The Site Selection Optimization of the Jointed Rock Masses Cavern in the Mountain with Different Slope Degree

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***Abstract*-A study on distribution characters of initial stress in the condition of gravity effect in the slopes within alp of which the slope angles poses 30°、45°、60° respectively were conducted by numerical analysis. After comparison, it is found that when closing to the region of slope surface, the difference of vertical stress between the value which are calculated by the direct buried depth and the actual value is huge. And the difference becomes huger with the slope becoming steeper. Then , a comparison has been made with excavating a cavern which poses 3 different positions separately at different distance from the slope toe in the condition of 45° slope angle and using the equivalent mechanical parameters of jointed rock mass to make numerical analysis to look the rock stability difference of the three schemes. It is found that the closer to slope surface (slope toe), the larger the plastic zone or the damage zone around the caverns becomes.**

Keywords: different slope degree, slope surface effect, initial stress, jointed rock mass, cavern stability

I INTRODUCTION

China is a mountainous country. Many underground projects of civil engineering and hydropower engineering are often excavated in alp valley area. Except at some major projects measuring the in-situ stress, most of them should evaluate the rock stability prior before construction. At this time the common method is evaluating or calculating the initial stress of the project area by calculating the direct buried depth (γh) over the cavern generally. Therefore, this article intend to study the distribution of initial stress in the mountain which poses different slop degree in the condition of gravity and with different lateral pressure coefficient of in-situ stress to explain that in some conditions the above common method to calculate σ_y will produce large error[1].

II THE DISTRIBUTION OF STRESS FIELD IN DIFFERENT SLOPE DEGREE OF AN ALP

Assuming the model is in a two-dimensional and under the plane strain condition, choosing the homogeneous elastic model to analysis and constraining the five boundaries of model contracted in one direction. Choosing 3 different slope degrees (30°、45°、60°) separately to analysis, the parameters as shown in table 1. In order to observe the value and the distribution characters of the vertical and the maximum stresses σyy and σmax in the mountain, two parameters are assumed[2]:

$$N_1 = \frac{\sigma_{\max}}{\gamma h} \quad (1)$$

$$N_2 = \frac{\sigma_{yy}}{\gamma h} \quad (2)$$

In which: σyy andσmax are the calculated vertical stress and the calculated maximum stress separately; γh is the value calculated by the direct vertical depth and the weight of rock.

TABLE 1: MECHANICAL PARAMETERS OF THE MODEL

No.	Density /[g/cm3]	Youngs Modulus/[GPa]	Poisson ratio
1	2610	18	0.21

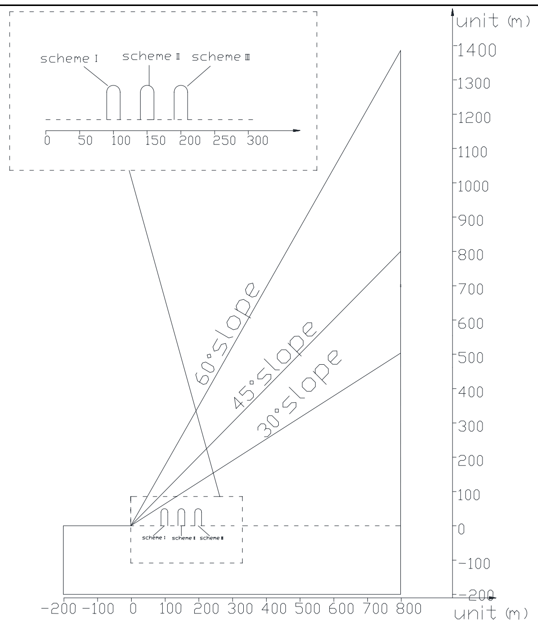

Fig.1: alpine slope with different degree

A. *The stress field in considering the gravity effect only*

When considering the gravity of mountain only, it is calculated while the slope poses 30°、45°、60°. Now choosing the stress at the horizontal elevation of 0 m in the mountain to analyze.

