Geotechnical Engineering - II

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Slope Stability-I

So welcome to Geotechnical Engineering II and I am going to start now the last topic which I wish to cover in this course, that is Slope Stability. And it is a beautiful example of the shear strength theory of geo-materials, soils, rock mass a combination of both and this is a situation which I am sure many of you must have observed in your urban, suburban areas, hilly terrains, in the industrial premises.

Particularly where whatever has been stacked in the form of a slope, fails. The last one which I was talking about the industrial premises stacking of the material or the by-products become a manmade failure, but if you consider the initial situation which we have been talking about these are the natural slope failures. So, this topic is of great interest to the governments, to the public, to the people who are in administration. Everybody, every walk of life.

Because this situation affects people much more as compared to any other situation which we have discussed so far. You must have come across news items or the TV news where the news comes during rains, the entire hillock has collapsed, and certain Express Highway or highway has got blocked. It is a good example of how natural slopes fail and what happens because of the failure of the natural slopes.

So, this is what initiates the discussion on slope stability. Now I in person would rather like to discuss more about the instability rather than the stability. The philosophy is if something is stable I need not to be bothered about.

But as the situation which I described it so happens that because of the loss of the shear strength and because of the forces which are acting on the hillocks or the slopes in the form of external agencies, natural forces or man-made forces also sometimes. The combination of these 2 becomes so critical that the instability in the slopes occur.

So, these slopes could be either naturally occurring or this could be man-made also. Naturally occurring slopes are hillocks, this could be huge, or this could be small and man-made slopes would be as we were talking about the industrial by-products. The heaps, we call them as heaps or sometimes stacks.

So given a chance, I would like to study the stability of the slopes and instability of the man-made systems which are coming out of the industrial by-products. It could be generalized situations. Now when we talk about the natural slope instability, suppose there is a situation like this, this is the profile of the hillock and the environmental agencies are acting on this and environmental agencies are forces, let us say. Rains, high temperatures, vegetation yes, wind forces also, yes why not.

Now suppose the natural weathering is occurring of this hillock and this hillock could be made up of soils, rocks or a combination of both or a combination of these materials. So, because of the natural weathering, what happens is the system might crack, so the cracking gets initiated, we have talked about cracking quite a lot.

The crack formation is because of the tensile strain development in the soil mass and due to desiccation. When the system is drying up, the moisture is lost and the system may get dried up resulting in cracks, it could be because of mechanical weathering also, it could be because of a situation that suppose there is a tree on the top of the hillock and the roots keep on spreading deep inside.

Roots apply enough pressure to form the cracks in the system. You must have noticed. Particularly when the rock mass is jointed. So subsequently when the rains come what happens this rainwater seeps into. So, suppose if I depict these environmental forces as particularly precipitation or the rains. So, the rainwater seeps into the system and now what is going to do?

Is going to trigger the failure of the hillock, why? Because this water in the cracks acts as a pore-water pressure. It applies pressure on the system. Now the stage is set for this hillock to fail. Now what is failure? The failure is movement of the mass. If the hillock is made up of soil or natural by-products, sorry man-made by-products. The mass would be of the by-products or the soils, or the rocks and so on.

Yes, it could be grains also. I might be having a heap of grains and beyond the angle of repose if I try to stabilise the slope the whole thing may fail, yes you are right, so that analysis can also be done over here. So, what is the tendency of the system because of this type of formations? There is a tendency that certain portion of this block has a tendency to get detached.

So, this soil mass or this rock mass has a tendency to get detached. Why? Because of the formation of the crack, water goes inside, earthquake comes, and this surface happens to be the weakest plane, weakest shear plane. How might this thing happen? In this slope the chances are that there could be a layer of clay, we call it as a clay seam.

So just now we have been talking about percolation of water and this percolation of water touches this clay seam, clay seam gets saturated, and the moment saturation occurs of clays, the shear strength tends to 0. So, what is going to happen? You have created a slip plane, remember until now we have been defining it as $45+\phi/2$, $45-\phi/2$ depending upon the active and passive situations.

