

Study on the Influence of Human Activities on Loess Landslide

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Abstract: In view of the frequent occurrence of human activity loess landslide, this paper focused on the influence of the main human activities such as irrigation, excavation, loading and mechanical vibration. The most typical mechanism of loess landslide caused by irrigation was the creep liquefaction mechanism. The main types were loess erosion slip type and plastic flow fracture type. The stress distribution of the slope was changed by slope toe excavation, the excavation destroyed the slope stability and formed the landslide hazard. When it was piled on top of loess slope, stress concentration was produced, which was disadvantageous to slope stability. When there were other inducing factors, the slope would be unstable. The effect of vibration on slope was various. However, the main factor was to reduce the strength of loess and create conditions for slope instability.

Preface

Loess is a kind of soil deposit formed in Quaternary period about 2 million years ago. After the implementation of the "Great Western Development" strategy, the economic development in the loess region had quickened. With the increasing speed of infrastructure construction, a large number of excavated loess slopes were encountered. Due to the complicated geological conditions and adverse climate conditions in loess areas, the number of loess landslides increased steadily. In view of the present situation, it was urgent to search for the development mechanism of the human activity loess landslide and seek effective prevention measures. In recent years, many scholars have devoted themselves to the work in this field, and have played an active role in human engineering construction, but they are still in the stage of exploration and need further study.

The human activity type loess landslide referred to the change of natural environment condition and loess slope structure caused by human engineering activity. The mechanism of landslide was complex, predisposing factors were different, but there were the following basic disaster process: human activities, the change of stress state and unstable sliding three stages. Human activity was the cause, the geological environment and structural features of the slope were internal causes. This paper mainly analyzed the influence of the main human activities such as irrigation, excavation, loading and mechanical vibration on the loess landslide, hoping to have some reference and reference significance for the study of the human activity loess landslide.

The Influence of Irrigation on Loess Landslides

The irrigation loess landslide is one of the most common landslides in the Loess Area in recent years. With the development of the loess region, the frequency of the landslide is increasing. Since 1976, large scale irrigation, the geological hazards such as loess landslide and collapse occurred frequently in JingYang plateau of Shaanxi South, and had caused serious property damage and casualties. A similar situation also occurred in HeiFang-tai of Gansu. According to statistics, there had been 100 slides in the past 1968~2009 years, especially in recent years, the frequency and scale of landslides had been increasing. HeiFangtai landslide group had caused 40 deaths, more than 100 people were injured. At the same time, the direct economic loss was 200 million yuan, and the indirect economic loss was 500 million yuan.

YanGuoxia Hydropower Station is located in the upper part of Heifangtai, the height of the Hydropower Station is 55m, and storage capacity is $3.2 \times 10^8 \text{m}^3$. After impoundment and irrigation, the hydrogeological conditions of the reservoir area had been changed. Under the long-term action of water head pressure, the water in reservoir area gradually flowed downstream, and the water content

of stratum increased. The softening action of water reduced the shear strength index of mudstone, and made the stability of loess slope deteriorate continuously. A large amount of water penetrated into the deep and formed a large number of sinkholes under the erosion and other "Loess Karst" landforms. Then, the weakening or loss of toe support forced to produce a large number of Loess landslide.

The most typical mechanism of the irrigation loess landslide was the loess sliding liquefaction mechanism [1], which explained the mechanism of the liquefaction of saturated loess caused by complex movement. The theory was put forward by J.D.Wang. When there was a saturated loess layer at the lower (or bottom) side of the loess slope, it was possible to liquefy the saturated loess under any vibration. The viscous force of the liquefied loess layer was too small or even zero, which accelerated the destabilization process of the Loess slope. According to the study Heifangtai landslide[2], the basic types of deformation and failure could be summarized in creep fracture type, plastic flow crack type and erosion slip type. Under natural conditions, the main types were creep sliding and fracturing, the main types of landslide included submerged sliding type and plastic flow fracture type under heavy irrigation.

The Influence of Excavation on Loess Landslide

In the loess area, the excavation of the loess slope was inevitable, and a large number of excavated slopes were formed. Loess itself had good standing and stability. After many small-scale excavation activities, even vertical slope body could remain stable. However, large-scale excavation activities, such as railway construction, water conservancy and hydropower construction, urban deep foundation pit excavation, often lead to slope instability. Once the slope excavation, the stress concentration was produced. Under the influence of the slope weight, it was easy to produce landslide and other slope disasters.

The Influence of Loading on Loess Landslide

Engineering load was the human activity, which had a significant impact on the stability of loess slope. Building on top of the loess slope was very common in Gansu Province.

In order to find out the influence of surcharge load on the stability of loess slope, N.Q. Wang established the loess slope rear loading model [3], and carried on the finite element analysis, the result was shown in Fig1 and Fig 2.

