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

Lecture – 31
Control and Stabilization of Landslide

So, welcome back, in last lecture we ended talking about Control and Stabilization. Now I would like to mention here is that like yeah of course, there is some part which we have covered in the other course of earth sciences for civil engineers. And we were thinking that probably we will skip this one, but I personally feel that this is an important aspect which need to be covered for those students who are exclusively looking for this course on Natural Hazards.

Now, as we have discussed in the couple of lectures on landslide that what are the main reasons for the landslides or what are the factors which can cause landslide.

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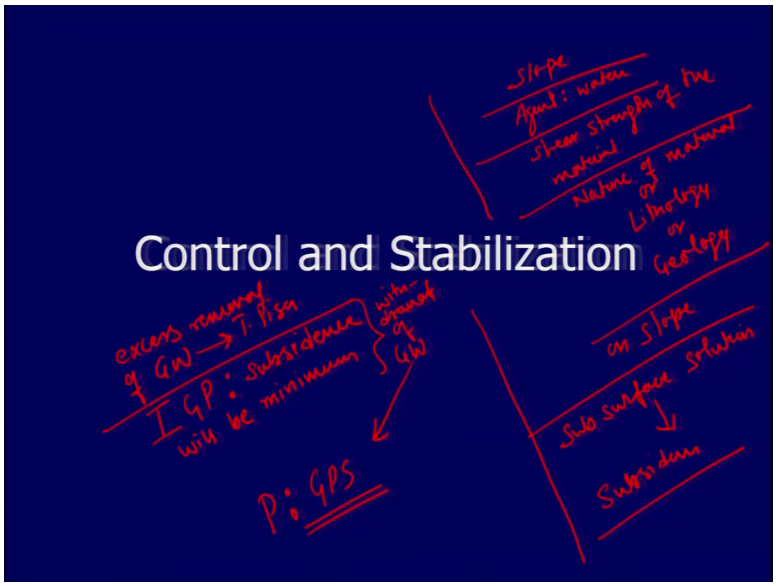

And the most important one what we had discussion one was the slope. Then we have the second one is the agent; an agent which I would say here either it is water which will affect the overall shear strength of the material. And of course, the nature of material or we can say the lithology or the geology of the material sitting on slope.

Other than this, we were all we also discussed upon that the factors that can affect or can trigger the landslide is mainly the geology is the most important yes of course, along with the slope, but you can have also the subsurface solution activity. And thus we talked about in the topic of subsidence. Further we also talked about that the subsidence can be because of the excess removal of groundwater.

And the best examples we took that was the tower of Pisa. Now, this is very common even in the area if you are talking about the withdrawal of groundwater in the indo gangetic plain. However, the subsidence will be too less like it will be minimum in case of the indo gangetic plain. And this again will be because of the withdrawal of groundwater. This we can pick up or we can have the precise measurements using GPS permanent GPS stations.

So, if you have the permanent GPS stations you can figure out the minor or minimum subsidence because of excess removal of water. So, these are the few things which we will definitely keep in mind, while talking about the landslide and different type of landslides. Of course, along with this the material we are talking the nature of material, the (Refer Time: 04:43) of lithology there is another important point which we should keep in mind is the geological structures.

So, geological structures, if we take and we gave some examples of the shear zones from the Raipur area near Dehradun.

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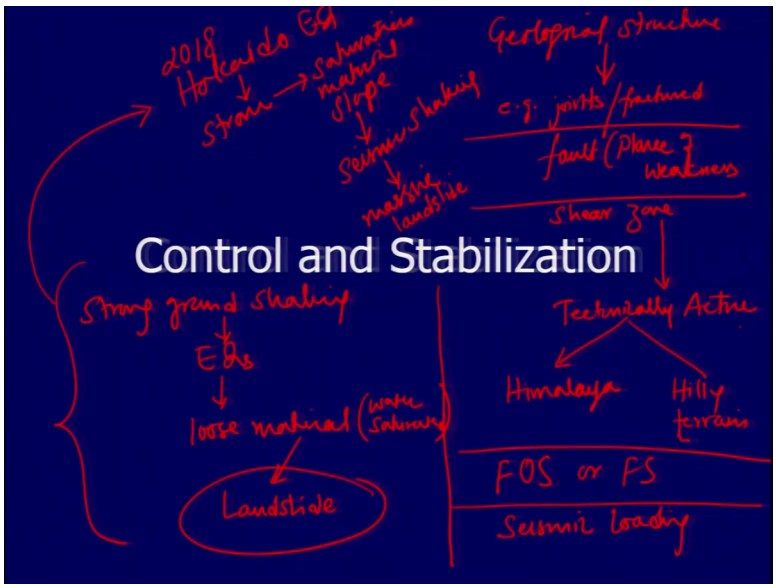

So, geological structure is another important factor of the aspect which will play an important role in facilitating the mass moment. So, this will help in, like for example, the what if you have joints or jointed rocks you have all fractured then another one is your fault.

Now, this is the plane of weakness. Then you have shear zones and this will be in the areas where we have or maybe this we will find in the areas which are tectonically active; so, where we will see this mainly in Himalayas, or in any hilly terrain. So, these are the few things which we should always keep in mind and taking this into consideration where we can evaluate and go for either the factor of safety or you can say FS.

