ENVIRONMENTAL IMPACT OF LANDSLIDES

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Abstract

The stability of slopes and embankments under static and seismic loads has been the subject of study for many researchers. Landslides can be triggered by natural physical processes such as heavy or prolonged rainfall, earthquakes, volcanic eruptions, rapid snow melt, slope undercutting by rivers or sea waves and permafrost thawing. They can also be triggered by man-made activities or by any combination of natural and/or man-induced processes. Landslides are generally induced when the shear stress on the slope material exceeds the material's shear strength. This paper presents the mechanisms and causes of landslides as well as the forms of failure of slopes and embankments under static and seismic loading, with examples of failures from both Greek and international experience. There is also mention to measures to protect and stabilize landslides, categories of slope stability analysis, and methods of seismic displacement analysis. The main objective of this work is to investigate the environmental impact of the failure of the slopes as well as the prevention and stabilization measures against landslides, mainly through environmental interventions and sustainability.

Introduction

The term slope stability describes the stability of an inclined soil formation or an artificial soil structure with a sloping, free surface. On each slope, the difference in level and the slopes in combination with the gravitational forces and the possible presence of water on the ground, create shear stresses inside the slopes, which are countered by the shear resistance of the soil. When the developing stresses exceed the shear strength, then they lead to breaking of the slope and landslide, as that of Figure 1 on the highway No. 3 of Taiwan, which took place in 2010.

Figure 1: Slope failure on motorway No. 3 of Taiwan.

The need therefore to assess stability has led to the development of analytical methods pertaining to either two or three dimensions. Some of the basic causes that can trigger the failure of a slope are the extreme sloping angle of the free surface, the low shear strength of soil or of one layer of soil, the reduction of soil shear strength due to an increase in pore water, the imposition of unfavourable external stresses, digging at the base of the slope or some earthquake. Types of failure typically encountered in loss of stability, including failures due to (a) erosion of slopes (b) erosion due to river (c) filling of cracks with rainwater (d) gravity and earthquake (e) weak layers within the soil formation (f) stresses on the upper surface of the slopes and (g) excavation at the base of the slopes.
It is important to know the types of landslides, as well as the failure mechanisms they present, in order to proceed with the analysis of stability and the calculation of a satisfactory safety factor.

Methodology

The research methodology of this work consists of the collection of data and photographic material from landslides that took place on both the Greek and the world map. There is also a brief reference to the measures against landslides as well as to the methods used for slope stability analysis.

Recording of results

In the course of the research effort, landslide phenomena that have occurred in the past around the world are presented.

Landslide in northern India (2013).
In northern India in 2013 deadly landslides hit the area after heavy rains caused floods, leaving behind more than 5,000 dead.

Figure 2: Consequences of the landslide in northern India.

Landslide in Vathi of Samos (2020).
The whole of Greece was shaken by the 6.7 magnitude earthquake of Samos in 2020. After the end of the earthquake, a landslide was created in the area of Avlakia. There was a detachment of a rock which fell into the sea without any injuries. The quake triggered small tsunamis that swept away everything in their path, causing severe damage to buildings and problems with the road network.

Figure 3: Landslide in the area of Avlakia.

Nigata-Ken Chuetsu (Japan 2004)
On 23/10/2004 an earthquake of magnitude M = 6.6 on the Richter scale occurred in the above region of Japan. Much damage was sustained by the transport networks due to soil failures because of slope slides.

Figure 3: Road damage during the Niigata - Ken Chuetsu earthquake (Japan)

Measures for protection and stabilization of soil and rocky slopes

Remedial measures include general works and construction of technical projects whose main purpose is the prevention of phenomena (preventive measures) or the restoration and stabilization of a soil movement (restoration or stabilization measures). Of particular interest are the measures to control and contain the landslides as shown below:

- Surface drainage works: Crack seals, Surface water drainage pipes,
- Shallow drainage works: Underground culverts, Strainers, Combined drainage culverts, 'External' drains, Horizontal drainage wells.
- Deep drainage works: Vertical drains, Horizontal drainage boreholes, Large diameter drainage wells, Drainage tunnels
- Excavations, Foot counterweights, Riverside riverbed stabilization works, Retaining walls, Piles, Well piles, Anchorages.

For the prevention of landslides, an important condition is to conduct research so that we know the soil materials, the existence of underground aquifers and their percentages. A fairly economical, not at all time-consuming and non-environmentally harmful measure to prevent landslides is the application of geotextile, as in this way we ensure the growth of vegetation in the problem area. This results in reduced excavations, conservation of natural aggregates and control of differential sediments. Another method of biological engineering for the stabilization of the slopes is to conduct hydroseeding in an embankment.

Suggestions

According to the authors of this article, in order to avoid major environmental and ecological disasters resulting from landslides, the cooperation of all bodies such as the Hellenic Technical Chamber, the Institute of Engineering Seismology and Earthquake Engineering as well as Earthquake Planning and Protection Organization is necessary so that all protection measures against natural disasters are implemented in a timely manner.

Conclusions

1. The volatility of slopes leads to the displacement of soil mass downstream, known as landslide and constitutes a significant risk to human activities and is often accompanied by the destruction of property, injury and loss of life.
2. Natural disasters, whenever and wherever they occur, often cause serious social, environmental and economic consequences, which require an urgent solution to the problem.
3. Significant impact on factors and variables of the natural and man-made environment that lead to deforestation, desertification, and extinction of biological species, as many endemic species are particularly sensitive to disturbance.
4. Water pollution and disturbances in the flow and natural environment of rivers in the event of failure of dam slopes.
5. Alternative stabilization methods have positive effects on surface landslides and soil materials, while at the same time not creating further environmental problems.