The Stability Study and Simulation of Soil Landslide Based on Bishop Method

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Abstract: Landslide is one of the most common disasters in nature and is a kind of slope failure. Many countries in the world suffered, because of its wide distribution, frequent occurrence and great harm. In China, the national economy and people's lives and property suffer heavy losses due to the landslide disaster. In this paper, first of all, we used the Bishop method to theoretically analyze the stability of a landslide in Sichuan Province, and then we established a simulation model in Flac3D, the rock and soil mechanics calculation software developed by ITASCA company in the United States, to analyze the stability of the landslide under complex conditions. Finally, the results of theoretical analysis and simulation are consistent, which can provide ideas and methods for geological disaster prevention in the future.

Keywords: Landslide, Stability Analysis, Simulation Integration.

1. Introduction
Landslide is one of the most common geological disasters. It refers to the process and phenomenon of rock and soil body sliding down along a certain soft surface "as a whole" or keeping the structure of rock and soil body locally under the influence of natural geological action and human activities and other factors, as well as the geomorphic form it forms. Due to complex factors such as geology, topography and weather, landslides often slide or collapse due to their own instability, affecting the surrounding roads, Bridges and residential areas, causing great threat to the safety of people's lives and property.

Compared with other countries, Geological disasters occur frequently in China and are more harmful. According to the statistics of China Geological and Environmental Monitoring Institute, from 1995 to 2003, sudden geological disasters such as landslides and mud-rock flows caused 10,499 deaths and missing persons, 65,356 injuries and property losses of 5.75 billion yuan. The image below shows a massive landslide in Sichuan Province, China, as shown in the following figure:
Fig.1 A major landslide disaster in Sichuan Province, China.

Not only our country is deeply affected by landslide, but also many countries in the world are affected by landslide. Landslides are sudden natural disasters. Because sudden natural disasters are unpredictable and break out suddenly, it is often difficult to film them. Therefore, modeling, analysis and simulation are particularly important, which can help enhance people's understanding of natural disasters and help decision makers to take correct measures for disaster prevention and relief.

In this paper, we first used the Bishop method to theoretically analyze the stability of a landslide in Sichuan Province, and then established a simulation model in Flac3D, the rock and soil mechanics calculation software developed by ITASCA company in the United States, to analyze the stability of the landslide under complex conditions. Finally, the results of theoretical analysis and simulation are compared.

2. The methods of landslide stability analysis
First of all, this paper USES the Bishop method to calculate the slope stability or safety factor Fs, and then, according to the occurrence of rainfall, earthquake and finally analyze the stability of the landslide in three cases.

2.1. Bishop method
The Bishop method is a circular slide analysis method considering the interaction forces between soil strips in slope stability analysis. Based on the limit equilibrium principle, this method USES the soil as a rigid body to rotate around the canter of the circle, and calculates its sliding force and anti-sliding force separately. Finally, the stability and safety factor is obtained. The interaction force between the soil strips is considered in the calculation, which is an improved circular sliding method. This method takes into account the action of inter-strip forces and assumes that the resultant force between soil strips is horizontal, and the derived safety factor is expressed as follows:

$$F_s = \frac{\sum_{i=1}^{n} \beta \phi_i b_i + (w_i + u_i h_i) \gamma \phi_i}{\Sigma w_i \sin \phi_i + \Sigma Q_1 / R}$$

(1)

The $Q_1$ is the horizontal seismic force, and the vertical distance from $Q_1$ to the center of the rounded circle is $e_1$.

The model structure is shown below, as shown in the following fig. 2.
2.2. Stability analysis of landslide

After obtaining the stability degree of the slope or the safety factor $F_s$, we analyze the stability of the landslide in the following three cases:

① No rain/earthquake conditions

With $F_s$ as the standard to evaluate the slope stability, the lower the value, the greater the possibility of landslide.

② Under rainfall conditions

Rainfall mainly causes the change of cohesive force $c$ and friction Angle $\phi$. With the increase of soil moisture content $x$, both $c$ and $\phi$ tended to decrease, but their variation ranges were different. In this study, we believe that for every 20mm increase in rainfall, the $c$ value decreases by 0.001N more than the initial value (empirical value). Similarly, for every 20mm increase in rainfall, $\phi$ decreases by 5° more than the initial value (empirical value). Then, the slope stability is evaluated with the recalculated $F_s$ as the standard, and the lower the value, the greater the possibility of landslide.