We also discussed about the seismic loading. And in most of the areas when you are having the strong ground shaking, which is triggered by earthquakes. And if you have loose material or if this material is water saturated will result in 2 landslides. And the best example of this what we discussed was your 2018 Hokkaido earthquake.

So, there was an very strong or strong which resulted into the saturation or over saturation of the materials sitting on slope. And finally, seismic shaking triggered the massive landslide. So, keep in mind all this when you are trying to evaluate any terrain.

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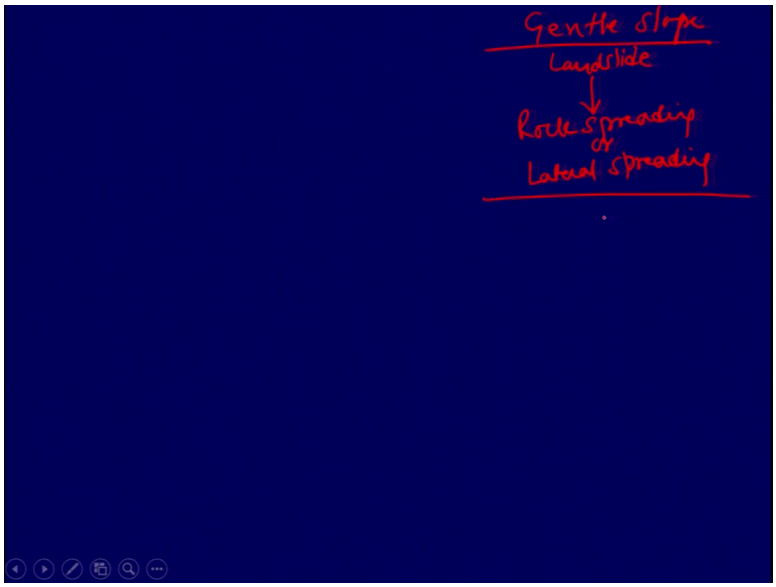

Of course the slope plays an important role, but what we additionally learned was that even you are having gentle slope. You may have you may experience landslides. And here we discussed about the example of rock spreading or lateral spreading. So, once you identify that the particular region is prone to landslide, then what best remedies you can and try to you can implement to reduce the event of landslides.

And that what we were talking about in the previous and we started talking about that. So, let us see what we have with us, how to reduce the chances of having landslides in that particular area. One of the example I gave was from Raipur area where they constructed an retaining wall, but they failed.

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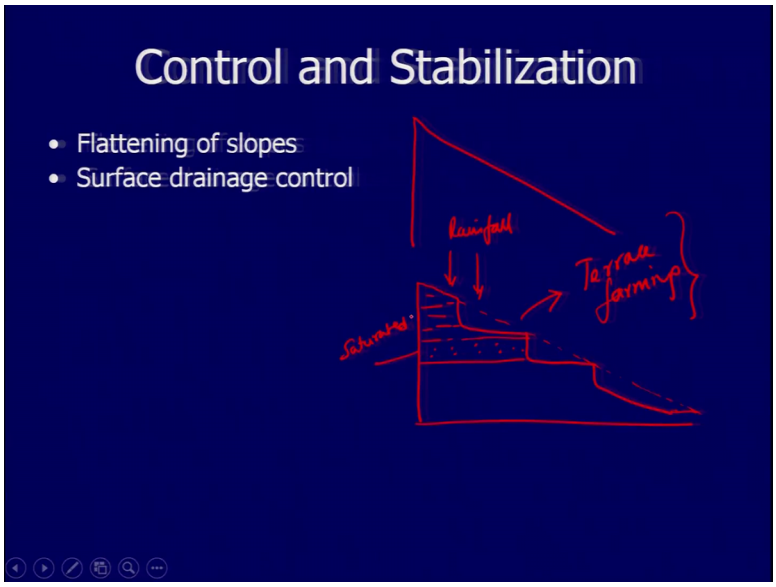

So, control the control and stabilization of slope, the best practice which has been seen in most of the villages is flattening of slope. So, if you go in any hilly areas what you see is basically suppose you are having a slope steep slope here. So, what they do is they will try to reduce the slope.

So, this reduction will help you to some extent to stabilize this slope. And you can also see this when you move to any hilly areas or the hill stations what we call is terrace farming. See even the local villages they understand that they need to stabilize the slope one and they also utilize this flatten area for agricultural practices.

Surface drainage control. So, the point here is that suppose you are having the lithology here suppose we have like sand body sitting here and then you have the clay or something like that and then. So, this if you have the rainfall what will percolate in the sandy units. And this sandy units when they become saturated can trigger a landslip or a mass movement.

So, suppose this I have drawn this horizontal, but usually you will not find that because the inclination itself is showing the part of the deformed structures or the inclined stratification or the status.

