

Influential Factors on the Stability of Building Slope

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Abstract. Based on the loess structure and topography of northern Shaanxi area, the construction slope model is built. The numerical simulation method is used to analyze the slope stability coefficient under conditions that the self-weight load, slope ratio and the distance from building to slope. The results are analyzed using soil mechanics. The results show that the construction load, slope ratio and d value have influences on the slope stability. The development trend of the slope stability coefficient with the change of the load depends mainly on the value of d . When the d value is less than 15m, the trend is rapid and continues to decrease; when the d value is 20m, the trend of the stability coefficient is gentle, and the stability coefficient increases with the increase of the load. The influential factors of the slope stability coefficient are different in different stages. The larger influential factors in the stage A is the building load, and the larger influential factor in the stage B is the slope ratio.

1. Introduction

The concept of building slope is defined in the “Technical Code for Construction Slope” (GB 50330-2013). Building slope is artificial slope formed by excavation or filling construction and natural slopes that adversely affect the safety or stability of buildings. In the central and western regions of China with more mountains and complex terrain. A large number of buildings are built on the top of the slope. The load of the building itself is critical to the stability of the slope. The coupling of external environmental impacts and building loads poses a serious threat to the safety of the local population and property. In July 2013, heavy rains hit Yan'an, resulting in 5799 landslides. The total economic loss caused by the flood reached 2.193 billion yuan. Twenty six people were killed, and 121 people injured due to the disaster [1]. Scholars of both home and abroad [2-7] used numerical simulation and mechanical analysis methods to study the stability of slopes under rainfall conditions. But their analysis processes often overlooks the impact of the top load on the slope. Based on the numerical simulation results, we use the soil mechanics method to analyze the stability coefficient of the established slope model and find the corresponding influential laws.



2. Principles and Methods

2.1. Fundamentals

SIGMA/W can be used to simulate the physical deformation process of rock under the action of its own load or external load. It is widely used in stress-strain analysis. Based on the finite element numerical simulation, the analysis results can be directly used in SLOPE/W software. SLOPE/W is based on the limit equilibrium theory used to analyze the stability of the slope and calculate the slope of the safety factor, and can produce deformation of the soil stability check. Finally, the results are analyzed by soil mechanics method. Based on the topography and geomorphology of loess area in northern Shaanxi, this paper chooses the theoretical basis of loess physical and mechanical parameters in Yan'an area. 36 different slope models were established with the load of the building and the position of the load. The deformation of the model under the load is simulated by SIGMA/W software. Then, the SLOPE/W software is used to analyze the stability of the deformed slope model.

2.2. 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 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) and 12m (four) 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. Different building height corresponding to the building weight load values were 200kPa, 400kPa, 600kPa and 800kPa.

(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. The mechanical parameters of loess are shown in Table 1.

Table 1. Theoretical values of loess physical mechanics.

Severe/(kN/m^3)	Deformation modulus/MPa	Poisson's ratio	$\varphi/(^{\circ})$	c
20	2	0.38	25	35

2.3. Model building

According to the loess nature and slope type in northern Shaanxi, 36 slope models were established with the slope load and the distance between building and slope. The simple loess building slope model is shown in Fig.1.

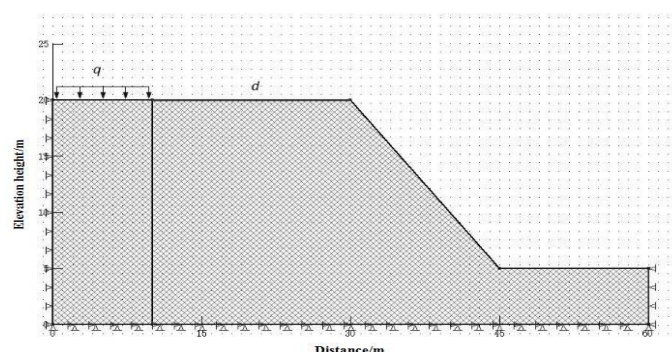


Figure 1. Schematic diagram of loess building slope model.

In the figure, q is the building's own weight load, d is the distance from the building to the slope, and the value of d is 10m, 15m and 20m respectively. The slope ratios are 1: 0.75, 1: 1 and 1: 1.25, respectively.

3. Results of calculation and analysis

3.1. Results of calculation

The internal stress variation and slope deformation of the slope are simulated by SIGMA / W software. The simulation results are shown in Fig.2. The stability coefficient of the slope after deformation is calculated by SLOPE / W software. The results are shown in Table 2 (due to the limited length here only d value of 10 cases).