③ Under seismic conditions

We define an indicator that is determined by both the critical acceleration and the seismic peak acceleration: the total plus velocity $a$.

$$a = \text{PGA} - a_c$$  \hspace{1cm} (2)

Determination of PGA: The corresponding relationship between seismic intensity and PGA of peak acceleration is as follows. Refer to China Earthquake Intensity Table (2016 edition, Tab. 1).

| Intensity | PGA (unit: m/s²) |
|-----------|------------------|
| I - IV | negligible | VIII: 25 (17.8~35.3) |
| V | 3.1 (2.2~4.4) | IX: 50.0 (35.4~70.7) |
| VI | 6.3 (4.5~8.9) | X: 100 (70.8~141.4) |
| VII | 12.5 (9.0~17.7) |

Tab.1 Corresponding Relationship between seismic intensity and PGA of peak Acceleration (unit m/s²).

Calculation of $a_c$: The sliding body is regarded as a rigid body. Assuming no deformation occurs inside the sliding body, finite displacement will occur when the external force exerted by the sliding body is greater than the critical acceleration. On the other hand, a slope can remain stable if it is not
subjected to critical acceleration. Generally speaking, the higher the critical acceleration value is, the greater the triggering external force it needs, and the more stable its performance in the earthquake will be.

\[ a_c = (F_s - 1)gsina \]  

Then, we selected a number of research areas in a landslide in Sichuan province, and calculated the time when the slide occurred, the safety coefficient, velocity, acceleration and other data of the region according to the above methods.

3. The Stability simulation of soil landslide

3.1. Establishment of three-dimensional landslide model

On the basis of the above analysis, we built a simulation 3D model in Flac3D, the rock and soil mechanics calculation software developed by ITASCA. The input of landslide model includes mesh mass, density parameters, gravity vector and sliding stress parameters.

The overall slope of the landslide body is steep, and the extension is longer, and the slope surface is uneven. There is a landslide platform, the area is not large, and there is no downward sloping and unlevelled phenomenon. There are springs, wetlands and new gullies on the surface of the landslide. As shown in fig.3, the blue part is the landslide body, and this part is the unstable place of the rock-soil structure; the green part is the relatively stable area of the landslide, which generally does not slide, and is called the sliding bed.

![Fig.3](image)

Fig.3 Slide body and slide bed.

The formation process of the landslide is divided into four stages:

① Creep deformation stage or landslide incubation stage. Under the long-term action of gravity, some rock (soil) bodies on the slope undergo slow, uniform and continuous micro-deformation, accompanied by local tensile shear failure. On the surface, tensile cracks appear at the back edge and widen and deepen, and intermittent shear cracks appear on both sides.

② Rapid deformation stage. With the development and interconnection of the intermittent fracture surface, the strength of the rock (soil) body is decreasing, the deformation rate of the rock (soil) body is increasing, the tensile crack surface at the back edge is deepening and broadening, the leading edge is uplifting, sometimes accompanied by tensile crack, and the deformation is also increasing sharply.

③ Sliding stage. When the sliding surface is fully connected, the skid resistance is significantly reduced, and the rock (soil) above the sliding surface slides out along the sliding surface.

④ Phase of gradual stabilization. With the loss of sliding energy, the sliding speed gradually decreases until the sliding stops and a new equilibrium is reached.

The above four stages are the general process of the landslide development. The model can simulate the mechanical behavior of soil, rock and other materials and analyze the plastic flow. The actual structure is fitted by adjusting the polyhedral elements in the three-dimensional mesh. The element material adopts linear or nonlinear constitutive model. Under the action of external forces, when the material has yield flow, the mesh can be deformed and shifted accordingly (large deformation mode). The model can simulate the plastic failure and flow of materials very accurately.
by using explicit Lagrangian algorithm and hybrid - discrete partitioning technique. Since there is no need to form a stiffness matrix, a large range of 3D problems can be solved based on a small memory space, as shown in the following fig. 4-6.

3.2. Parameter input and model solution
The input parameters of landslide model include the coordinate parameters (material) from p0 to p7 and the sliding bed (Bin) from p0 to p7. The coordinate frame is a rectangular coordinate system in meters in space. Then the group function is used to form the material and Bin into a whole, so as to facilitate the operation of the whole landslide.

Next, the parameters of the whole model are set. The setting of face ran plane and max edge value is to initialize the model. Then we parameterize the quality and density of the initial grid and assign the boundary conditions: constrain the boundary surfaces $x=0$ and $x=6$. Finally, the plane of the whole model is fixed.

For the whole model, the sliding effect can be achieved by changing the grave value of the final gravity vector. The figure below is the output result of landslide model when $\text{grave}=0,0,-13$.

4. Conclusion
In this paper, the stability of a landslide in Sichuan province is studied. First, the stability is analyzed theoretically by using the Bishop method, and then a simulation model is established in Flac3D, the rock and soil mechanics calculation software developed by ITASCA company in the United States, to analyze the stability of the landslide under complex conditions. Finally, the results of theoretical analysis and simulation are in good agreement. The technology can be used to display the deformation, displacement status and trend of geological disasters, provide ideas and data for the prevention and
control of geological disasters, and inform relevant departments to take timely protective measures to reduce the loss of life and property caused by landslide disasters.

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