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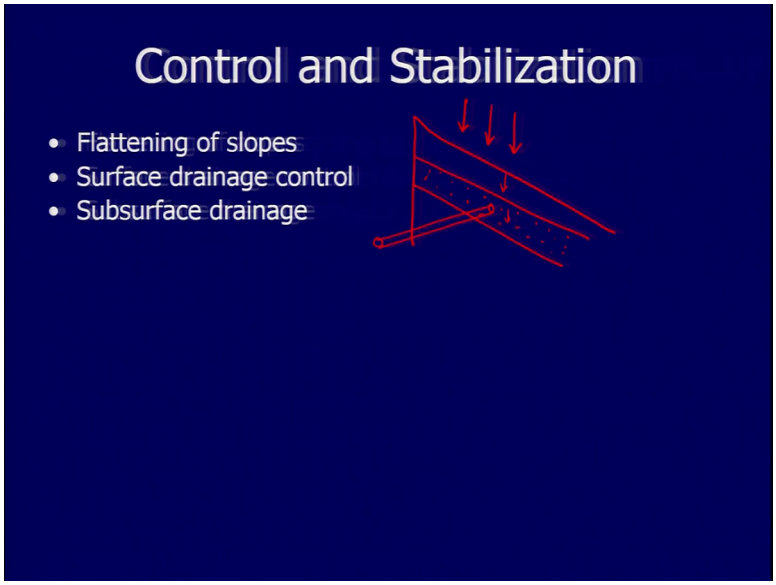

So, if you are having an inclined status, then you have like the succession here. And this is the unit which is short of an what we call vernable unit. And which can slip in future if this becomes saturated. So, the best way is to remove the water as soon as possible through the slope.

So, you are not allowing the water to get percolated. Another one is subsurface drainage. Even if you are not able to control the percolation of the water in this, one can do is one can put in perforated pipe here and drain out the water as early as possible. So, you can control this through putting this type of technique.

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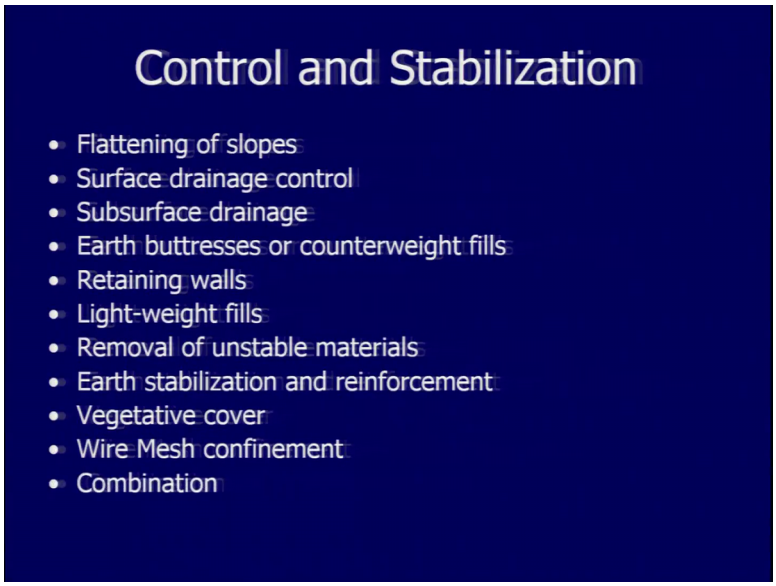

Then you are having the earthen buttress or you can put the counter weight fill. So, this we will discuss quickly then we are having a retaining wall one of the examples we have already discussed. We can have lightweight fills to avoid the slip or to protect the slip or stop the slip further a removal of unstable material.

And you can reinforce using the better material, earth stabilization and reinforcement vegetation cover wire mesh confinements. You can do where you are having in you expect to have a rock falls. So, you can protect that with putting the wire mesh. And then combination of any one of this you can put depending on the conditions or the side conditions.

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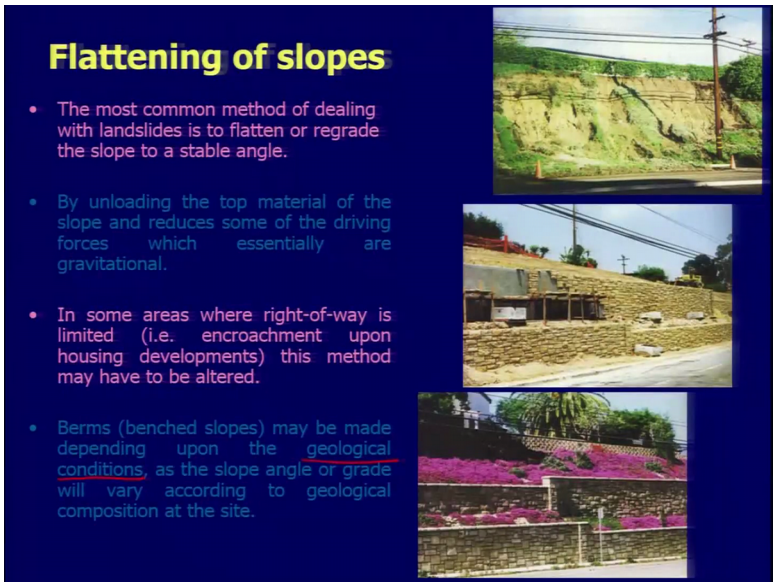

So, flattening of slope very simple the most common method of tailing with landslide is flattening or regrade the slope to a stable angle that, what I have explained in the previous one. That can be done by loading the top material by unloading the top material of this slope and reduce some of the driving forces which essentially our gravitational.

