Influence of Building Load on the Stability of Loess Slope

Zhihai Zhao[1,a], Zhangjian Xu[1] , Yanjie Sun[2,b] and Yunou Sheng[1]

[1]Northwest Research Institute of Engineering Investigations and Design, Xi' an 710003，China;

[2]College of Geology & Environment ,Xi' an University of Science &Technology, Xi' an 710054, China.

[a]15891763959@163.com, [b]747720426@qq.com

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Abstract. In light of the characteristics of loess and slope type in northern Shaanxi, six slope models were established with slope building load as variable. Six types of models were analyzed by soil mechanics, numerical simulation and multiple regression analysis to find the influence of slope load on slope stability. The conclusions show that the stability of the loess slope has a significant relation with the building load. With the increase of building load, the variation trend of slope stability coefficient is different: when the *d* value is 20m, the slope stability coefficient increases in the range of 0~600kPa for the building load, and decreases in the range of 600~1000kPa.

Introduction

Housing construction in mountainous regions has grown rapidly with the increase in population and acceleration of urbanization. And the stability of the building slope has a direct affect on the safety of the building on the top of slope. The key to whether the slope can be used as a construction land or not is the form of the building load on the slope. When the building load is too large or the point of action from the shoulder is too close, the shear stress of slope will be significantly greater than its shear strength, resulting in reduced slope stability. Although several scholars have probed into the slope stability[1-6], there are few studies on the impact of different forms of building load on the slope stability. Generally speaking, the slope stability factor decreases as the building load increases. The instability is the main form of the destruction of the construction slope. Based on the limit equilibrium theory, numerical simulation and multiple regression are used to analyze the influence of building load on slope stability, so as to guide the construction of slope area.

Research Methods

Taking the northern slope of Shaanxi Province as an example, the slope model is established with the slope building load as the variable. The mechanical parameters of loess in the model are assigned to the loess properties in Yan’an area. Firstly, the finite element numerical simulation software SIGMA/W module is used to simulate the stress change and volume change of each model under the condition of the load of the top slope. Secondly, the SLOPE/W module is used to calculate the stability coefficient of each model after deformation. Finally, the stability coefficients of each model are summarized.

Model Parameter Selection and Model Construction

Six types of slope models were established for the loess and slope types in northern Shaanxi. In order to simplify the calculation, the model's slope ratio is 1:1. The loess mechanics parameters in the model will be assigned to the loess nature of the Yan'an area. The simple loess building slope model is shown in Fig.1.

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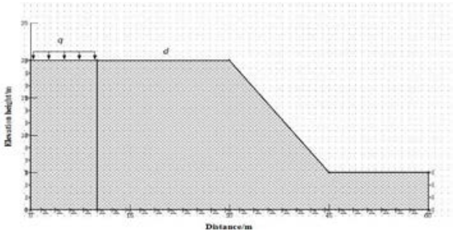

Fig.1 Schematic diagram of loess building slope model

In the figure, *q* is the building's load, and *d* is the distance from the edge to the top of the slope. The *d* values in this paper is 20m.

Parameter Selection. According to the "Building Structure Load Specification"(GB 50009-2012), the residential load in China is generally 2kN/m^2. Since this paper mainly explores the variation law of the slope under the self-weight load of the building, the building self- Of the load as a uniform load. This article has a building floor area of 100m^2. The building height is 3m (layer), 6m (two), 9m (three), 12m (four) and 15m respectively, and the height of each building is 3m. (Five layers). The height of the building corresponding to the building load value as shown in Table 1. According to the "Technical Code for Construction Slope" (GB 50330-2013), the slope stability coefficient 1.2 is taken as the critical value of slope stability.

Table 1 Load of buildings with different layers

Building height/m	0	3	6	9	12	15
Load value/kPa	0	200	400	600	800	1000

According to the field investigation and the large number of research results [5,6], the loess type in Yan'an area is mainly Malan loess (Q3) and limestone (Q2). Therefore, the physical and mechanical parameters of loess in the study area are shown in Table 2.

