Geotechnical Engineering - II

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Lecture No. 45

Slope Stability-II

So, we have discussed a lot of things about slope stability, and I wanted to show you some peculiar scenarios where the failure of the slope has occurred. Look at this I mean if you just type on net, you will get so much of information about the type of failures. So, this was a highway project, there is a highway, multi-lane passing through the foothills.

And how it has been created? What we were discussing over here. There was a hillock and certain portion has been chopped off to create a highway infrastructure. There is another highway which you can see over here at the top and then this much soil mass has caved in, this is a beautiful example of landslide.

Now if you analyse this picture further, you will see that the material has flown out just like a slurry, it looks like, it is not slurry there could be enough water. So, water happens to be the driving force for taking the debris from this point up to covering almost the entire highway during the rains. Yes, it could be because of earthquake also, liquefaction.

Another thing you must have noticed that this soil mass or the rock mass or debris have come out and then there is a volumetric deformation depression. So, there is a detachment of the entire material along this slip surface. If you look into the 3D, you can realise that there is a scar formation and the whole mass has moved down.

Cleaning up operation is going on, the question is this much portion has caved in, this much portion has failed whether the rest of the slope is stable or not and how to rehabilitate the failed slope. Then these are the techniques which a geotechnical engineer would be practicing.

Now, if you want to see the slides these are some good pictures, these are deep seated. I will show you some more pictures so that you can understand how the failures are taking place.

This is a beautiful example of there is a hillock on the side left hand side on which you have a pavement or the road, and there is a river which is flowing from the toe of the hillock. So, this situation can be easily studied by this type of idealization. In this case for creating infrastructure, we remove the soil mass or the rock mass by blasting, by cutting.

Now hear what is happening in this case, the river which is flowing is responsible for cutting the toe of the hillock because of soil washing, erosion. So, the mechanism of cutting is different. In the first case it was human activity. In the second case, this is more of the natural process flooding takes place in the river and that water eats up the toe of the hillock.

By all means what is happening is when this much of the soil mass rock mass gets removed the failure takes place. These are the local failure, because of the rains, as we started discussing today's discussion, it may so happen that the water may percolate, and the entire thing may get washed out.

So, there are different types of slides which are shown over here. This is a subject which attracts a blog also by the way and you will find that there is a blog on these landslides. 15th March 2021 very recent one. So, whenever you get time, you please visit this blog also. It is a very hot topic people are trying to come out with the solutions.

But I hope you will realise the natural forces and the nature is much more powerful as compared to our knowledge of understanding the ambiguities associated with the natural structures, heterogeneities of the natural structures and then why do they fail, and why do they become susceptible. Normally, these types of situations occur because of the human interventions. It is very right thing you pointed out.

Suppose if I consider a situation where the hillock is this. So, this was the case when you had the cutting of the material, cutting at the toe, so cutting at the toe destabilizes. Another situation suppose, rather than cutting, I start building up something over here. Somebody wants to build a big villa or a multi-storey building, now what is going to happen?

You are loading the slope. So, when you are loading the slope, the state of stress inside the system becomes so critical that the material might fail. So, this becomes another mechanism

of failure. So, cutting which is equivalent to unloading, remember the stress paths? Unloading is $\Delta\sigma<0$, loading is the situation where you have $\Delta\sigma>0$, positive, both are detrimental.

Another situation could be because of the seepage, the seepage on the contrary, suppose rather than loading it, this is the loading process which makes system unstable. If I do excavation on the top let us say, what is going to happen? $\Delta\sigma_v$ is becoming negative, vertical loads, so what is going to happen to $\Delta\sigma_H$, they also get equilibrated under active conditions.

So that means, if I would have excavated it, let us say from the top. The loading on the slope or the hillock decreases the stability increases. So, thumb rule says if you want to stabilise a hillock, you should never cut it at the base, do excavation and remove the material from the top. Now this is what is known as removal or unloading.

Removal could be of rehabilitated structures also, there is a colony I mean you ask people to evacuate place. So, this is the removal, excavation, excavation should be again controlled. You cannot use blasting to remove the material from the top.

Now having done this much theory part of what causes instability in the slopes, we will have to bring in the mechanistic aspects. So, the mechanistic aspects are like this. What is the role of forces which are acting on the system? So, what are the forces which are acting on the system? So, we divide them in two categories, internal and external forces.