So, you can do that also one. So, when we are talking about the terrace type farming situation, then in that case you are unloading the material and as well as you have reduced the slope. And in some areas where the right of way is limited that is encroachment upon housing development this method may have to be alerted. Sorry scope focus currently. So, in some areas where the right of way is limited where there is an encroachment because of the development you can alter this method.

There is one of the best example which has been shown here. And again as I told that the best way is to understand the site conditions. So, you need to understand the geological conditions and based on the locations and the area you may alter the method or you can have the combination of more than one method as we were talking in the previous slide.

So, the example which has been shown here it is very simple. So, it is not a very huge landslide material, which can come down, but the way it was been done. So, it is in combination of 2 the reduction of the slope putting retaining walls here to protect this slide or stop this slide further and as along with that putting vegetation here. So, you have beautified the area as well as you have almost reduce the chance of land slip or

mass movement which has been seen in this field or photograph on the top. This is the one of the best way which one can do to minimize the mass moment.

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Example from Uttarakhand and this is the picture which was been taken while moving to Nainital where, here most of the places are marked by active landslide.

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Similar thing has been done some slope angle has been reduced as well as been protected by putting the retaining walls.

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Close up of that. And of course, at the same time some portion has also been covered putting and the concrete they have done reinforcement.

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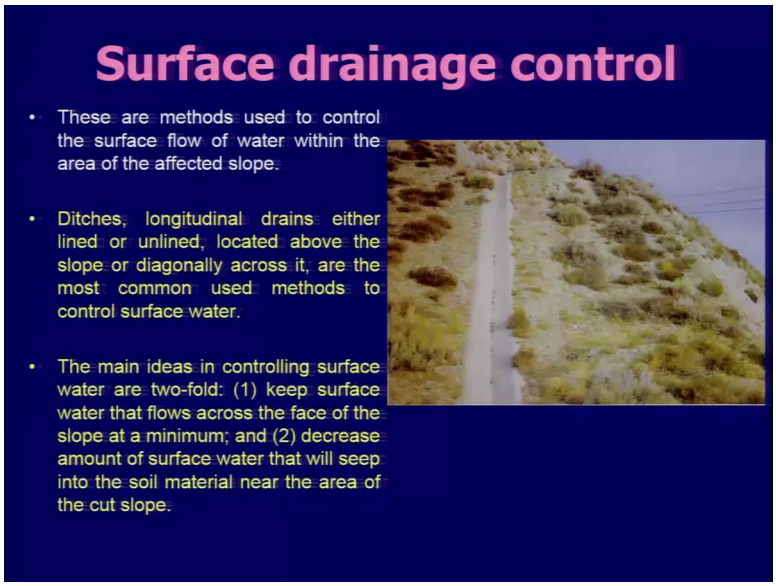

Surface drainage control. You can either construct the small water pathways to drain out the water as fast as possible.

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It is another example. This is from Japan whether the combination of three what they have uses one is the wire mesh here they have reduced the slope putting the benches reinforcement has also been then. And then and water pathways have been constructed to drain out the water as fast as possible. So, you can depending on the geology of the area plus the geological structures present. You can have different combinations close up of that.

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So, you have the wire mesh this is basically done for the beautification also and then you have number of drainage or the water pathways which have been consecutive to remove the water when not allowing the water to percolate down as early as possible as well as they have done the reinforcement.

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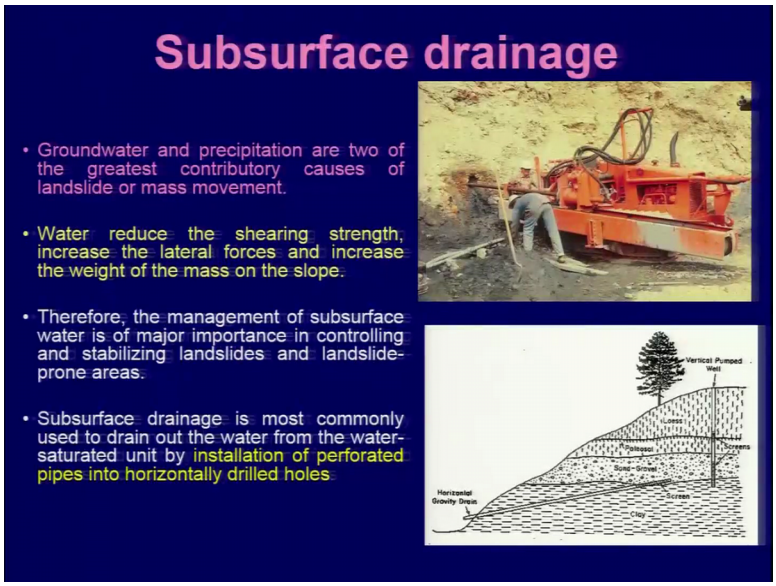

Subsurface drainage if you have the section like this. For example, you have this is an loess, loess is a windblown deposit in some area, but does not bother for all this. What we see is that we have a loose material here and we have in thick soil and then we have sandy gravel. And then finally, clay so, this unit if it is been saturated, it will can could be fluidized and can result into the mass movement. So, the idea is that you allow the water to pass through as early as possible even if this becomes saturated. So, there is another way to do the subsurface draining of the material to driven the landslip.

