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Finite Element Simulation of Water on the Slope Stability of Transmission Tower Foundation

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Abstract

In northwest and southern regions of China, after heavy rains tend to be a lot of landslides or avalanches and other slope instability phenomena which cause great losses. But our transmission lines inevitably will go through the Southwest, southern foothills. Generally, transmission towers built on top of the mountain or steep hillside. Abundant rainfall contains in the mountains of China’s southwest. Transmission tower slope failure caused by rain or groundwater accounts for a large percentage. Therefore, the effect of water on the mountain slope stability analysis for the transmission tower can provide theoretical support for slope sliding forecast or monitoring. It’s also essential for safety of transmission lines, prevention of disasters.

Keywords: Slope stability; Tower Foundation; Finite Element Method

1. Introduction

In recent years, the slope of the natural disasters landslides, landslide, debris flow caused by the instability phenomenon mostly because of the influence of water, from the "ten landslide nine water" this sentence can be seen in the water is one of the important conditions of slope stability, according to Li Dexin, where the research of [1] et al, Siming, Southwest China Northwest China often occurrence of natural disasters, landslides, debris flow after the heavy rain, and set up at the top of the mountain or mountain tower inevitably affected, therefore, the research on transmission tower slope stability analysis, slope stability can provide theoretical support for iron tower foundation, thus reducing the impact of natural disasters on the basis of the tower.

Slope [2] is the crust surface with lateral airport surface geological body, is the general term for the slope, slope and lower depth of slope body. And base tower slope in mountainous area mainly includes formation of natural terrain consisting of natural slope and artificial excavation of slope engineering [3], as shown in Figure 1:

Fig.1 Natural slopes on the tower legs

2. Factors affecting slope stability

Many factors affect the slope stability, such as: the composition and structure of the slope rock mass, sliding surface, shear strength, water and fracture development status, etc.. This paper mainly discusses the influence of water on the stability of slope in the slope stability calculation. For the slope of the iron tower, rainfall is the most important external cause of the landslide, [4], water infiltration into the soil voids or rock cracks, will make the earth rock shear strength reduction, which led to the accident.

2.1 The influence of water on slope stability

The influence of water on slope stability has two forms: surface water will cause erosion of the rock mass, which can cause the loss of the lateral restraint or the supporting role of the bottom.

Soil in the slope is due to the rock's weathering, stripping, removal, and the formation of the geological role of the soil, and the depth of the soil, the soil is closely related to the soil, the more loose the surface soil. The surface erosion of [16] is that the water in the process of the surface flow of water in the process of the surface of the slope is more uniform. Therefore, the groundwater changes the physical, chemical and mechanical properties of the rock (soil), and also changes its physical, mechanical properties and chemical composition.

2.2 water on the physical function of rock mass

The water will cause the lubrication effect on the discontinuous boundary of the rock and soil. The friction of the water is reduced, and the shear stress increases along the discontinuity. Rock and soil will be softened and muddy, which is mainly manifested in the change of the physical shape of the filling material in the structural plane of the soil and rock mass.

2.3 The chemical action of water on rock and soil

Changing the mineral composition of rock and soil is the main chemical action of water on rock and soil, and it will affect the mechanical properties of rock and soil. Such as: ion exchange, dissolution and dissolution, hydration, hydrolysis, oxidation, reduction, etc..

2.4 The mechanical effect of water on rock mass

The mechanical properties of rock and soil are mainly influenced by the hydrostatic pressure and hydrodynamic pressure. By reducing the effective stress of rock and soil, the former can reduce the strength of rock and soil, and the hydrostatic pressure in the fractured rock can cause the further expansion and deformation; the latter is to reduce the shear strength of rock and soil.

To sum up, the water in the deformation and failure of slope has a pivotal role, is influencing the slope deformation failure and the stability of the important factors [5].

3. Analysis on slope stability of 3 transmission towers

There are two main approaches to the analysis of slope stability, the limit equilibrium method and numerical analysis method. In the process of calculating the limit equilibrium method, the stress strain relation of the soil itself is not considered in the process of calculation. The numerical analysis method overcomes this shortcoming, and provides the correct method for slope stability analysis. The finite element method of finite element strength reduction method can determine the safety factor to analyze the stability of the slope. In this paper, by using finite element method, effective strength reduction factor of FS on the mountain of transmission tower slope stability (including the effect of deformation displacement of slope, slope, slope plastic strain) was studied by using finite element software.

3.1 finite element strength reduction method

The so-called strength reduction, which is in the ideal elastic-plastic finite element method, the shear strength parameters of slope rock is gradually reduced until it reaches the state of failure, the program can be based on the elastic plastic calculation results are destroyed sliding surface, at the same time, the strength of the slope of the reserve security system F. So there is

$$C' = C / F \qquad (1\text{-}1)$$

$$\tan\varphi' = \tan\varphi / F \qquad (1\text{-}2)$$

Among them, the C and the initial cohesion and friction angle of the slope soil, C 'and the cohesion and friction angle of the soil after reduction.