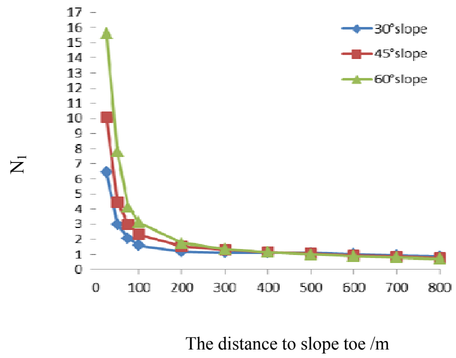

Fig.2: The value of N1 on the 0 m elevation in alps with different slope degrees

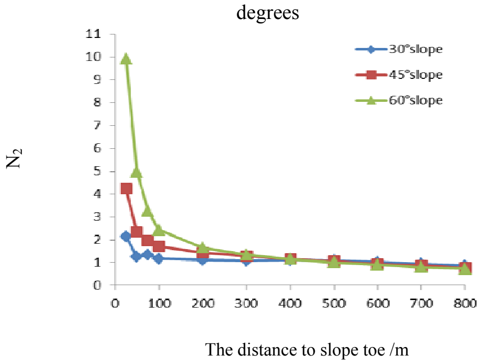

Fig.3: The value of N2 on the 0 m elevation in alps with different slope degrees

As shown in the figure 2、3, in the elevation of 0 m, within the distance of 100 m from the slope toe, the value of N1、N2 change greatly. Near the slope toe, the maximum value of N1 and N2 can be 16 and 10; In the range of 100 m-200 m distance belongs to transition region; Beyond the range of 200 m distance, the value of N1、N2 always around 1.

B. *The case of considering the additional horizontal stress based on the gravity effect*

When adding the additional horizontal tectonic stress by applying the body forces method in the foundation of considering gravity effect case an analysis. Assuming the lateral pressure coefficient is 1.5, choosing the stress distribution on the elevation of 0 m in the mountain to analyze.

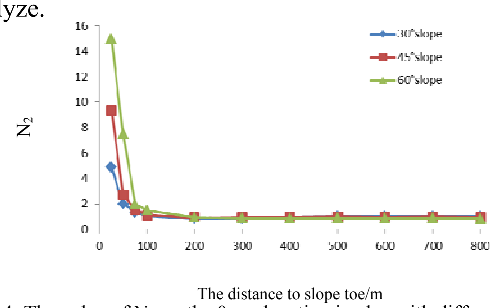

Fig.4: The value of N_2 on the 0 m elevation in alps with different slope degrees

Here only the distribution figure of N2 is presented, the distribution regulation of N1 is similar to N2.As shown in the figure 6, in the elevation of 0 m, with the effect of gravity and lateral stress coefficient of 1.5, within the distance of 100 m from the slope surface, the value of N1、N2 change greatly, the maximum value of N1、N2 can be 40 and 10; In the range of 100 m-200 m distance belongs to transition region; Beyond the range of 200 m distance, the value of N1、N2 always around 1.

It can be seen from the above, the nearer to the slope toe or the slope surface, due to the stress concentration or the slope surface effect, the larger N becomes. And as shown in the figure, this phenomenon in the slope of 60°is the most obvious, the slope of 45° takes the second place, however, in the slope of 30 the change of N is tempered obviously. It is indicated furthermore that the larger the lateral pressure coefficient is, the more obvious the increase of N1、N2 due to the slope surface effect.

III THE SITE SELECTION OPTIMIZATION OF THE JOINTED ROCK MASSES CAVERN IN THE MOUNTAIN

The jointed rock masses are a very familiar kind of complex rock masses. This section will reference the distribution model of the jointed rock masses to generate REV by stochastic method. Then proceeding loading test by numerical method to obtain the equivalent mechanical parameters.

A. *The parameters of the stochastic distributed jointed rock mass*

By site investigation and statistical analysis in a project, the distribution regularities of the jointed fracture characteristic parameters are obtained. Then programing composition to generate a series of stochastically distributed fracture grid specimens in different dimensions[3]; The mechanical parameters of unit body are assigned stochastically according to the gauss normal distribution in the same specimen. The generated specimen is shown as the follow figure. In the simulation, variation coefficient vis defined as the ratio of expected valueμand variance S to describe the discrete degree of normal distribution, that is:

$$\nu = \frac{S}{\mu} \qquad (3)$$

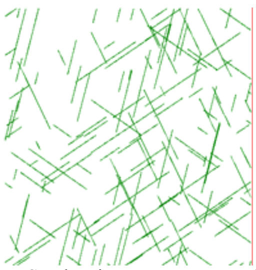

Fig.5: Stochastic Fracture Networks

Then analyzing the generated specimen by numerical method and simulating the compression test in the condition of different confining pressure to obtain the mohr envelope in quadratic form of specimen. The equivalent mechanical parameters in the condition with different confining pressure can be obtained by derivation of the mohr envelope in form:

$$\tau = C + k\sigma \tag{4}$$

In which, $k = \tan\Phi = \frac{d\tau}{d\sigma} = \frac{a}{2\sqrt{\tau_0 + a\sigma}}$,

$$C = \sqrt{\tau_0 + a\sigma} - \frac{a\sigma}{2\sqrt{\tau_0 + a\sigma}}$$

Φ is the internal friction angle of rock mass when $\sigma=\sigma i$, C is the cohesion of rock mass, $\tau 0$ is the tensile strength of rock mass, a is the fitting parameters.