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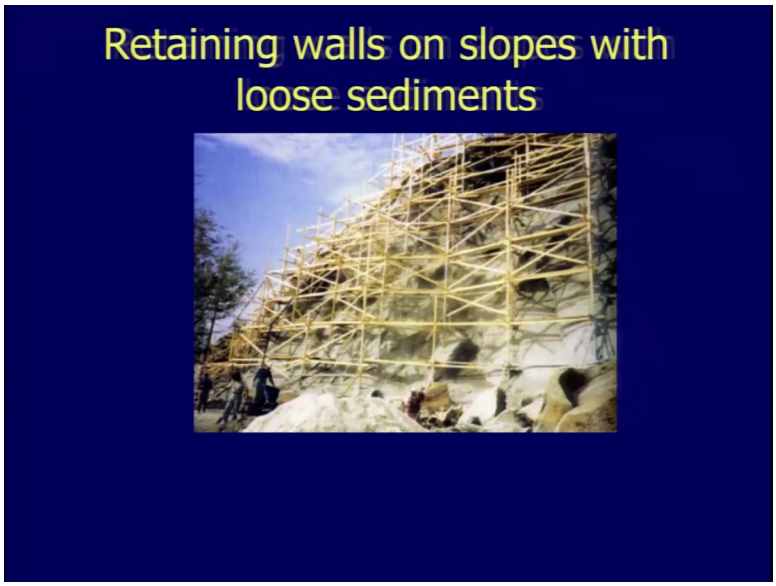

Retaining walls, if you are having a very loose material.

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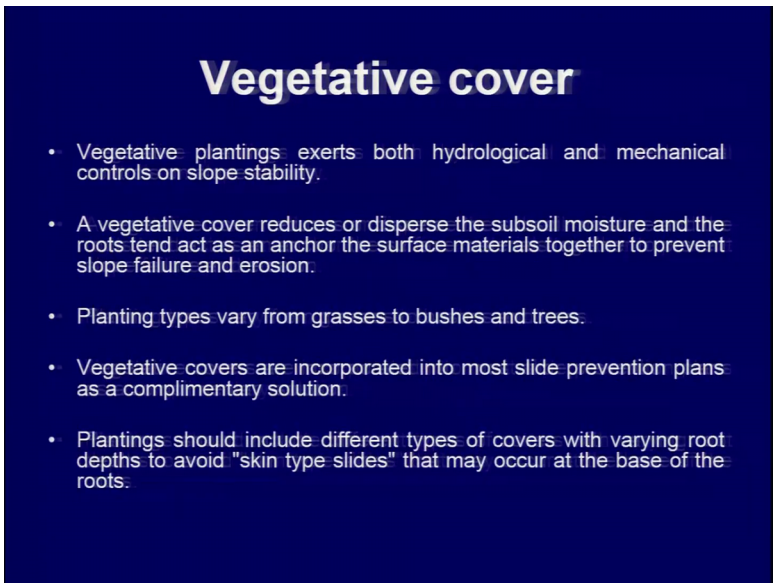

Vegetation cover; now vegetative plantings exerts both hydrological and mechanical controls on this slope stability. Vegetation cover reduces the subsurface moisture and the root tends to act as an anchor. So, this can reduce the chances of land slip increases the stability, but of course, if you are putting very heavy trees on our planting very heavy trees which can put additional load on the slope can also trigger the landslide.

So, when I need to be very careful that what type of vegetation, we can put or we will do the planting on the slope depending on the material.

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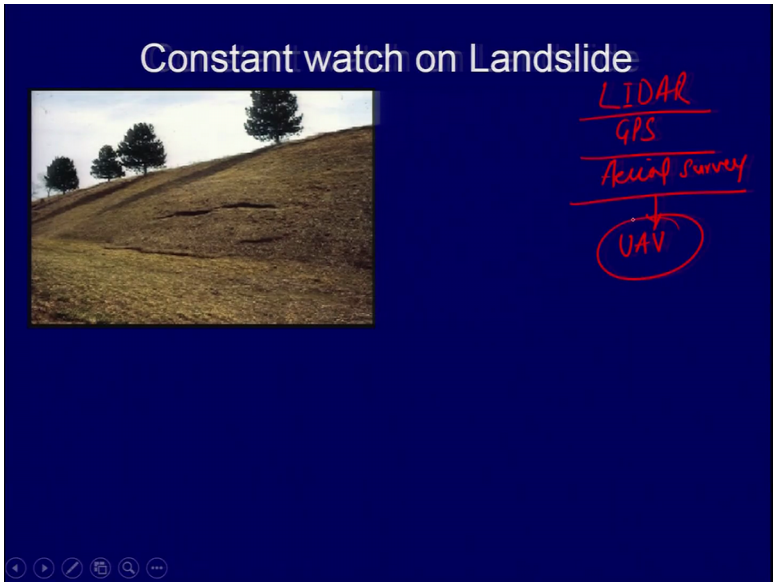

Constant watch is also important. This can be done either by using satellite data or drone photographs, or you can even do this put by putting GPS stations. And nowadays what we do is we do LIDAR mapping. So, once you know that this for any particular area is susceptible to landslides you can have periodic mapping either by LIDAR or GPS or by aerial survey.

