ENVIRONMENTAL GEOSCIENCES

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Lecture-17

Geological Hazards - Landslides

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are continuing the module three in which we have already discussed four lectures. That is the lecture one related to the dip, strike, folds and faults, its environmental interpretation. Lecture two, Geological Hazards- Earthquake. Lecture three, Geological Hazards-Volcanoes.

Lecture four, Geological Hazards- Floods. And today we will discuss the lecture five that is Geological Hazards Landslides. In this lecture, the important concepts will be covered like introduction to landslide, causes of landslide, types of landslides, impact of landslides and prevention of landslides. Now let us understand the term landslide. In many regions of the world, a temporary instability of superficial rock masses-consolidated or unconsolidated, has always been an acute problem.

These superficial masses leave their original positions abruptly or extremely slowly and start either a downgrade flow or movement or a vertically downward sinking giving rise to baffling situations, especially when they happen to occur in regions of any importance, that is, along the highways, railway lines, valleys, reservoirs, or under heavy structures. Such movements of the superficial masses which may be slow or rapid, minor or major and may involve consolidated or unconsolidated rocks loose material and may take place in any manner in any direction are popularly grouped as or called as landslides. So where a mass of earth or rock slide down the slope along a definite zone or the surface, the movement is typically called as landslide. This movement takes place under gravity and is facilitated by moisture which acts as a lubricant agent.

The landslide starts with slow movements along a slip surface followed by a more rapid movement of the separated portion of the earth mass. Now, causes of landslides. Many factors are known to cooperate in causing a mass of material to slide or flow. Some of them play a direct role and are easily understood, whereas others are indirectly responsible for the instability of the land masses. All such factors that facilitate landsliding in one way or another are generally grouped into two categories.

The first factor is the internal factors and the second factor is the external factors. So now we will understand the internal factors. Generally these internal factors include the nature of slope, water content, composition of the mass and geological structures. Now first is the nature of slope. Some slopes are very stable even when very steep whereas others are inherently stable even at very gentle angles.

But a great majority of failures are confined to slopes only indicating that slopes are directly responsible for mass failure. The same mass under exactly similar conditions would not fail if it happens to form a flat land. Every mass of material is acted upon by two sets of forces. First is the force of gravity and the second is the frictional force. The former tends to pull the body downwards whereas the latter opposes any such tendency.

The gravitational pull on the materials of a slope results in the development of internal stresses within the mass, which would be of not much significance if the mass has a high shearing strength. But as and when these internal stresses become more strong enough to overcome the frictional forces, they create shear surfaces within the mass along which it starts failing. When left to gravity forces alone, most unconsolidated materials have frictional forces sufficient enough to enable them remain stable up to the angles of 35°. Above this slope angle, gravity forces gets an upper hand. Similarly, consolidated, massive, unjointed and crystalline rocks would stand easily even in vertical cliffs.

As such, when failures are observed in these two types of materials at slope angles far less than these, it could be at once concluded that the gravity forces have been greatly assisted by some other factors in overcoming the frictional forces of the mass. Natural situations which offer such conditions for combination and cooperation of gravity forces with other factors in reducing the frictional forces of masses are numerous and varied. Next is the water content. Much importance is attached to the role of water in causing mass movements. It may act in a number of ways to reduce the shearing strength of the rock or soil mass.

Even mere presence of water in the pore spaces of rock has been found to effect all the strength properties adversely. When water within the mass is also capable of flow around the grains as it opens the situation along slopes, it exerts an additional force on the grains tending to displace them along the direction of water movement. Similarly when water happens to move along a plane of weakness within the mass, that plane gets lubricated and may turn into an effective plane of shear failure. In sliding type of failure, this lubricating action is of great importance. Land masses apparently quite stable during dry period start moving down slope during or immediately after rains along known surfaces of weakness.

A still different way in which water may weaken the rock and soil mass is through its repeated change of state with climatic changes. Water freezing within the pores of the mass expands and exerts considerable pressure, thawing of ice crystals so formed saturates the grains with water produced by frost action. These processes may be repeated for a number of years in cold humid regions, resulting in making the formerly stable slopes of massive nature into the unstable slopes of incoherent nature. Flowage, whether slow or rapid ,invariably involves presence of water. Rock masses rich in clay particles are especially prone to failure by water action.

Water seeping into the pores acts in double manner. First, it exerts pore pressure and second, it causes dispersal of clay particles by getting attached to their surfaces or is even absorbed by them. In either case, the original consolidation or packing is disturbed and the shear strength of the mass is reduced. Solvent action of water may remove rock masses like those of limestones etc. from critical zones or portions, again reducing the shearing strength of the mass. The next is the composition of the mass.

