay in many locations which are sitting but at uhh at greater height but they right now they don't have any lakes which uhh exist there okay. So this indicates that in past also, uhh the landslide close to the channels or the valleys blocked the rivers resulting into formation of artificial uhh of a natural dams and which when breaches will result into the flooding in that area okay.

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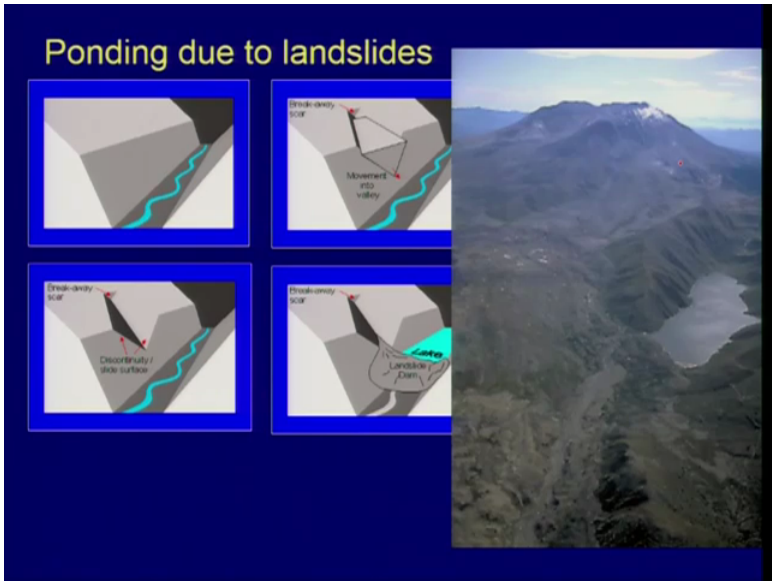

So this is an example of again an the small lake which has been developed because of the choking up of the the channel here so this is a stream here which goes but this got choked up because of the the landslide.

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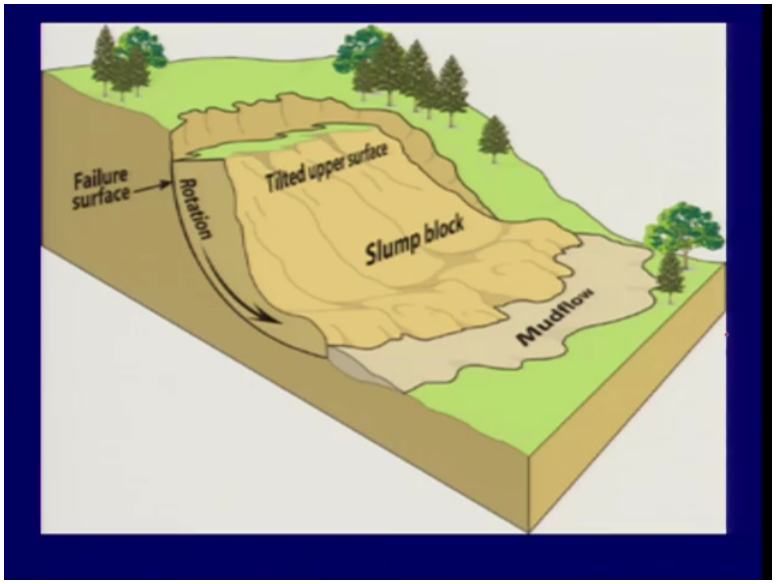

So rotational slide as we were talking about.

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Another example from uhh Himalayas close to (no) near to Dehradun. Now this is again uhh I would like to explain here that in most of the uhh the the regions in uhh the hilly terrain the roads are (())(32:24) across the the river channel on the riverbed okay. You will not they will not do uhh the the good foundations and all that they will just lay down the roads on the top of the riverbeds and what will happen over the time after the (eve) each floods that you will find that this is eroded away and slowly it will go off okay.