And now having the facilities available by UAV; one can do the mapping of the area which we suspect that this area can experience land slip in future. And you can compare the photographs taken at different time or the period and try to understand what will be the scenario in future.

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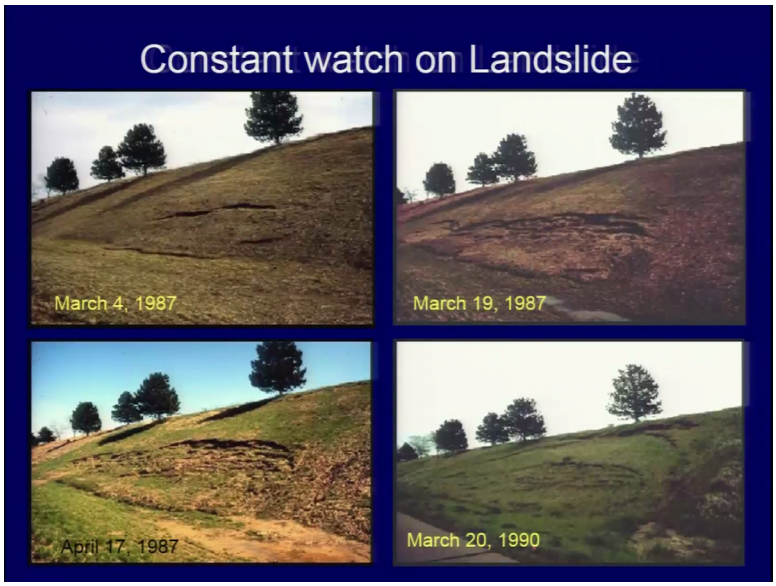

And what is the pace of the moment of landslides. This example is a very good example. From US the photograph was taken in on March 4th 1987. Then March 19 what do you see here is development of extensional cracks and more have developed covering larger area and this material has slides that started sliding down. Whereas, here you will just see one shot up an vap here, but do you see this material has rolled oven over the surface. More slip coming up with this scar. So, this is I hope you will be able to identify that what type of landslides or the mass moment is this ok.

Finally, it affected the upper part also and this was in 1990. So, almost if you see 87 3 years later the landslide or the effect of the landslide has covered almost of the entire slope. So, if you keep watching this carefully and see understand that, how much what is the movement which is taking place one can easily figure out.

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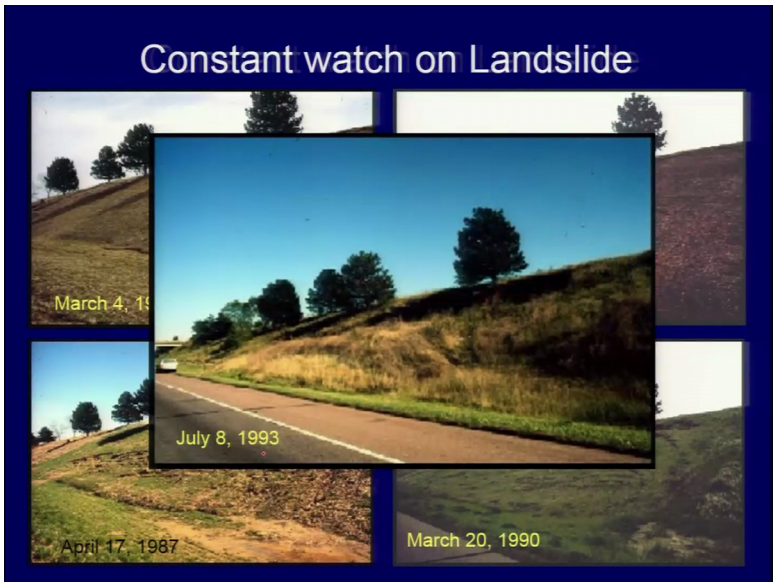

And then finally, it slide it down and this was in 93; so, the interval of almost 3 years.

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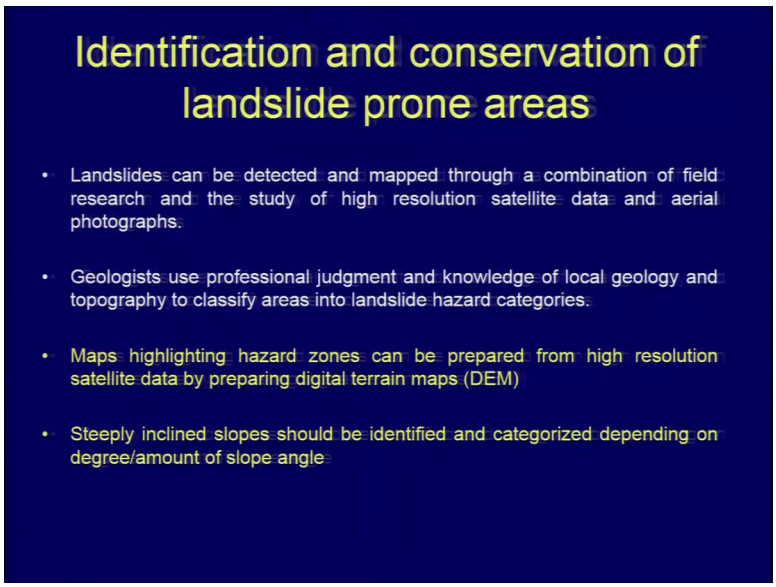