Some materials are stable in a given set of conditions of slope and water content whereas others may be practically unstable under those very conditions. This clearly suggests that composition plays an important part in defining the stability of the masses. Sandstone, for example, exhibit a great variation in their chemical composition. Siliceous sandstone would be highly stable even during intensive rains and at steep slopes, whereas clayey or calcareous sandstones may suffer repeated failures under same conditions. Presence of few known weak minerals in a rock mass endangers its stability of such minerals like clays, glauconite, gypsum, mica, calcite and rock salt may be easily mentioned.

These minerals are either taken in solution, producing open spaces within the mass or they form weak slippery bases on coming in contact with water. Along with composition, they play an important part. It indicates the degree and manner of packing of texture of rocks, that is, grain or crystals. As such, it controls the porosity and permeability of the mass, which are very important factors influencing the percolation of water through the mass. Therefore, compact and impervious rocks are more stable than porous and permeable masses of same composition under similar conditions.

Next is the geological structures. Of all the geological structures, the inclination of the strata, presence and disposition of shear and fault zones and joints and other planes of weakness are important in defining their stability. Dip factor is of great importance in situations where the rocks are of different mineralogical composition and textural types. In such cases, beds dipping towards the free face of the valley are most likely to fail, especially when assisted by other conditions. The steeper the dip, the poorer is the stability of such a mass.

The condition becomes highly critical when the strata comprises one or more thick or thin layers of clay amongst the sequence. Such clay seams get easily lubricated by water and facilitate sliding. Joints and shear zones and other such planes of weakness as schistocity, foliation, cleavage and fractures of miscellaneous origins all contribute to the instability of the rock masses perched on slopes. Their effectiveness in promoting failure is a function of their spacing and attitude. A rock mass showing any one or more of these structural features may not be unstable at all unless the spacing of that particular structure is too close, and or they are critically inclined that is towards the free side of the valley.

All of these features reduce the shearing strength of the mass on the one hand and provide for ready surfaces for sliding of failure especially after lubrication on the other hand. Now external factors. So among them are included vibrations of diverse origins. A mass may be stable but critically that is the gravitational force have not yet overcome the frictional resistance. A slight vibration or jerk to the mass would greatly add up against the frictional resistance and mass would become unstable.

Repeated vibrations as due to the heavy traffic on hill roads may be a greatly contributing factor towards causing the failure of delicately balanced masses. Vibrations due to the natural causes such as earthquakes often initiate mass failure that may continue much after the quake. Another important external factor often overlooked is the removal of the support at the foot of the slope as during excavation for road widening. The slope which might have been previously stable becomes hazardous after such an excavation. A similar cause for slope failure is loading a critical region of slope from above.

It is also a common exercise during highway construction in hilly regions. A part of the slope may have to be loaded for the construction of a road embankment. Removal of vegetable cover, especially trees from slopes, is a third external factor which have contributed in a large number of cases towards the slope failure. So the two figures are here. Showing the loading may induce slope failure along arrows and excavation may induce slope failure along arrows.

Now the types of landslides. So we have seen the effects. Then type of landslide. The major type of landslides are slump, rock slides and rock falls. Slump.

In a nearly homogeneous cohesive material such as clays and some soils, a slope fails primarily by shear and the slip surface is approximately cylindrical or spoon-shaped. The movement of the mass starts by cracking along a shearing surface and then the separated mass slides down rapidly. Such a slide is called a slump or shear slide. Slump is often accompanied by bulges at the toe. Rock slide is the next. When detached blocks of the bedrock move down the hill, it is called a rock slide.

In a rock slide, the movement takes place on the bedding planes, joints or any other planes of weakness in the country rocks. Next is the rock falls. From steep rock slopes, blocks of rock of varying sizes, which are loosened by weathering, suddenly fall downward under the influence of gravity. This phenomenon is called as rockfall. The rockfalls supply tailors, which are commonly found at the foot of cliffs in the higher mountain regions.

impact of landslides. First one is the environmental impact. Loss of vegetation. Landslides strip away top soil and vegetation leading to deforestation and habitat destruction. Second impact is the soil erosion. Large amount of soil and debris are displaced causing long-term soil degradation Altered landforms, landslides reshape landscapes, forming new terrains such as scarps, debris fields or blocked valleys. And the fourth is the water pollution. Sediment from landslides often contaminates rivers and lakes, affecting aquatic ecosystems. Second impact is economic impacts.

Property damage. Landslides destroy homes, infrastructure and farmland, leading to higher repair and rebuilding costs. Disruption of services. Damage to roads, bridges, and utilities disrupts transportation and essential services. Economic losses, communities reliant on agriculture, tourism, or mining may face severe economical setbacks. Social impacts- loss of lives. Landslide can cause fatalities, particularly in densely populated or poorly planned areas. Displacement of communities is the next point.

