Landslides

The down slope movement of large volumes of surface materials under gravitational influences represents an important type of environmental hazard. Depending on the nature, these movements tend to be grouped generally into landslides, debris flow, rock fall or avalanches. Mass movements may be physically triggered either by seismic activity or atmospheric events.

The factors that trigger landslides are : (i) heavy and prolonged rainfall (ii) cutting and deep excavation on slopes for building, roads, canals and mining, without appropriate disposal of debris; and (iii) earthquake stock and tremor's on every slope height, slope-inclination and unit weight of slope forming material shearing stresses are also added.

Landslides, leading to disaster, are common natural occurrences in India and other parts of the world. In India, landslides are a regular feature in the Himalayas. In the eastern Himalayas, the number of such incidents per year is quite higher than in western parts but astonishingly involve fewer casualties. On the other hand, western Himalayas are the host of devastating landslides and their consequences are more tragic. Both these portions of Himalayas are considered as the landslide prone areas of the country.

Mechanism of landslides

Occurrence of landslides includes a number of mechanisms, which are again affected by a number of factors. The major factors responsible for causing landslides are listed below :

(A) Natural Factors

1. **Resistance and sheer stress.** The resistance and the shear stress land to disturb the slope material. Landslides are down slope movement of rock and soil along slip surface. They are always associated with disturbance of equilibrium relationship, which exists between stress and strength in material resting on slope. The relationship between stress and strength is

determined by factor such as height and steepness of the slope and density strength cohesion and friction of the materials and the slope. Hill slope instability occurs when the strength of the material comprising the slope is exceeded by down slope stress. The shear strength of the material is the maximum resistance to shear stress and depends on :

(*a*) Internal Cohesion, (*b*) Internal Friction.

2. **Variation in weight.** Change in the weight imposed on a slope (loading) result from both natural and human agencies and may alter the degree of stability depending on pre-existing slope conditions. Natural process producing a variation in weight include :
   - (*i*) Runoff pounding, precipitation, evapotranspiration and drainage.
   - (*ii*) Deposition and erosion by mass movement.
   - (*iii*) Deposition and erosion from other geographic processes.
   - (*iv*) Over trust faulting.
   - (*v*) Extrusion of volcanic material.
   - (*vi*) Vegetation growth and vegetation destruction.
   - (*vii*) Seepage drag from percolating water.
   - (*viii*) Variation in atmospheric pressure.

   Human factors responsible for variation of weight include :
   - (*i*) A forestation and deforestation.
   - (*ii*) Storage and conveyance of water is another fluid.
   - (*iii*) Leakage of water and fluids from storage and conveyance methods.
   - (*iv*) Industrial activity
   - (*v*) Machinery (mobile and static).
   - (*vi*) Land developments, road construction
   - (*vii*) Erection of buildings and other structures.
3. **Increase in slope height.** In response to fluvial down cutting slope height occurs most commonly. As increased height may result in increased weight over a potential share plane, is influence of weight on stability. Thus with a constant shear plane angle increase in height may cause failure in a cohesive slope but not in a cohesion less slope.

   The process which creates slope relief invariably involve the removal of material from the slope face and thus a reduction in lateral support for slope face, which sets up a zone of negative earth pressure of tension extending for some distance into the slope. At the limit of the zone of tension a vertical crack may appear because of the leading cause of landslides.
4. **Lateral support and slope angle.** Material, which is in contact with the slope or is part of the slope and offers more resistance than shear, constitutes lateral support. Generally lateral support is generated by slope material at the top or base of the slope or in some instances by water and ice bodies or artificial support consequently by removal of lateral support in the natural setting which occurs most commonly as a result of slope.
5. **Removal of underlying support.** The processes responsible for removal of underlying support include :
   - (*i*) Surface action by localized weathering and erosion agents.
   - (*ii*) Preferential surface erosion or weathering as a result of differences in readability.
   - (*iii*) Localized or diffuse subterranean removal of material by mechanical eluviations and selection.

6. **Joint Process.** There are number of active factors like root wedging, cleft water pressure, ice wedging, water wedging, clay swelling, etc., operating primarily within joints and other void spaces. These actions are therefore referred to as joint processes.
7. Seism city and other vibrations.
8. Changes in water content.