Identification conservation of landslide prone areas; landslides can be detected and mapped through the combination of field research and the study of high resolution satellite data or by using aerial photographs of that particular area. So, you will need to repeat the survey again and again. Geologists use professional judgments and knowledge of local geology topography. So, local geology as well as topography to classify the area into different landslide hazard categories.

Maps highlighting hazard zones can be prepared from high resolution satellite data through having or by having the digital terrain maps of or digital elevation map DEM's. So, you can easily work out the steepness or the incline slopes, which you can identify and depending on the degree of slope you can categorize the areas which will slip in future. So, these are few things which when one can do easily.

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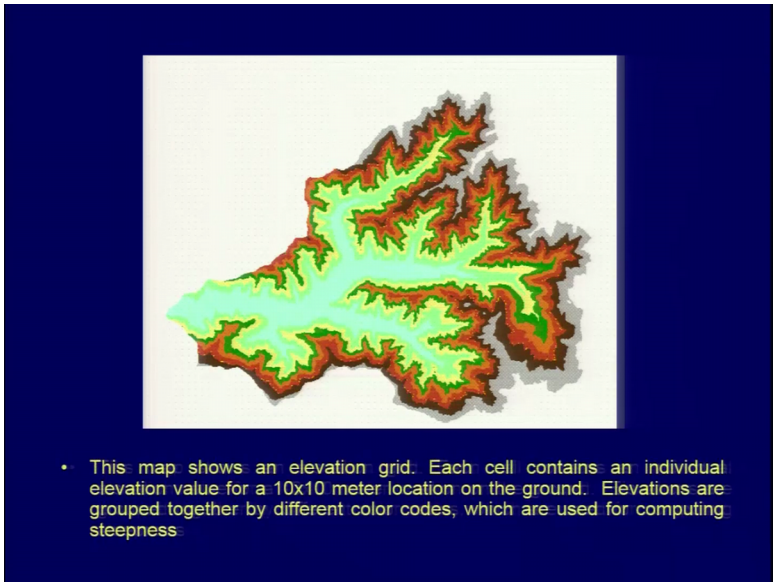

And prepare the digital elevation models. And even with the high resolution satellite data you can prepare 3D models, that is what we call 3D prospective views.

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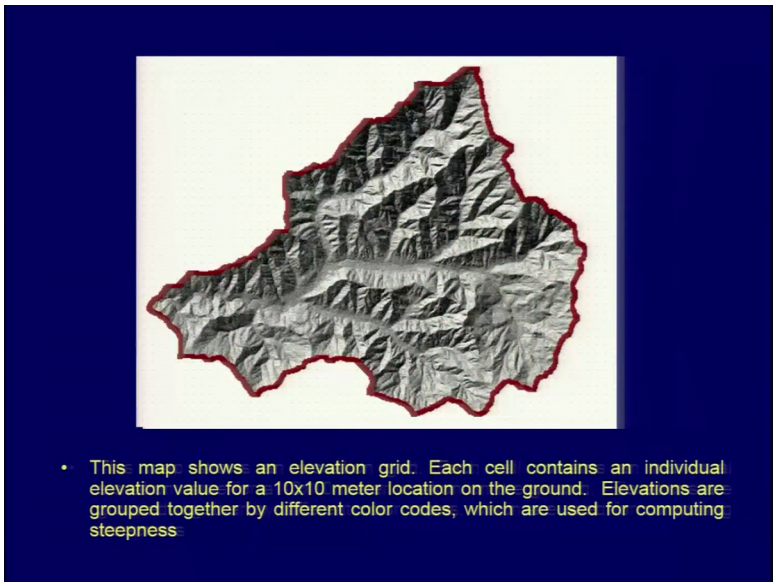

So, this is an in shaded relief map. And you have in GIS you can have understanding with the for the areas and all that you can identify the slopes. And based on those slopes you can also categorize that which area will be prone to landslide.