For C and the strength reduction, the input slope model is calculated. With the increase of the strength reduction factor, the cohesion and friction angle decreases, the plastic strain increases and the plastic zone increases. When the plastic zone develops into a penetrating area, the slope is unstable, and the solution is not convergent at this time. At the same time, the horizontal displacement of the slope is also large. Therefore, the slope stability of the slope is determined by observing the plastic strain, plastic zone, displacement and convergence of postprocessing, until the program is not convergent.

3.2 calculating examples

The slope is shown in Figure 2, and the material properties of the soil layer are shown in Table 1. The stability of the slope is analyzed by the calculation and analysis.

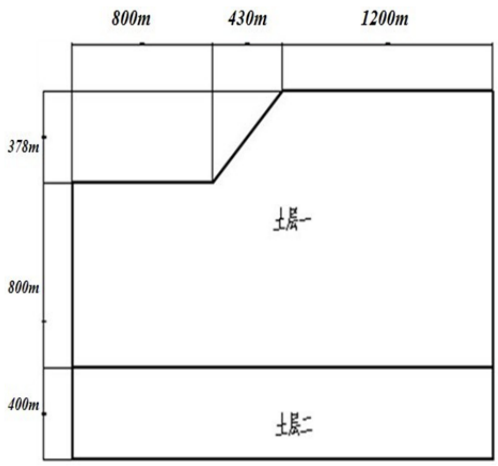

Fig.2 Slope calculation example

Because the slope is a long solid, the calculation model can be simplified as a plane strain problem. It is assumed that the external force of the slope does not change with the Z axis, and the displacement and strain are in the plane. For slope deformation and stability analysis, the plane assumption is reasonable.

In the model, the model can be used to simulate the deformation of the slope and the development of plastic zone.

The unit type is PLANE82, which is set up; the material properties of the soil layer one or two, and the material parameters of the soil layer are defined, and the soil parameters of F=1.2, F=1.4, F=1.8, F=2.2,, F=2.6, =2.8, F, F=3.0, F=2.4,,,, F=2.0,, F=1.6,,,,,, 1-1, 1-2. Specific values see table 2. When f = 1 is no reduction, to get the slope failure results, will be reduced after the parameters are substituted into the model to calculate, by the convergence of the procedure and does not converge to judge the stability of the slope. If the convergence of the program, the slope is stable, and vice versa.

First, the definition of material properties, such as elastic modulus, Poisson's ratio, density, etc., and then establish a good slope model, and its grid division, as shown in Figure 3, 4.

Then the constraint and load are applied to select all nodes on the boundary of the model, and the horizontal direction is applied to the horizontal direction. The displacement constraints are applied to the bottom of the slope, and the gravity acceleration is applied to the model.

Different strength reduction factors (corresponding to the material number) were calculated respectively.

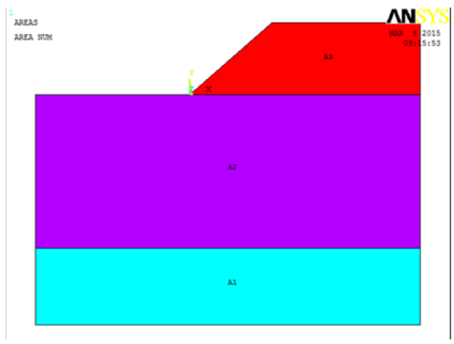

Fig.3 Variable slope model

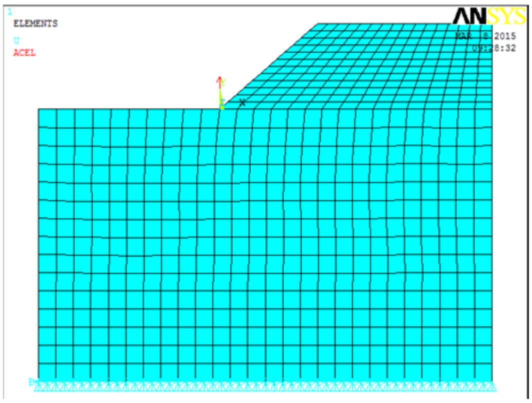

Fig.4 Slope model after applying constraint and gravity load

With the increase of the reduction factor, the plastic strain of the slope increases, and the plastic zone increases. When the plastic zone develops into a penetrating area, the instability of the slope will lead to the convergence, and the horizontal displacement of the slope will become larger. Therefore, we mainly through the observation of the slope of the slope of the plastic zone, plastic zone, displacement and convergence to determine the stability of the slope or not.