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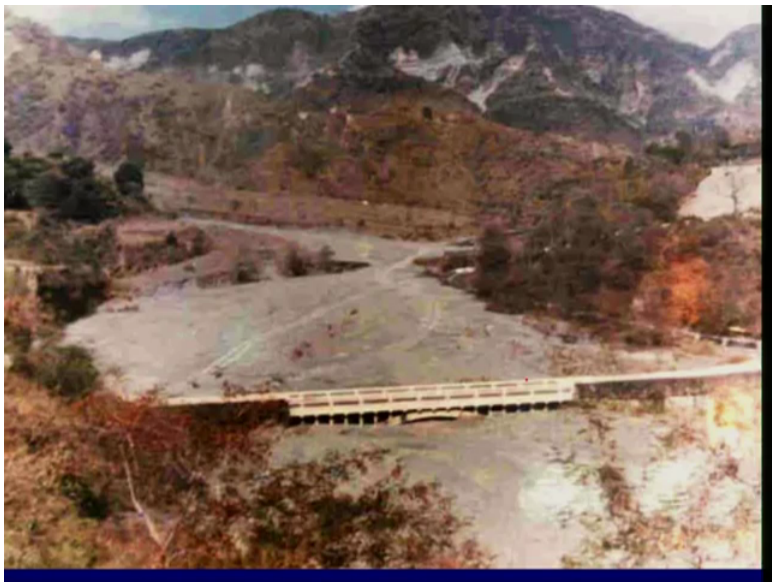

This is one of the good example which uhh uhh we observed in Himalayas which uhh again close to the uhh Dehradun area uhh uhh and uhh the backdrop if you see here, you are having some uhh whitish patches, these are nothing but the perennial I will say. The landslide is active here and this is close to the main boundary thrust okay and this area is, the the landslides which has been known as Kalagarh landslide here so this bridge was constructed long back, may be 40 years back and I will see the close up of this so the problem was that because of the shared material is available here, because of the ongoing deformation of the Indian (pla) between the Indian plate and the Eurasian plate, whenever there is a rain, this all material will be flowed down into the channel and this will block uhh the the riverbed here okay or this material will and it will fill up the riverbed and doesn't allow the water to flow under the bridge but it will flow over it.

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So over the time, what they did was, they constructed this photograph we were showing, we were looking this uhh from the uhh the downstream side.

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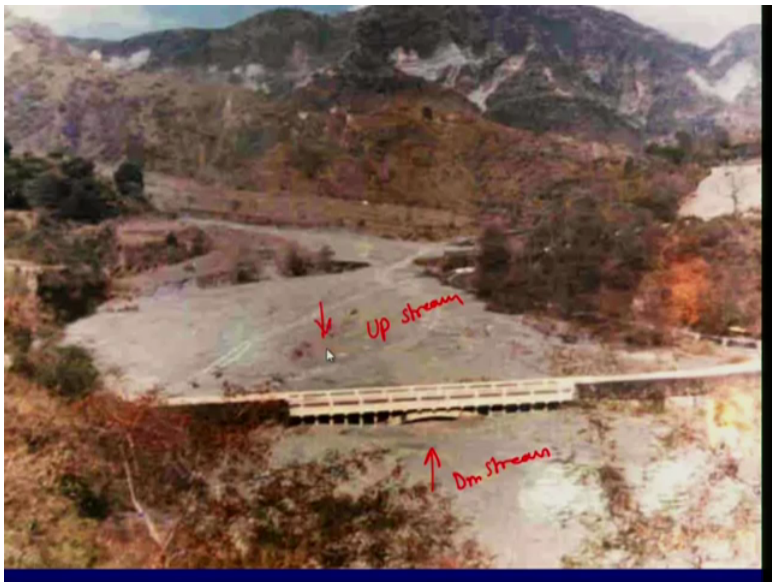

This is the this is the upstream and this is your downstream so this we are viewing from here. The next photograph, we are viewing from this side okay so just keep in mind that one.

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What they did was uhh they constructed the retaining wall okay so this whitish part which you see here is your wall which was constructed again on the riverbed but to protect the the bridge here okay. So that you have through and through passage of water uhh during the uhh rainy season or heavy rains okay and what happened was quite interesting okay.