Table 2 Loess physical and mechanical parameters

Severe/(kN/m^3)	Deformation modulus/MPa	Poisson's ratio	Internal friction angle/(°)	Coh.
20	2	0.38	25	35

Model Establishment.(Q3) and limestone (Q2) are mainly in the depth of 15m in northern Shaanxi. In general, Malan loess (Q3) is thicker in Yan'an area, so this model chooses Q3 loess As the object of study. The height of the model is 15m. First assign the model. The left and right borders and the bottom of the slope are fixed in the model, and the corresponding load is applied to the top of the slope instead of the stress change caused by the load of the building. Figure 2 shows the building distance from the slope shoulder distance of 20m and the building load of 800kPa in the case of the establishment on the model.

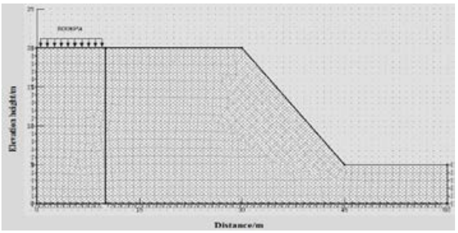

Fig. 2 Example of a model calculation

Taking the above model as an example, six models were established to study the corresponding stability coefficient under gravity loading. The parameters and codes of the six models in the case of gravity loading are shown in Table 3. The model code in the case of no gravity load is model O.

Table 3 Numerical simulation model settings

Code	d/m	Building load/kN
A1	20	200
A2	20	400
A3	20	600
A4	20	800
A5	20	1000

Results and Analysis

Results of calculation. The model was constructed using the Geo-studio of SIGMA/W module. The analysis results are shown in Fig.3.

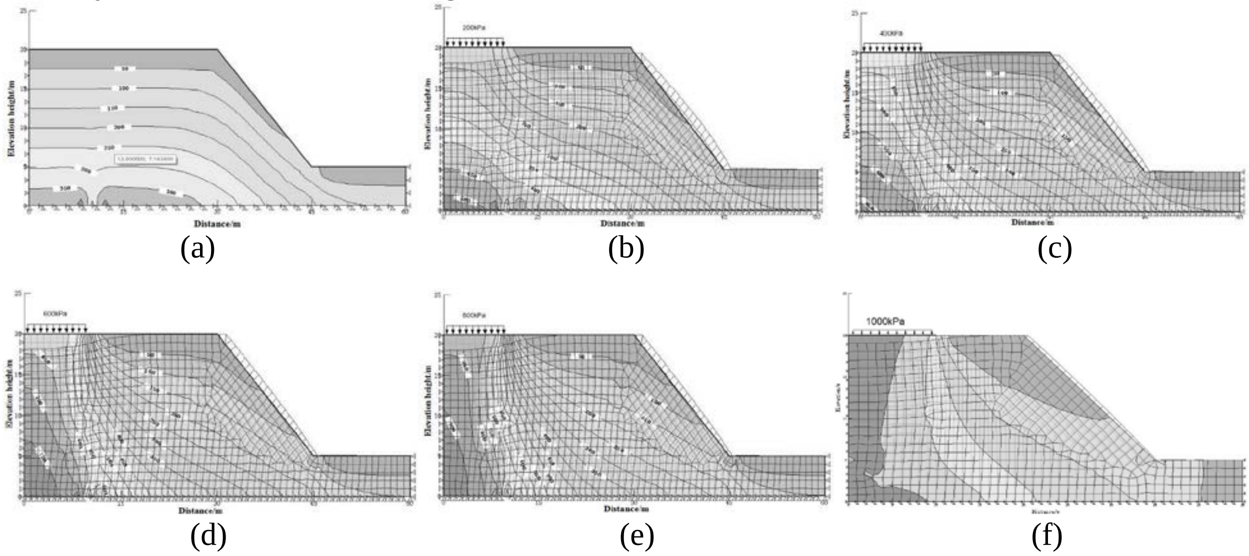

Fig.3 Variation of stress changes in cloud and slope under different gravity loads:a.Stress and displacement of the slope under no load;b.Stress and displacement of the slope under 200kPa;c.Stress and displacement of the slope under 400kPa;d.Stress and displacement of the slope under 600kPa;e.Stress and displacement of the slope under 800kPa;f.Stress and displacement of the slope under 1000kPa.