But now here, the failure is going to get triggered along the clay seam, which happens to be the weakest shear plane because of percolation of water and loss of shear strength. Under these circumstances what is going to happen? This block starts sliding, so the first mechanism of movement of the mass is sliding. Now sliding I am sure you must be aware, that will happen when a block is moving along the slip surface.

The parent material becomes the contact surface on which the destabilized or detached block has a tendency to move, clear.

So, I have introduced 2 more words, this is the destabilized block I said. Now block is nothing but a rigid body and this is the parent surface or parent mass. So, there is a detachment with respect to the parent material, the tendency of the system is to slide on a plane. So plane is very important here, we will be talking about this later on and the movement occurs, it could be linear, it could be circular, it could be a log-spiral surface, we have talked about all these things, you remember.

We have talked about the log spiral surface when they the effect of friction of the wall which we considered. So, we drew concave and convex slip surfaces passing through the toe of the wall. So, the sliding could be on a plane, which could be a straight line, planar failures, it could be a circular failure, it could be a combination of the 2, forming it a log spiral let us say.

Now what will what is going to happen, this situation can easily be depicted as, there is a block which is sliding along a surface, which is inclined at an angle of α. Now you can use the concept of mechanics and you can do the analysis. The condition is that the block remains intact because this is a rigid body, but there is a detachment along the surface, and this is the parent body.

As this movement occurs, the chances are that this material or this block might get crumbled, is a bulk, so bulk is not going to follow only sliding, is it not? So, the chances are that this whole block may get pulverized in small, small pieces or even bigger pieces, and the entire thing may start flowing.

You must have seen in movies or sometimes in YouTube videos, when the slope failures occur, the chances are that the slide may take place first followed by disintegration of the rigid body and we call it also as a disaggregated material and then this has a tendency to flow. So, the second mechanism of the movement of the mass is flow. Fine?

And you may say that the sliding causes flow to occur. The third condition would be, what is that we call it as fall. Very steep slopes, so there might be a very steep slope, say or a cliff. Now this is the natural cliff, the weathering of the rock mass occurs, detachment and this block has a tendency to fall, it detaches and falls because of the gravity, gravity motion free fall.

Depending upon the contour of the slope or the rock mass or the hillock it might come and hit over here. Again depending upon the contours, it might slide or if suppose, there is another border line over here, what is going to happen this will come and hit it this it gets fragmented and all these small, small particles they form a consortium of the material which has a tendency to flow.

So, in other words, when the movement of the mass takes place, this could follow sliding, flow and fall. Mostly, we talk about the rock falls. Beautiful example is Mumbai Khandala highway.

So, every rainy season you hear about in newspapers, that the rock fall has occurred and it has got accumulated the debris, we call them as debris.

So, debris are nothing but a consortium of the materials which used to be a part of the hillock and after movement of the mass they have become discrete. Yes, management of debris is a big question. Management is a big issue, you are right. Another problem is how to clean up the site after the failure has occurred, cleaning up of the site, of the affected area, yes, so that I can open the traffic to public.

So, cleaning up of the affected area so that I can open the traffic flow. So, most of the disasters occur because of these debris. And suppose there is a rehabilitation somewhere at the foothills of this rock mass, what might happen?

This type of situation may occur and the entire village or the hutments or the rehabilitated area may get buried inside the moved debris. That also happens and you might have heard in newspapers. I am sure you must have come across.

See, the fourth variety of the fourth mechanism of movement of the mass is what is known as creep, extremely slow movement of the hillock or the material or the mass of the slope. Creep is extremely slow movement of the material, sliding, flow, and fall could be instantaneous. The impacts are going to be much more in terms of the loss of property and the life could be because of sliding, flow and fall.

So, what I have tried to demonstrate to you is that the mechanism of movement of the mass which is getting detached from the parent body could be because of sliding, flow, fall, and creep, when creep occurs the tension cracks develop. So, suppose if I have a slope and I will observe that suppose there was an electricity pole somewhere here or there was a cottage or there was some facility.

Now what is that you are going to observe is that this whole system is sliding down very slowly and hence the tension cracks might develop over here. So sliding is something where the moving material remains largely in contact with the parent or underlying rocks. Yes, during the movement, which takes place along a discrete boundary shear surface.