People living in affected areas may lose their homes and livelihoods, forcing relocation. Psychological stress. Survivors often experience trauma and anxiety due to loss of property, loved ones and security. Infrastructure impacts. Transportation disruption.

Landslide can block roads, railways and airports, halting movement and trade. Utility damage. Power lines, water lines, and communication networks are often damaged, affecting daily life and recovery efforts. Secondary hazards, flooding. Landslides can block rivers, creating temporary dams that may lead to catastrophic floods if breached.

Increased erosion, subsequent rains may exaggerate soil erosion in the landslide-prone areas. Now, the prevention of landslides. So it is always useful to compile a history of the slides in any given region as this will be of much assistance in understanding more perfectly the cause of the failure. Moreover, this will help in devising more effective measures for combating landslides. Many methods for controlling the slides are available and choice of any method will depend on factors like nature of slide, the underlying cause for it and the nature and amount of material involved and the economic considerations.

Among such methods, the most important are providing adequate drainage, constructing retaining walls and stabilizing the slopes. The first factor is the drainage. It involves the removal of moisture from within the rocks as well as preventing any further moisture to approach the material susceptible to sliding. This may be achieved either by surface drainage or by subsurface drainage or by both methods. Construction of interception ditches, waterways, trenches and drainage channels may become necessary.

Grouting the joints and other fractures may also prove helpful. Second is the retaining structures. All such devices like construction of retaining walls etc. are aimed at stopping the moving mass by force and their success is always doubtful. Construction of successful retaining walls requires an accurate assessment of the force which the wall has to withstand. Retaining walls may prove exceptionally successful where the ground is neither too fine nor to plastic.

The sliding mass is likely to remain dry and the movement is of a shallow nature. Retaining walls may prove a failure when they are designed to stop slides of great thickness or for long rising slopes. In addition to the construction of retaining walls and providing adequate drainage, oiling of the surface of sliding material has been adopted in some cases, its usefulness lies in reducing the absorption of the rain by sliding material. The next is the slope treatment. When the material involved is soil and situation is a slope, the failure is attributed to a loss of stability due to any of those causes discussed earlier.

In such cases, the treatment involves stability computations for the particular types of soil and slope, and if such computations indicate that a given slope of the soil will not be stable, then the solution lies in either flattening the slope or decreasing the load or increasing the shearing resistance of the soil by decreasing its water content with the help of drains and evaporation methods or by obtaining additional shearing resistance by the use of piles. So just concluding the lectures what we have discussed in this landslides First, we have discussed the introduction that is landslides involve the sudden or gradual movement of superficial rock masses under the influence of gravity, often exacerbated by moisture acting as a lubricant. They can occur along slopes in various forms, causing significant disruption, particularly in critical areas like highways, railways and reservoirs.

Then we have discussed the causes of landslides. Internal factors include slope, nature, water content, mass composition, and geological structures which influence stability and shear strength. External factors such as vibrations, removal of slopes, support, and overloading contribute to the mass in a stability and trigger landslides. Next, we have discussed about the type of landslides. The three types we have discussed, slump, rock slide and rock fall.

And in slump, shearing movement is in cohesive materials like clay forming a spoon-shaped slip surface. Rock slide and rock fall, rock blocks move along planes of weakness or fall due to the weathering creating talus at cliff's base. And the impact and prevention of landslides are also discussed. Impact, environmental and economical and social impact we have seen in the lecture, loss of vegetation, soil erosion, altered landforms and water pollution were discussed in the environmental impact whereas infrastructure damage, community displacement, economic losses and psychological stress have been discussed in the economic and social impacts. Prevention methods including drainage system to reduce moisture, retaining structures for stability, and slope treatment techniques to address the underlying causes. Effective prediction involves historical data analysis and implementing region-specific preventing measures. Conclusion of the Module 3 is understanding the geological features, such as deep strike folds and faults is essential for interpreting the Earth's structural behavior and its environmental impacts.

These features often influence the occurrence of geological hazards like earthquakes, volcanoes, floods, and landslides. Such hazards can have devastating effects on the ecosystem, infrastructure, and human lives. Effective mitigation and preparedness rely on geological studies that link structural features to hazard risks. By integrating the geological knowledge with environmental management, we can reduce the impact of these natural events and promote sustainable development in hazard-prone areas, ensuring resilience and safety for the communities and ecosystems. These are the references from where I have taken the lectures of the Module 3 from P.K. Mukherjee, Testbook of Geology,

Mahapatra, Geology of India, then Earle, S., Physical Geology, Bangar, K.M, Principle of Engineering Geology, Singh Parbin, Textbook of Engineering and General Geology, Donald R. Coates, Environmental Geology, and Carla W Montgomery, the Environmental Geology. Thank you very much to all.