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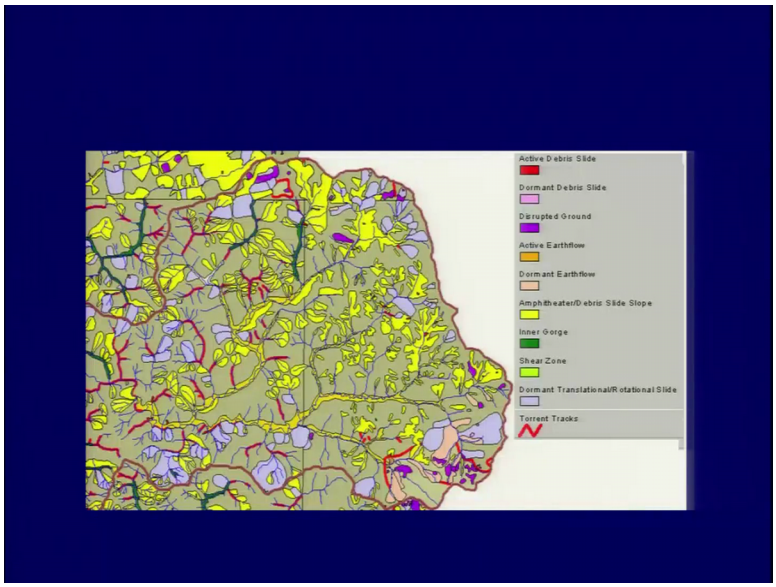

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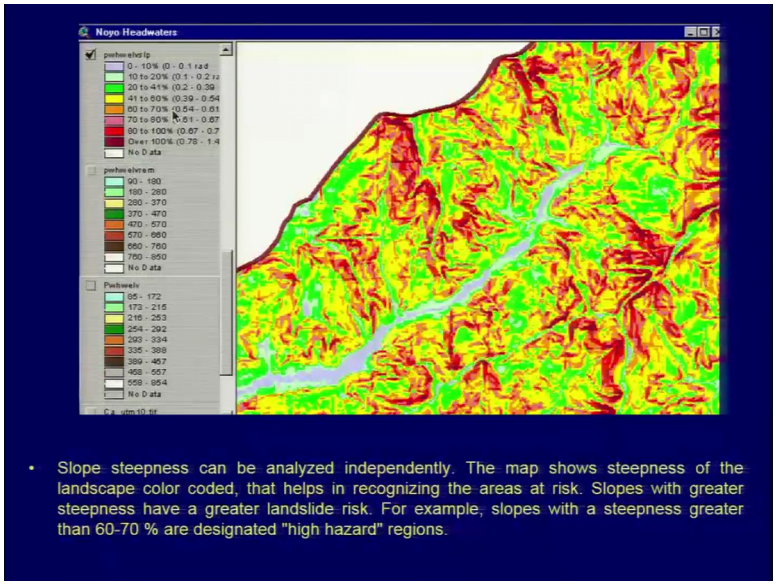

So, these are few maps which shows the classification of the slope. And, you can categorize that which areas will be moderately affected or which areas are under high hazard from the landslide.

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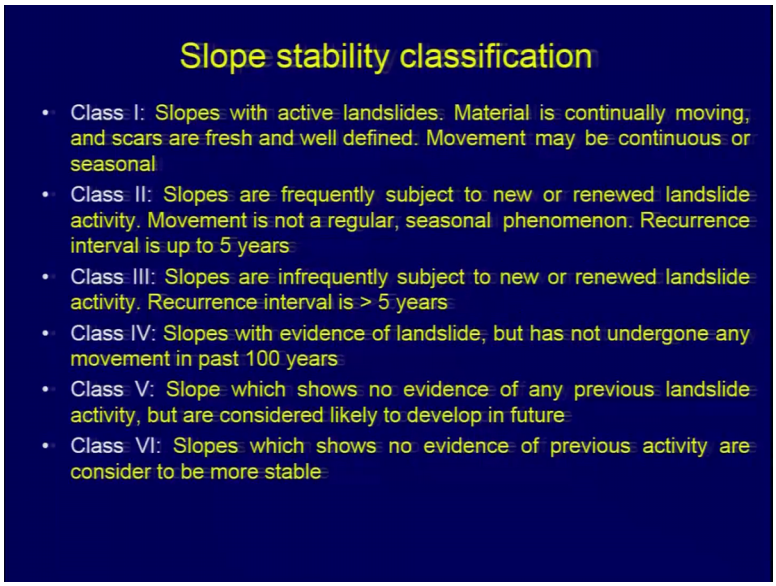

So, slope stability classification you can have your own, but in general if you take class one slopes with active landslide material is continuously moving. So, this you can classify as an class 1, and based on looking at the fresh scars which are well defined movement may be continuous or seasonal. So, you can classify this in class I class II slopes are frequently subjected to new or renewed landslides activity. Movement is not a regulars or seasonal phenomena recurrence is at the interval of from 5 years.

Slopes that is class III are infrequently subject to new or renewed landslide activities recurrence is greater than 5 years. Class IV slopes with evidence of landslide has not undergone any movement in past 100 years. So, this is more or less a safer site, but this of course, you cannot deny that this will not have the landslide. Class V slopes which shows no evidence of any previous landslide, but are considered likely to develop in future.

So, this here you will have to apply the knowledge of slope, the lithology and the geological structures. Class VI slopes which shows no evidence of previous activities of landslide are considered to be more stable. So, these are few classes, but as I told that you can have your own classes of talking about this day slope stability, classification. Nevertheless, you need to consider that any area which are having ideal conditions in terms of the slope in terms of the material may be subjected to landslide during an earthquake.

So, I will stop here and we will continue with the new topic in the next class on floods.

Thank you so much.