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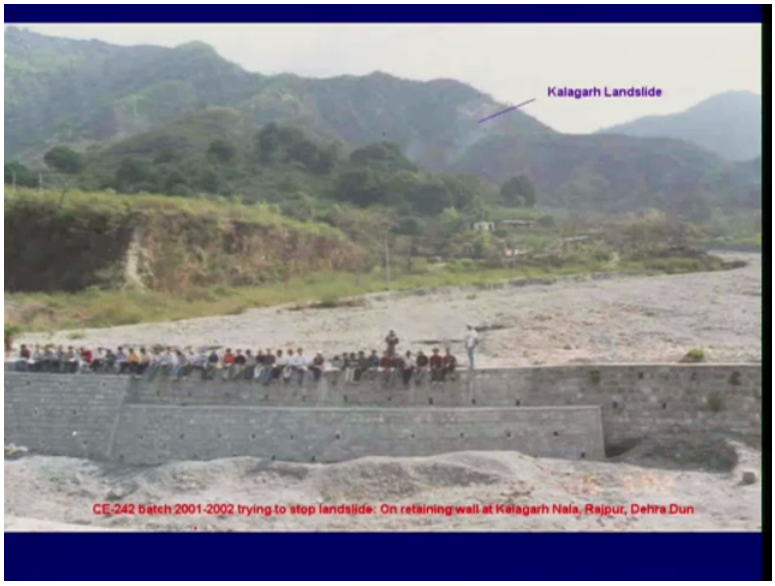

So in 2001-02, we took the field trip here. Our B.Tech batch is sitting on the the retaining wall here which was been created again. The photograph is uhh from we are looking from downstream to upstream, you can see some scarps here of the landslide, Kalagarh landslide so we found that it's huge was been constructed and to protect the material which is coming down during the heavy rains and choking up the river here okay or the choking up the riverbed and uhh uhh damaging probably. It will damage the the bridge also. So this was in 2001-02 batch which we took. What happened next okay.

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You can see this one here. So what was the problem here again the same okay. The retaining wall was been constructed on the riverbed so there was an percolation of water underneath so water flowed through this and it removed the material or the or the wall from the base. Still the top more or less intact here but this moved okay. So this is another example what we can take of the landslip okay, so the top remains intact but the subsurface material moved.

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DAY 3


DAY 4


DAY 5


DAY 6

Please look at this video which shows that in 7 to 8 days, the slip occurred along this slope okay and you can see the the material coming on the road here and this going down.

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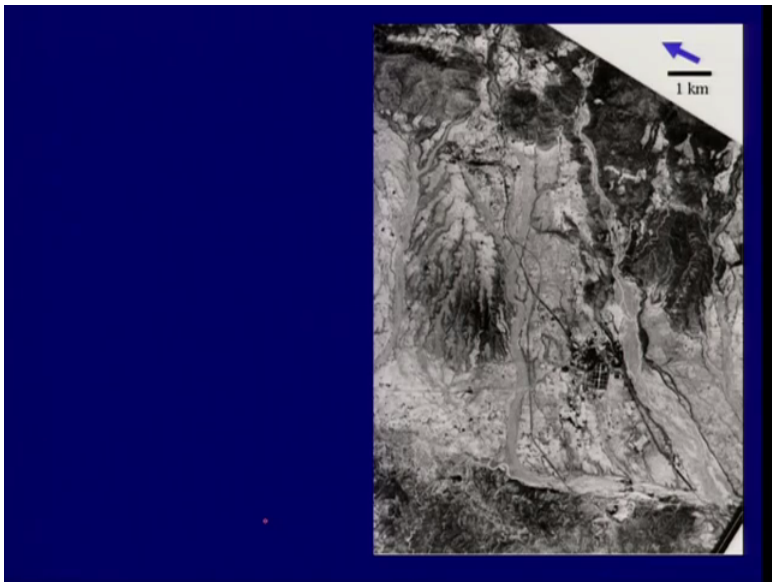

Now coming to this part, this is an example from uhh the Himalaya where, okay we can uhh uhh continue in the next lecture. Thank you so much.