CS380
The 2nd International Conference on Applied Mathematics, Modeling and Computer Simulation (AMMCS 2022)
August 13-14, 2022
Wuhan, China

Stability Analysis of Slope Reinforced by Frame with Anchors Considering Anchor Failure

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01 Introduction

In engineering practice, it is found that some anchoring slopes lead to local anchor failure due to construction, environment, design and other factors, resulting in slope instability, directly resulting in casualties and economic losses.

At present, the main evaluation indexes of slope stability are safety factor and permanent displacement. For the deformed slope, especially the slope under construction, a single "safety factor" is not enough to fully reflect the stability of the slope.

Therefore, by explaining and predicting the instability failure mode and time of large slope with displacement, quantifying the failure degree of slope permanent displacement to slope can be used as a reliable basis for evaluating the stability of large slope.

02 Engineering example

In a slope project in Tianshui, Gansu Province, the slope height is 12m and the slope is 75 degrees.

Table.1. Table of soil parameter

parameter	γ(kN/m³)	c(kPa)	φ(°)	μ
soil	16.5	15	28	0.32

Table.2. Design parameters for anchors

z	s/m	s_v/m	D/mm	d/mm	l_{aj}/m	l_{nj}/m	l/m
11	2	2.5	150	28	6	10	16
8.5	2	2.5	150	28	5	9	14
6	2	2.5	150	28	4	8	12
3.5	2	2.5	150	28	4	7	11
1	2	2.5	150	28	3	5	8

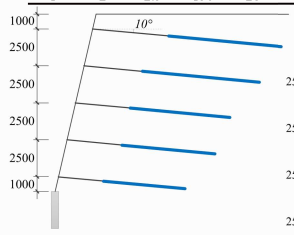


Figure 1. Schematic diagram for calculation of slope reinforced by frame with anchors

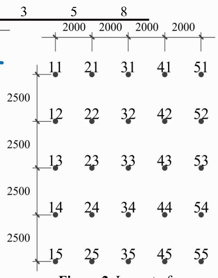
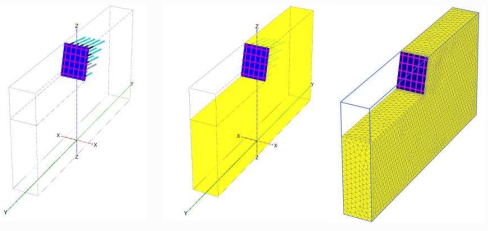


Figure 2. Layout of anchors



a) Structural model
b) Numerical model diagram
c) Meshing of finite element model

Figure 3. Finite element model of slope reinforced by frame with anchors

According to the general situation of the project, five three-dimensional models of loess slope reinforced by frame with anchors are established by PLAXIS 3D finite element software. the geometric model size is 10m in x-axis direction, 80m in y-axis direction and 40m in z-axis direction, as shown in figure 3. The constitutive model of this project case is HS-small.

03 Calculation analysis

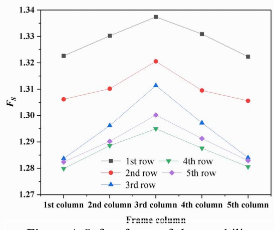


Figure 4. Safety factor of slope stability after failure of single anchor at different positions

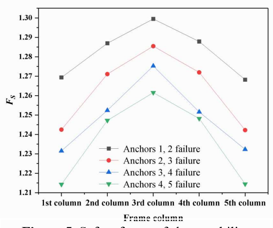


Figure 5. Safety factor of slope stability after simultaneous failure of two vertical adjacent

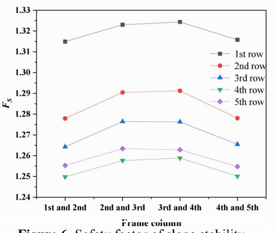


Figure 6. Safety factor of slope stability after simultaneous failure of two horizontal adjacent anchors

The closer the failure anchor is to the middle of the slope and the top of the slope, the smaller the influence on the safety factor of the slope. The closer the failure anchor is to the outer edge of the slope and the foot of the slope, the greater the influence on the slope displacement.

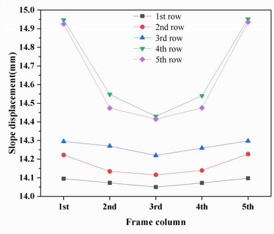


Figure 7. Slope displacement after failure of single anchor at different positions

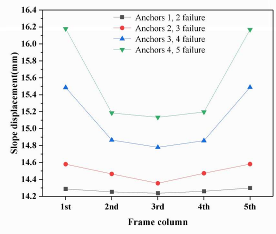


Figure 8. Slope displacement diagram after simultaneous failure of two vertical adjacent anchors

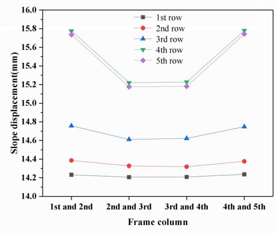


Figure 9. Slope displacement diagram after simultaneous failure of two horizontal adjacent anchors

There is an obvious crack zone in the unsupported slope, but the displacement of the slope is greatly improved after support, and the displacement of the slope tends to decrease step by step from the top of the slope to the bottom of the slope.

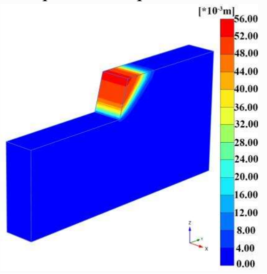


Figure 10. Displacement cloud map of unsupported slope

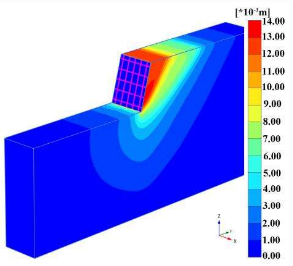


Figure 11. Displacement diagram of slope reinforced by frame with anchors

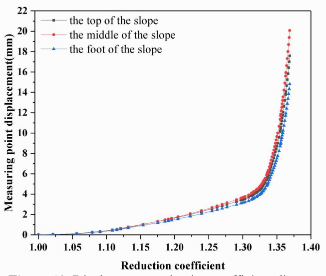


Figure 12. Displacement-reduction coefficient diagram

There is a certain relationship between the stability and displacement of the slope. In the process of gradual instability of the slope, the displacement of the slope accumulates until sliding occurs.

At the same time of calculating the safety factor of the slope, we can directly understand the changing law of the slope displacement, and obtain the relationship curve between the slope deformation and stability, which provides some reference for the on-site deformation monitoring and information development.