ISSN: 2710-0588

Landslide and Slope Protection Measures in Loess Plateau

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Abstract

This paper focuses on the landslide problem in the Loess Plateau. Firstly, the geological, topographic and climatic background characteristics of the Loess Plateau are described, and the causes of landslide in this area are analyzed, including natural factors (such as landform, geotechnical properties, precipitation, earthquake, etc.) and human factors (such as engineering construction, irrigation, mining, etc.). Then, the types and characteristics of landslides in the Loess Plateau are discussed in detail. Finally, the protection measures for the loess Plateau slope are systematically introduced, including engineering measures (such as retaining wall, anti-slide pile, etc.), biological measures (such as afforestation, etc.) and other comprehensive measures, aiming at providing theoretical basis and practical guidance for landslide prevention and ecological protection in the Loess Plateau.

Keywords

Landslide, slope protection, engineering measures, vegetation measures, Loess Plateau.

1. Introduction

The Loess Plateau is located in the north-central region of China with complex geological structure. It is mainly located in the synclinal tectonic unit of the Ordos platform, surrounded by fault zones. This geological structure makes the stratum structure in this area relatively unstable, which has buried hidden dangers for the occurrence of geological disasters such as landslides [1-3]. For example, in the vicinity of some fault zones, the integrity of rock and soil is damaged, which is easy to produce cracks, and groundwater is easy to move along these cracks, thus affecting the stability of soil. The Loess Plateau has unique topographic and geomorphic features, with Loess Tableland, Liang and MAO as the main geomorphic types [4-6]. Loess Tableland is a large area of flat highlands, Liang is a long strip of highlands, and MAO is an isolated steamed bread shaped hill. The existence of these geomorphic types makes the areas with large relief and steep slope widely exist. For example, in the Liangmao area, the slope slope often reaches 20-30 degrees or steeper, and this steep terrain provides favorable terrain conditions for landslides. The Loess Plateau is a semi-arid continental monsoon climate with concentrated precipitation and heavy rain. Annual precipitation ranges from 300-600 mm, with most of the precipitation concentrated in July-September [7-8]. The erosion force of rainstorm is very strong, and a large amount of rainfall in a short time will rapidly increase the water content of soil and reduce the shear strength of soil. At the same time, the long dry season makes

ISSN: 2710-0588

the loess in the alternating state of dry and wet for a long time, which will cause cracks in the loess and further destroy the structural stability of the soil.

2. Causes of landslide in Loess Plateau

2.1. Natural factors

The Loess Plateau has large topography and steep slope. Under the action of gravity, the soil itself has a tendency to slide downward. This trend is more obvious on the sides of some gullies, the margins of tableland and ridge. For example, in the area of gully development, the slope foot is hollowed out due to the continuous cutting erosion of gully, and the upper soil loses support, which is prone to landslide. Loess is a special kind of soil with large pores and vertical joint development. Its particle composition is mainly powder and its cohesion is relatively low. When the water content in loess increases, the friction between soil particles decreases and the shear strength decreases. Moreover, vertical joints in loess make it easier for rainwater to seep down, further damaging the integrity of the soil and triggering landslides.

Precipitation is an important inducing factor of landslide in Loess Plateau. The concentrated rainstorm will saturate loess rapidly and increase pore water pressure. According to the principle of effective stress, the increase of pore water pressure will lead to the decrease of effective stress of soil, thus reducing the shear strength of soil. For example, a rainstorm of more than 50 mm may cause some slopes in a critical stable state to slide. The Loess Plateau is located in the seismic zone, and the seismic activity will have a shaking effect on the soil. The propagation of seismic waves will change the stress state inside the soil, increase the shear stress of the soil, and destroy the structure of the soil. When the earthquake intensity reaches a certain degree, it is easy to cause landslides. For example, in some historical earthquakes, a large number of landslides occurred in the loess slope near the epicenter.

2.2. Human Factors

If reasonable engineering geological principles are not followed in the construction of roads and houses on the Loess Plateau, landslides may occur. For example, when building a road, the cutting slope is too steep, which destroys the original soil balance. Moreover, vibration and loading in construction will also affect the stability of soil. The vibration generated by heavy machinery operation in some large-scale construction projects may cause cracks in the originally stable slope, and then cause landslides.