What are the internal forces? Pore-water pressure, leaching of salts, yes, it is possible why not? That means the loss in shear strength is because of internal seepage, and what seepage does? It basically increases the pore-water pressure. So, the moment pore-water pressure increases the effectiveness is going to decrease instability is going to occur, internal. External all type of forces, steepening of the slope, somebody might come and deposit the material on the edges, why not?

So, suppose if you overload it from here. Construct a building, this is supposed to be a building on the face of the hillock, it is in fashion, everybody wants to stay on the hillocks, hillside areas. So, you are loading the slope either at the top or on the sides, this is going to be detrimental on the slope surface. What else could be? Earthquakes, rains, vibrations (manmade).

So, in case of the internal forces, we were talking about the seepage, leaching of salts is the main problem. When leaching occurs, what happens? The bonding between the particles is going to get lost, so either the bonding becomes weak, or it becomes dissoluted, cementing material, remember in Geotechnical Engineering-I we were talking about the cementitious agents, which bound the particles together, that could be the situation.

So, bonds between the particles get broken because of the seepage, because of the leaching, salt migration and so on, it is a difficult thing to say.

Now let us go back to the because now, the whole discussion which we have done so far has to be given a sort of a mechanistic overview. So, the sliding is, this is the hillock, this portion of the rock mass becomes unstable, it starts sliding down, this is the slip surface. It becomes linear translational motion. You had a surface and there is a fault, is this, okay?

So, we talked about the translational motion and now I am going to talk about the circular slide or nonlinear translation. So, because of this fault and suppose if this is the layer I of the strata, what may happen? There could be a geological activity or manmade activity this side of the material I am loading, I am creating a dam over here, there are famous faults at several locations in the country where the infrastructure has been done, big dams have been done, all these things have been under debate, please check it on the net.

So, because of that movement, it may so happen there that the failure might occur like this and this surface which are looking like this might become like this. So, this is a circular slide. So, the whole description which we have done so far, now, I am bringing it to a situation from where the mechanistic models can be developed.

When we talk about the mechanics, these situations can easily be handled by considering two types of forces which cause instability. There also we are talking about two types of forces internal and external. Clear? So, these two are the same thing that means, from here I have to use the concept of 1 and 2 in such a manner that I can imbibe it on mechanics aspects of the slope stability.

How will we do that? External forces are the ones which are causing destabilization. So let us talk about the internal forces which stabilise the system. Number 2, the ones which are external,

external forces destabilize the system. What are the stabilizing forces, internal forces? Shear strength, because shear strength is the one which gets affected because of seepage, leaching of salts, truly speaking.

This has nothing but c and ϕ, which you have studied so far, shear strength parameters, they could be drained, they could be undrained, they could be effective, they could be total depending upon the drainage conditions and the structure life of the structure, correct you are right. And that the rate of shearing, quick failure or slow failure and all those things can be imbibed together over here.

So stabilizing forces are the ones which are mostly shear strength of the soil or the rock mass. They prevent against failure, the failure could be any one of them and when we are talking about the simple mechanics models, sliding, these mechanics concepts are not valid for flow, fall, and creep. What about the destabilizing forces? All these forces which are acting externally are the destabilizing forces.

Gravity yes, number 1. So, gravity is the destabilizing force, because the slide or the failure is taking place because of the gravity, weathering process, but weathering is a mechanism, it is not a force. Water yes, you are right, so water when it enters into the system creates pore-water pressure enhancement and what it does? it is again internal because the water goes sits inside the cracks applies the pressure on the system. So, you may say that the water after tension cracks have developed acts as an external force which activates failures.

So, what should be done with the water? Drain it out of the slopes, provide drainage systems, how to do that? You provide drainage, insert pipes, this is not the correct way to insert pipes, it should be the other way around. So, what we should be doing? So, this is not a correct thing what we should be doing? Water drains freely in the direction of gravity.

So, what you should be doing is, you can drill weep holes and install them so that if it is a freely draining material the pore water pressures will not build up, the seepage which has gone because of the rains can be collected and channelled out. The simplest possible method would be this is again a difficult method because when you install drains when you are drilling and putting weep poles you are destabilizing the soil mass or the hillock.

So, the best thing would be you do proper drainage control on the surface. So, suppose if I look at the top view of this hillock, this is how the top view looks like. So here I should provide proper drainage, channelized drainage, a network of drainage, correct? So this way the water will move only in the direction and then I can control it by collecting and then draining out of the slopes.

So, a proper network to channelize the rainwater has to be provided to stabilise the slopes, these are all techniques for stabilization true, alright? So now, what I will do is I will discuss may be the analysis of the slope instability from the next lecture onwards.