(B) Human Factors

The human induced factors responsible for origin of landslides may be listed as below :

(*i*) **Slope cutting for constructions.** Excavations for road construction in geologically sensitive belts have been triggering massive landslides. The blasting for a hill road with its associated disruption is inevitably a major destabilizing influence.

(*ii*) **Deforestation.** The people are entirely dependent on forests for their basic needs of fuel and construction of houses.

In the deforested area the soil receives all rainfall produced by rainstorm. The raindrops reach the ground with full intensity and smash the tiny soil particles. As a result soil surface becomes hard and compacted as its pores are clogged with fine particles produced due to splash.

In water does not infiltrate and runs down the slope as surface runoff causing floods and landslides.

Controlling Landslides

Once a landslide starts, nothing can be done to stop it. But means are available for assessing the risks of a landslide in a particular area. In advanced countries like France, Canada, Switzerland etc., there are government departments to give advance warnings. Again in the slide-prone areas, roads are protected with thick and durable concrete tunnels; fragile mountain slide are bound by steel railings to prevent sliding. Such facilities are not accessible in our country. But some steps, which can only check incidents of landslides, are as follows :

1. Prepare zonal maps and danger ratings of slide-prone areas of Himalayas. Once such information is available, these areas can be avoided for habitation, road making and other purposes, which in turn can prevent fatalities.
2. Indiscriminate deforestation and uncontrolled terracing on the hill slopes must be stopped.
3. Various afforestation programmes at regular intervals are also to be taken up on the hills as plants bind the soil more effectively than any other physical or chemical cohesive agents.
4. As stagnant water is a possible cause of landslide, there should be sufficient provisions to channel rainwater down the slope into the nearest river below.
5. It would never be suggested that construction of roads and dams in the Himalayas should be stopped as they are responsible for landslides. What is required is to develop better technologies and better monitoring systems to assess the risks before such operations are undertaken.
6. Overall awareness among people must be developed as they can recognize the early indications such as crevices on the rocks, rock falls or subsidence in the ground, which usually occurs just prior to a massive slide.

Various governmental organizations such as Central Road Research Institute (New Delhi), Border Roads Organization, National Geophysical Research Institute (Hyderabad), etc. are always working against landslides by conducting various research and developmental

programmes, case, studies and routine works to develop new preventive measures of zoning, danger rating, and early warning and real time detection as well as suppression of such hazards. In this context, scientists of Central Road Research Institute (CRRI) have developed certain control techniques and preventive measures to avert landslides in the hilly regions of our country.

7. The sustained movement of slide-debris prevents plant's rooting on the bare slopes. To overcome this difficulty, CRRI has suggested use of asphalt mulch technique. Here, at first certain local plants are planted on the subjected slope in rows. Then an asphalt mulch is sprayed over the slope, which in turn promotes the growth of plants by retaining the roots at their places. After a certain period the asphalt mulch is replaced by agreed vegetation.
8. In some cases jute or coir netting is used instead of asphalt mulch. The net restricts the flow of water thus reducing the probability of soil erosion.
9. By introducing horizontal drilling technique, the drainage of water deep inside the mountain slopes has successfully been performed.
10. Besides, there are several techniques like stone columns and line slurry injection; jute, geotexitiles and other synthetic media which give the strength and load bearing capacity of hilly terrain to avoid subsidence, slide and other disorders.

Our green planet is full of various natural calamities like drought, earthquake, flood, forest fire, volcanic eruption or others and landslide is just another disaster that cannot be avoided. Landslide is not the end of the world. It is a natural calamity.

Besides the above measures following long-term measures are proposed

(*i*) Unloading of loose mass at the crown is to be done in suitable slopes and in accordance with the findings of the stability analysis.
(*ii*) There is a break in slope at intermediate level, i.e., where a retaining structure has to be constructed for augmenting.
(*iii*) Protection of surface by way of soil, reinforcement measures such as geo-grid, etc.
(*iv*) Possibility of deep anchors with the toe for taking advantage of passive pressures.
(*v*) Injection of thick cement grout or clay at selected areas.
(*vi*) Evolution of effective drainage system.

Besides the above measures, considering the mountains sensibility following steps can be taken

(*i*) During road construction rocks should not be cut down straight.
(*ii*) According to slope condition measurement environmental planning should be adopted.
(*iii*) New settlement should be constructed according to norms.
(*iv*) Explosive should not be used excessively.
(*v*) Trees of broad leaves and soil containing roots should be planted.