Improper irrigation will cause the water table to rise. In some agricultural irrigation areas of the Loess Plateau, long-term irrigation leads to the rise of groundwater level, which makes the loess in a state of fullness of water. The shear strength of loess saturated with water is reduced, which is easy to cause landslide. For example, some slopes near irrigation channels are prone to small-scale landslides due to rising water tables.

The Loess Plateau region has certain mineral resources, such as coal and so on. In the process of mining, the formation of underground goaf will cause surface deformation. The soil above the goaf loses its support and is prone to collapse and landslide. Moreover, if the waste slag stacking in the mining process is not reasonable, it may also increase the load of the slope and cause landslide.

3. Types and Characteristics of Landslides in the Loess Plateau

3.1. Landslide Types

This kind of landslide mainly occurs in the shallow part of the loess layer, and the depth of the sliding surface is usually between 1 and 3 meters. The scale of shallow landslide is relatively small, and the influence range is limited. It is mainly caused by rainfall and other factors that

ISSN: 2710-0588

lead to the increase of water content and the decrease of shear strength of loess surface soil. For example, in the vicinity of some small hillside terraces, the soil near the embankment is easily saturated after rainfall, and shallow landslides often occur.

The depth of the sliding surface of the mid-level landslide is between 3 and 10 meters. The scale of such landslides is larger than that of shallow landslides, and it often involves multiple layers in the loess layer. The occurrence of middle-level landslide may be due to the comprehensive effect of many factors, such as terrain, rock and soil properties and precipitation. For example, on some slopes with steeper slopes and thicker loess layers, midlevel landslides may occur after continuous rainfall, with the volume of the sliding soil reaching thousands of cubic meters.

The sliding surface depth of deep landslide is more than 10 meters, which is the largest and most serious type of landslide in the Loess Plateau. The formation of deep landslides is often related to geological structure, long-term groundwater action and large-scale human activities. For example, in the loess slope above some underground goaf areas or near large water conservancy projects, deep landslides may occur due to the destruction of underground structures and long-term water infiltration, and the volume of sliding soil may reach hundreds of thousands of cubic meters or even more.

3.2. Landslide characteristics

Landslides in the Loess Plateau have obvious seasonality, and most of the landslides occur in the rainy season. This is because the rainfall in rainy season is concentrated and the soil water content increases rapidly. Especially during heavy rains, landslides occur more frequently. For example, from July to September every year, there is a high incidence of landslides on the Loess Plateau, and many landslide disasters occur during this period.

In a certain area, landslides in the Loess Plateau often show a mass occurrence. When a landslide occurs in a region, due to the similarity of terrain, geology and other conditions, the surrounding slope is also susceptible to landslide. For example, after a large rainstorm, multiple landslide points may appear on both sides of a gully at the same time, forming a landslide cluster.

Some landslides in the Loess Plateau have the characteristics of high-speed sliding. Due to the special properties of loess, once landslide occurs, soil can slide rapidly under the action of gravity. Some deep landslides can slide at a speed of several meters per second or more, and such high-speed landslides are extremely destructive, destroying large numbers of buildings and farmland in a short period of time.

4. Slope Protection Measures on Loess Plateau

4.1. Engineering Measures

Retaining wall is a common slope protection engineering measure. It resists the lateral pressure of soil through its own weight and structure to prevent slope sliding. In the Loess Plateau area, according to different terrain and engineering needs, different types of gravity retaining wall, cantilever retaining wall and buttress retaining wall can be used. Gravity retaining wall relies on its own weight to maintain stability, which is suitable for slopes with low height and wide feet. The cantilever retaining wall uses the cantilever structure to resist the earth pressure, which is suitable for the condition of large wall height and good foundation. Buttress retaining wall is the addition of buttresses on the basis of cantilever retaining walls to enhance the stability of the structure and is suitable for higher slopes. In the construction process, attention should be paid to the foundation treatment of the retaining wall to ensure that it has sufficient carrying capacity, and at the same time to ensure that the drainage system of the retaining wall is good to avoid the water behind the wall affecting the stability of the wall.

ISSN: 2710-0588

Anti-slide pile is a kind of deep underground pile structure, which can resist the thrust of landslide through the interaction between pile and surrounding soil. In the Loess plateau, the design and construction of anti-slide pile need to consider the special properties of loess. The diameter, length and spacing of anti-slide piles should be determined according to the scale of landslide, the nature of soil and the thrust of landslide. For example, for deep landslides, it is necessary to use large diameter and long length anti-slide piles, and the pile spacing should be properly reduced. In the construction process, it is necessary to ensure the verticality and the quality of the pile body, and pay attention to the connection between the pile top and the slope body to ensure the effective transfer of force.