The stability coefficients of 6 kinds of models after stress change are analyzed by using the SLOPE/W module of Geo-studio. The results are shown in Table 4.

Table 4 Numerical simulation model settings

Code	d/m	Building load/kN	Stability coefficient
O	-	0	1.695
A1	20	200	1.709
A2	20	400	1.726
A3	20	600	1.734
A4	20	800	1.726
A5	20	1000	0.981

Analysis of Results. It is assumed that the sliding surface of the cohesive soil slope is a cylindrical surface for homogeneous simple slope. The soil on the sliding surface as a rigid body, and as a detached body. The various forces acting on the body under the limit equilibrium are analyzed, and the stable safety factor K of the soil slope is defined by the ratio of the average shear strength and the average stress on the whole sliding surface[7]. As shown in equation (1).

$$K = \frac{\tau_f}{\tau} \quad (1)$$

Where τ_f is the shear strength and τ is the shear stress. The shear strength and shear stress expression of the cohesive soil are shown in equations (2) and (3), and the expression of the total stress σ is shown in equation (4).

$$\tau_f = c + \sigma \tan\varphi \quad (2)$$

$$\tau = \frac{1}{2}(\sigma_1 - \sigma_3)\sin 2\alpha \quad (3)$$

$$\sigma = \frac{1}{2}(\sigma_1 + \sigma_3) + \frac{1}{2}(\sigma_1 - \sigma_3)\cos 2\alpha \quad (4)$$

Where c is the cohesion, φ is the internal friction angle, σ_1 and σ_3 are the two principal stresses acting on the soil respectively. In general, we define σ1 as large stress and σ_3 as small stress. The model set up in this paper is considered to be subject only to the construction load, the ground reaction force and the internal compressive stress. The force in the vertical direction is set to σ_1, and the force in the horizontal direction (confining pressure) is set to σ_3. Since the force in the vertical direction is indefinite, the two stresses can not be simply compared, so the stable safety factor *K* can be expressed by equation (5). In order to facilitate the analysis of numerical simulation results, where the value of α is 45 °. The simplified expression is expressed by equation (6).

$$K = \frac{c + \left[\frac{1}{2}(\sigma_1 + \sigma_3) + \frac{1}{2}|\sigma_1 - \sigma_3|\cos 2\alpha\right]\tan\varphi}{\frac{1}{2}|\sigma_1 - \sigma_3|\sin 2\alpha} \quad (5)$$

$$K = \frac{c + \left[\frac{1}{2}(\sigma_1 + \sigma_3)\right]\tan\varphi}{\frac{1}{2}|\sigma_1 - \sigma_3|} \quad (6)$$

In the slope of the vertical direction of the building due to the role of heavy load, but also by the horizontal direction of the extrusion stress. The force in the vertical direction is less than the force in the horizontal direction, and the force in the vertical direction increases with the increase of the dead weight load, and is finally greater than the horizontal direction. According to equation (6), it can be found that $|\sigma_1$-$\sigma_3|$ (deviation stress) has a process from large to small to large in the process of increasing force in the horizontal direction. Therefore, at d is 20m, the stability coefficient gradually increases from small to reduce the situation.

Summary

The soil mechanics and multiple regression analysis are used to analyze the influence of the self-weight load on the stability coefficient of the building slope. The following conclusions have been drawn.

(1)The stability of the loess slope has a significant relationship with the building load.

(2)With the increase of building load, the variation trend of slope stability coefficient is different. When the d value is 20m, the slope stability coefficient becomes larger in the range of 0~ 600kPa for the building load, and decreases in the range of 600~1000kPa.

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