Programing composition in FISH language which can assign automatically based on the stress state of the position where the unit is .

B. The site selection optimization of caverns.

Now the study of relationship between rock masses stability and different cavern position will be conducted. Assuming the cavern is 50 m in hight and 20 m in width and there are three different positions of the cavern which is excavated in four steps (as shown in the figure 10).

The site scheme Ⅰ.Ⅱ.Ⅲ are 100 m、150 m、200 m far from the slope toe separately.

It can be known from the result which has been calculated again based on the new equivalent mechanical parameters from above that the regularity of the stress distribution in different slope degree mountains as shown in section 1 is basically same as which in intact rock. The only difference is the detail value. In this section an analysis of cavern stability in slope of 45°using the equivalent mechanical parameters of jointed rock masses is conducted. The units of model are assigned according to the strength parameter of jointed rock masses (2). The cohesion and the internal friction angle can be obtained:

$$C = \sqrt{2.4265\sigma + 0.6063} - \frac{2.4265\sigma}{2\sqrt{2.4265\sigma + 0.6063}} \tag{4}$$

$$\tan\phi = \frac{2.4265}{2\sqrt{2.4265\sigma + 0.6063}} \tag{5}$$

The other mechanical parameters has been shown in the following table

TABLE 2: THE MECHANICAL PARAMETERS OF JOINTED ROCK MASSES

rock classification.	density /[g/cm3]	deformation modulus /[GPa]	poisson ratio	shear strength		tensile strength /[MP]
				Φ	c /[MPa]	
II	2610	3.17	0.2	assigned automatically		0.5

When the effect of mountain gravity is considered only, the plastic zones around caverns in different cavern positions are shown in figure 6.

It can be seen in figures follow, the plastic zones in schemes Ⅰ, Ⅱ, Ⅲ are 5179 m3 1559 m3 and 1450 m3 respectively. And it can be known that the closer to slope toe of the cavern, the larger the plastic zone becomes and the more disadvantageous to the stability of jointed rock masses. This result indicates that the normal calculation method—-which regards the weight of direct buried depth above cavern as the initial vertical stress—is incorrect within a certain distance to slope surface(slope toe).

When the lateral stress coefficient is of 1.5, the plastic zone in jointed rock masses becomes much larger. As the same, the plastic zone in scheme Ⅰ which is the nearest to slope toe is the largest.

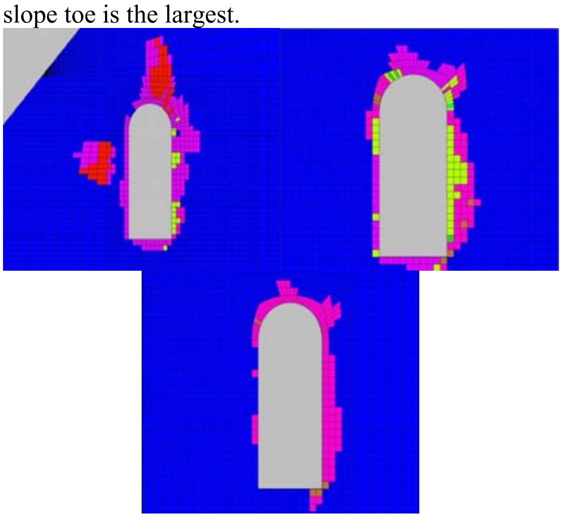

Fig.6: The distribution of plastic zone in scheme Ⅰ, Ⅱ, Ⅲ

IV CONCLUSION AND DISCUSSION

1. On the same elevation in mountain, from the slope surface to the inner mountain, when the slope is steeper, the stress within a distance of 100 m-200 m from slope surface is much larger than expected. Then the maximum stress experienced a process that the value of the max stress decreases in the beginning and then rises. And with the horizontal buried depth increasing, the stress approaches the value of $\sigma y=\gamma h$ gradually. And this regularity becomes more obvious with the slope becoming steeper. So when confirming the value of σy, the slope degree and the mountain height should be taken in consideration, and it is incorrect which calculates the vertical stress according to the vertical buried depth directly

2.Within the slope surface, when the cavern is excavated on the same horizontal elevation but different distance from the slope surface, the rock masses stability will be very different. In the same working condition, within the distance of 100 m-200 m, the closer the cavern is to slope toe, the larger the plastic zone or the damage zone becomes and the more worse to the stability of jointed rock masses.

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