Slope protection engineering includes plastering, shotcrete and slurry masonry slope protection. Plastering is to apply a layer of cement mortar and other materials on the slope to prevent rain erosion and weathering. Shotcrete is the use of jet to spray concrete or cement mortar to the slope, its protection effect is better, suitable for steep slope. Slurry brick slope protection is a slope protection structure made of stone and mortar, which has high strength and stability. When performing slope protection works, it is necessary to clean and smooth the slope first to ensure that the protective material is well bonded to the slope.

Drainage engineering is very important for slope protection in loess plateau. Since precipitation is an important inducing factor of landslide, effective drainage can reduce the moisture content of soil and improve the shear strength of soil. Drainage engineering includes surface drainage and underground drainage. Surface drainage is mainly to set up cut-off ditches, drains, etc., to lead rainwater away from the slope in time. The cut-off ditch should be set at a certain distance above the top of the slope to prevent rainwater from flowing into the slope. The drainage ditch is set along the slope or the foot of the slope to discharge the water inside the slope. Underground drainage can be used in the form of seepage ditch, blind ditch, etc., to reduce the groundwater level. Permeable materials are filled in the diaphane and blind diaphanes, which can guide groundwater outside the slope.

4.2. Biological Measures

Afforestation is an important biological measure for slope protection in loess Plateau. The roots of trees can penetrate deep into the soil and play the role of soil consolidation. Different tree species have different adaptability in the Loess Plateau, so the local climate, soil and other conditions should be considered when selecting tree species. For example, black locust, Chinese pine and other tree species have better adaptability in the Loess plateau. Afforestation can not only improve the shear strength of soil, but also trap rain through the tree crown and reduce the erosion of raindrops on the slope. In the process of afforestation, we should pay attention to the afforestation density and afforestation mode, and adopt the appropriate mixed forest model can improve the afforestation effect.

Planting grass for slope protection is a simple and effective biological measure. Herbaceous plants grow quickly and their roots can consolidate soil in a relatively short time. In the Loess Plateau, the grass species suitable for planting are alfalfa, dogtooth root and so on. Planting grass can form a layer of vegetation cover on the slope, reduce the direct erosion of rain on the slope, and the transpiration of vegetation can reduce the water content of soil. When planting grass, it is necessary to pay attention to the sowing amount, seeding time and seeding method of grass seeds to ensure the germination rate and growth effect of grass seeds.

4.3. Comprehensive Measures

In slope protection of loess Plateau, comprehensive measures are often adopted. For example, in some large-scale landslide control projects, engineering measures can be first used to conduct preliminary landslide control, such as setting anti-slide piles, retaining walls, etc., and then biological measures can be carried out to further improve the stability of the slope through

ISSN: 2710-0588

afforestation and grass protection. Comprehensive measures can also combine engineering measures with agricultural measures, such as setting small retaining walls at the edge of the slope terrace, while planting suitable crops in the terrace, and improving the stability of the slope through the root system of the crop and the protection of the ladder ridge.

5. Conclusion

The problem of landslide in Loess Plateau is the result of many natural factors and human factors. The types of landslides are diverse and their characteristics are obvious, which poses a serious threat to the local ecological environment, infrastructure and people's life and property safety. In order to effectively control the landslide disaster in the Loess Plateau, it is necessary to take a variety of protective measures, including engineering measures, biological measures and comprehensive measures. The reasonable application of these measures can improve the stability of the slope, reduce the occurrence of landslide, and also help to improve the ecological environment of the Loess Plateau and achieve sustainable development.

In the future research and practice, it is necessary to further study the characteristics of loess, the formation mechanism of landslide and the optimization of protective measures, so as to better deal with the problem of landslide on the Loess Plateau.

Acknowledgements

This work was financially supported by the Scientific Research Item of Shaanxi Provincial Land Engineering Construction Group (DJNY2024-38 and DJTD-2023-1), Key Research and Development Program of Shaanxi, China (Program No. 2022ZDLNY02-01and 2023-ZDLNY-52), Xi'an Science and Technology Plan Project, China (22NYGG0001).

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