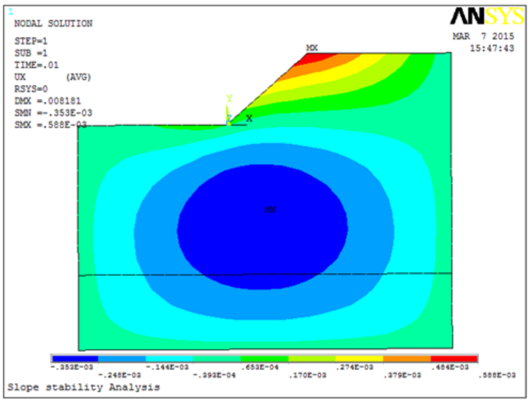

Fig.5 *X direction, F=1 direction of the upper moving cloud*

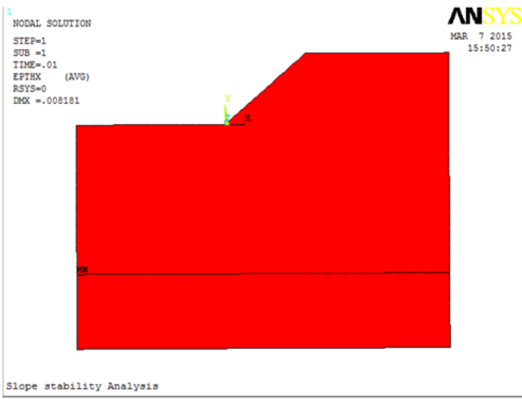

Fig.6 F=1, plastic strain cloud

From figure five, it can be seen that the maximum horizontal displacement is 5.88mm; from Figure 6, there is no plastic strain, no plastic zone, that is, at this time there is no plastic deformation of the slope.

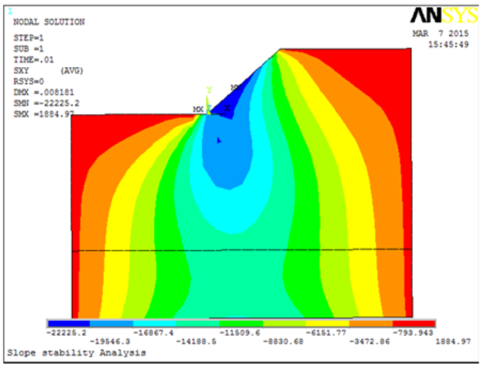

Figure 7 the average stress in the X-Y direction

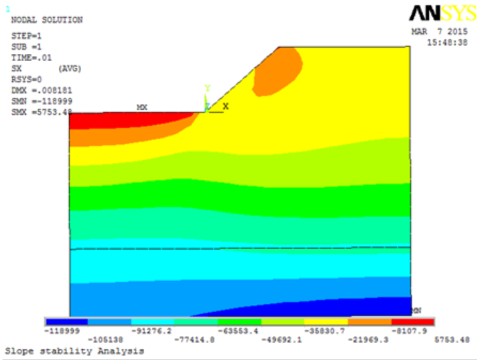

Figure 8 stress in X direction

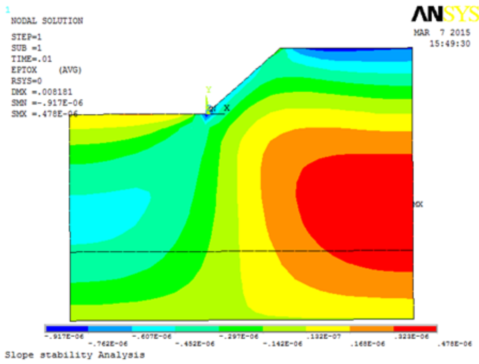

Figure 9 total pull in X direction

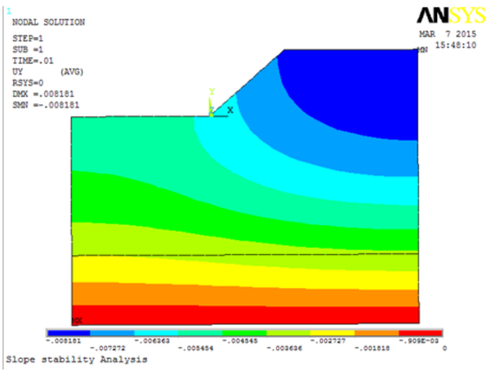

Fig. 10 displacement in Y direction

4. Conclusion

In this paper, by using the finite element method, the influence of the F on the maximum displacement and plastic strain of the slope of the mountain transmission tower is studied:

1) the increase of the precipitation and the increase of the water level of the water level, the mechanical properties of rock and soil, the cohesion and the friction angle decreases, the corresponding strength reduction coefficient is obtained.

2) with the increase of the strength reduction factor, the maximum displacement is slowly increasing, and then decreases slowly until the model is unstable.