So, if you want to define this sliding is the moving material remains in contact with the parent or underlying rocks, during the movement which takes place along a discrete boundary that means, there has to be a boundary or a shear surface.

Now when you talk about the flow, it is because of the internal deformation of the material. So how do you define this? So, this is because of the internal deformation, this is translational, so this could be translational linear or circular or non-linear also. Different situation might occur. So, when we talk about the flow internal deformation what it does?

When the material becomes this aggregated and can move without the concentration of displacements at the boundary shear. Yes, there could be a situation that the flow could also be along the contact surface. So, when I was talking about the flow phenomena here, this is the direction of the flow, all these particles or this mass has become disaggregated, still the flow is taking place along the surface. Is this part clear.

The third one is the fall as I just defined it takes place from the steep phases in the soils and the rock mass and it involves immediate separation, immediate separation of the falling material from the parent material, yes. And then creep is something which is happening very slow, very-very slowly and there is this very slow movement of the soil mass. But mostly, faults happen in extremely steep slopes.

I will show you one example of, if you type on net- slope stability or slow failure you will get several pictures. So, if you just type it on net, you will find this is a topic which has been a very critical issue which geotechnical engineers are facing in every civilized society. The main reason is in the name of civilization we create infrastructure, infrastructure could be roads.

So, suppose there is a mountain, this is the natural hillock and suppose, I want to create a facility as he said, I want to create a road here. The road alignment is like this that this passes through the hillock or say tunnelling whatever. I have to remove this soil mass. Now in the process of cutting this what I have done? I have removed the passive earth pressure which this block was providing to the entire rock mass.

So, the moment you have removed this, what is going to happen? The system is becoming vulnerable to this whole system becomes vulnerable to failure, why? Because the active earth

pressure which is acting on the system is going to destabilize it. So, what do I need to do? Club it with whatever we have discussed until now in earth pressure theory, what should I be doing? Yes.

So, create a retention system over here. Yes, you are right. So, create a retention system over here, now this becomes my retention system. It could be a retaining wall, gravity retaining wall, it could also be a gabion wall. Check on internet what is the meaning of the word gabion wall or sometimes when you are passing through the hilly terrains you will find that they take steel cages made up of steel wires.

And then there is a flap here and then they place stones, big boulders, they pack them, these are manually packed. So, each unit is about 1 m^3 and then cover the flap on the top of this, so this becomes one unit. I can place it over here and similar units can be placed one over the other properly designed and interlink with each other, fine?

If the situation permits me, you can have a sheet pile wall also but be careful you have to check the material whether the sheet piling can be done or not. Yes, and remember, when you are doing sheet piling and when you are tamping the sheet piles, the chances are that you are creating so many vibrations that yes that because of the induced vibrations, the soil mass or the rock mass may become unstable.

But now we are able to integrate all the concepts which I have discussed in the class so far. Very nice. So, in the hilly terrains you must be seeing gravity retaining walls are done, gabion walls are done, RCC walls are also done. Though I am against doing RCC walls because whenever you have a system which is becoming or which is prone to become unstable, because of mobilization of active earth pressures, rigid structure should not be used, these structures are going to collapse in the due course of time, why?

Because of settlements, because they are rigid. So, suppose the soil mass rock mass settles, there is a creep which is taking place, the slope is moving laterally sinking might occur who knows, the material might be sinking subsidence earth forces. So, whenever you have a rigid system, it is ultimately going to settle, collapse, crack and fail. It is better to use flexible systems like gabions, so this becomes a flexible system.

The concepts remain same, you have to just find out what is the weight of this block and how much passive earth pressure I can induce to stabilize the hillock. Well, these are the remediation you are talking about. For that mechanics is involved, for that you have to do a mechanistic model to analyse what should be the cross section of the retention system so that this hillock is not vulnerable to fit.

Sometimes what we may do, we may go for piling also. That means, if you have the foundations of the retaining wall and if I think that the bearing is not much, what I may do. I may rest this structure on the piles, so this becomes a piled structure. It depends like when you know the concepts, you can apply them in solving a problem and giving the solution.