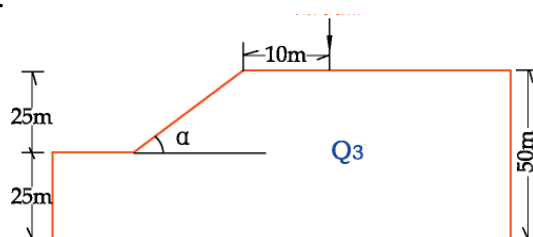


Fig.1. Loading model of loess slope

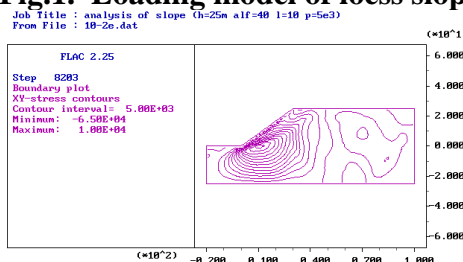


Fig. 2. Shear stress distribution after loading (Iteration 8203 steps)

From Fig 1, 2 could be seen, applying a load in the man-made loess slope, slope and slope toe produced obvious stress concentration phenomenon, which was unfavorable to the stability of the

slope. Under the action of mechanical vibration, rainfall and so on, the slope was prone to unstable sliding.

The Influence of Mechanical Vibration on Landslide

The vibration of machines in large-scale engineering activities was unavoidable. At the same time, the slope of highway and railway was affected by vehicle vibration for a long time, and had a negative influence on the stability of slope. The author thought that the effect of vibration on the slope was various, but the main factor was to reduce the strength of loess and created conditions for slope instability.

N.Q. Wang pointed out that [4]: Under the action of vibration, the change of loess microstructure was the root cause of its strength reduction. In order to find out the change of loess strength under vibration and its influence on the slope stability, the dynamic strength of loess was studied by using the GDS imported from England. The standard size of loess specimens was $\Phi 50\text{mm} \times h100\text{mm}$, and table 1 was the basic geotechnical parameters of the loess.

Table 1 Routine Physical and Mechanical Indexes of Loess Samples

Index	w / %	g/cm^3	e_0	w_L / %	w_p / %	$a_{0.1-0.2}/(MPa)^{-1}$	E_s / MPa	$\Phi/^\circ$	C / KPa
Data	9.1	1.55	0.893	23.8	15.9	0.31	6.039	31.9	15

In the triaxial test, a dynamic stress was applied to the sample on the basis of Mohr Coulomb failure criterion. When the equivalent vibration time was reached, the dynamic strength index of the specimen was measured. Different stress Mohr's circle could be obtained from different stress states. The principle of the experiment was expressed as Eq. 1:

$$\frac{s_1 - s_3}{2} = C \cos f + \frac{s_1 + s_3}{2} \sin f \quad (1)$$

In the formula, s_1 is the large principal stress, s_3 is the minor principal stress, C is the cohesive force, and f is the internal friction angle .

Then by drawing these Mohr circle tangent (Fig3) , the dynamic shear strength parameters was obtained. Fig 3 shows that internal friction angle is 16° and the cohesion is 3.26 kPa.

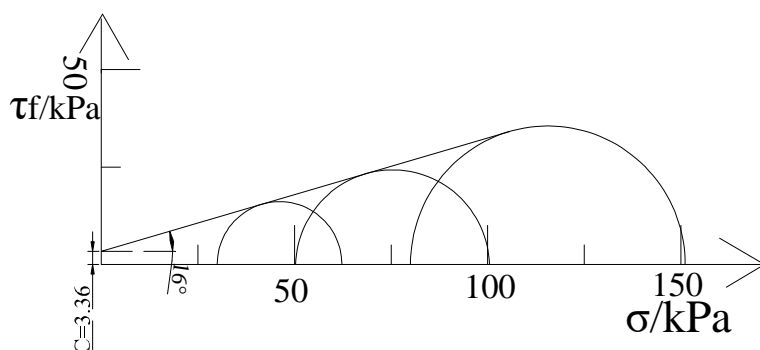


Fig. 3. Dynamic three axis stress mohr circle and moore envelope

The dynamic strength of loess could be obtained by stress Mohr circle, and the dynamic strength was compared with the direct shear strength (Table 2).

Table 2 Comparison of loess strength

	strength index	data
Direct shear test	internal friction angle ($^{\circ}$)	31.9
	cohesion (kPa)	15
Dynamic triaxial test	internal friction angle ($^{\circ}$)	16
	cohesion (kPa)	3.26

Table 2 shows that the strength of loess is obviously reduced. The decrease of strength adversely affected the stability of the slope, and the internal stress balance of the slope was destroyed. The loess was clipped along the stress concentration zone. The decrease of loess strength led to the formation of loess landslide.

Conclusion

Irrigation, excavation, stacking and mechanical vibration are the main influencing factors for the loess landslide. The essential effect of human activities is to change the stress of slope.

Irrigation changes the distribution of groundwater, reduces the soil strength, and then causes the landslide disaster.

The excavation activity is sensitive to the slope, and it is easy to produce stress concentration. Under the influence of the slope weight, it is easy to produce landslide disaster.

Loading makes the slope slide force increase, which is disadvantageous to slope stability and prone to instability sliding.

The mechanical vibration greatly reduces the strength of the soil and is unfavorable to the stability of the slope.

Acknowledgements

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