Table 2. Calculation results of the stability factors on slopes.

Code	Slope ratio	q/kPa	d/m	Stability coefficient
1	1:0.75	200	10	1.361
2	1:0.75	400	10	1.153
3	1:0.75	600	10	1.022
4	1:0.75	800	10	0.939
5	1:1	200	10	1.483
6	1:1	400	10	1.242
7	1:1	600	10	1.100
8	1:1	800	10	0.995
9	1:1.25	200	10	1.661
10	1:1.25	400	10	1.377
11	1:1.25	600	10	1.235
12	1:1.25	800	10	1.116

For ease of analysis, the results of 36 models were plotted using Origin software. The drawing results are shown in Figure 2.

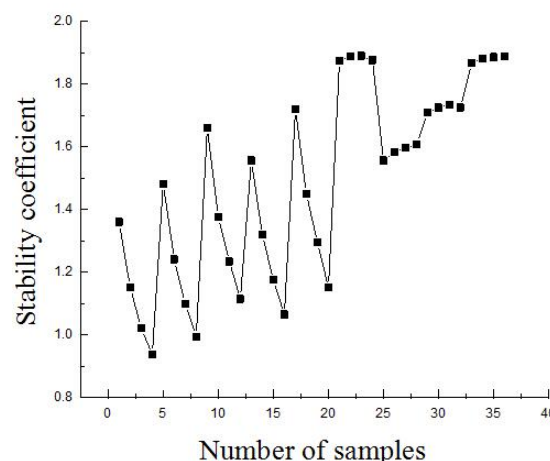


Figure 2. The slope stability factors obtained by Geo-studio.

It can be seen from Fig. 2 that the trend of slope stability can be divided into rapid and gentle stages with the change of building load and d value. Respectively, called the A and B stages. The number of consecutive samples per four can be seen as a smaller stage of development. It can be seen from the figure that each sample is determined by the building load, and the smaller stage of

development of the A stage is rapidly reduced. B stage of the smaller stages of development are relatively gentle, and there has been an increasing trend. At this time, it is possible to obtain the development trend of slope stability coefficient in stage A under construction load. The development trend of the B-stage slope stability coefficient is slowly increasing and decreasing or increasing. It is known from Table 2 and Figure 2 that each of the three smaller stages of development is determined by the different slope ratios at the same d values, and it can be seen that as the slope ratio decreases, the d value and the load are constant Stability coefficient becomes larger. It is found from Fig. 2 and Table 2 that the value of d value directly affects the development trend of the whole slope stability coefficient. In the case of the same load and slope ratio, the greater the d value, the greater the corresponding stability coefficient. It is found from Fig.2 that the construction load has a great influence on the slope stability coefficient in the A stage, and the stability coefficient of the slope ratio is relatively large in the B stage.

3.2. Results analysis

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 [8]. 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 σ_1 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 20, the stability coefficient gradually increases from small to reduce the situation.

It can be seen from equation (6) that the slope is unstable when σ_3 is σ_1 and the stability coefficient is decreasing. When σ_3 is larger than σ_1 , the stability coefficient K of the slope will increase as the load increases. In general, the greater the distance from the slope of the building, the greater the pressure σ_3 . The value of σ_3 will continue to increase with the d value increases, and σ_1 value unchanged, so with the d value increases the slope stability coefficient development trend will slow down. When the value of d is in the range of 10~15m, σ_3 is smaller than σ_1 , and the development trend of slope stability coefficient is mainly in stage A. And the d value reaches 20m, σ_3 is larger than σ_1 , so the slope stability coefficient will increase.

4. Conclusion

The building load, slope ratio and d value are variables. Geo-studio is used to solve the slope stability coefficient when the three variables change, and the results are analyzed by the soil mechanics method.

(1) The construction load, slope ratio and d value have influences on the slope stability. The development trend of the slope stability coefficient with the change of load depends mainly on the value of d .

(2) d value has effect on the change trend of stability coefficient. When d value is less than 15m, the change trend of stability coefficient with the increase of load is rapid and decreases continuously. When d value is 20m, the trend is gentle, and with the increase in load the development trend of slope stability has increased.

(3) The influential factors of the slope stability coefficient are different in different stages. The larger influential factors in the stage A is the building load, and the larger influential factors in the stage B is the slope ratio.

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