ATLANTIS PRESS
Advances in Engineering Research, volume 164
8th International Conference on Manufacturing Science and Engineering (ICMSE 2018)

Study on Instability Probability of Xiaya River Slope Based on Monte-Carlo Method

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Keywords: Monte-Carlo method; Java language; Bishop method; landslide unstable; Probability

Abstract. Rainfall reduces the possibility of increasing landslide instability. In order to study the stability of landslides with multi-stage sliding surface under rainfall conditions, this paper studies the physical and mechanical properties of soils with different moisture contents through direct shear tests of unsaturated soils And then analyze the safety factor and the probability of instability under multi-stage landslide. However, the traditional methods for analyzing the stability of landslides are relatively definite and have certain limitations, and the uncertainties of landslides are not fully considered. Therefore, this paper takes Xiaya River landslide in Baoji City, Shaanxi Province as an example, and uses Monte-Carlo simulation method and Bishop method to analyze the safety factor and the probability of instability of the landslide under different moisture contents.

Introduction

The enhancement of human social activities and the deterioration of the environment have caused serious geological disasters in many parts of our country. According to statistics, there were 42,955 landslides in China from 2012 to 2016, accounting for 71.1% of the total number of geological disasters and the number of casualties was 3,217. Therefore, the analysis of landslide stability is of great significance. M. Fall[1] and others used a method of comprehensively evaluating the stability of natural slopes, and concluded that the landslide was affected by the nature of the soil, weathering and hydrogeological conditions. Qiu Haijun[2] and others put forward the concept of geometric scale diameter, and evaluated the landslide risk in northern Shaanxi from the quantity and scale of loess landslides. Zheng Jing[3] calculated the stability coefficient by arc sliding method and polyline sliding method, and divided the landslide into three grades according to the severity of consequences. Xu Qing et al[4] found that the safety factor calculated by the block element method and the limit equilibrium method are very close, and the finite element method is relatively small. The predecessors have made remarkable achievements. However, the current safety factor calculation mainly adopts limit equilibrium method[5], such as Fellenius method, Bishop method and unbalanced thrust method, etc These methods are simple in model and calculation formula , Can solve complex cross-sectional shape and consider a variety of loading forms. However, due to the complexity of rock and soil and the environmental impact of human engineering activities, there are still many uncertainties in the stability analysis, such as uncertainty of landslide mass, uncertainty of force, etc.[6-7].

In view of these uncertainties, combined with Monte-Carlo method, using MATLAB R2016a to generate lots of parameter which meet the conditions and brought into the Bishop formula. This calculation is different from the results obtained by the traditional method, it's more accurate. After calculating plenty of safety factors (1000 in the example), then find the mean and standard deviation of F, make a distribution law and find the probability of instability, and make an assessment finally. The method takes into account the variability of rock and soil mass, which can more objectively reflect the probability of landslide accidents.

Monte-Carlo slope stability analysis method

The traditional limit equilibrium method takes parameters of rock and soil as definite values, and then calculates the definite judgment index-safety factor. It ignores the variability of parameters, and the result is often inconsistent with the actual. Therefore, introduce the Monte-Carlo method to describe the randomness and variability of parameters, that is to use mathematical methods to simulate and generate stochastic parameters of rock and soil in time, put parameters into Bishop formula [8], and then come to specific analysis results. It fully considers randomness and dispersion of geotechnical parameters. Through random simulation process, the safety factor of landslide can be calculated. By numerical processing, the probability of instability can be analyzed, and the overall safety status of landslide can be more accurately and fully reflected. And Monte-Carlo method is simple, with the continuous improvement of the computer level, the number of simulation, the simulation accuracy is continuously improved, the corresponding calculation is more accurate and reliable.

As the safety factor can be regarded as the ratio of anti-skidding force and anti-skidding force, the slope is stable when F> 1; when F <1, the landslide is likely to slide down and is unstable. In some calculation results, the result of F <1 is M, and when the total number of result events N is large enough, the frequency can be approximated as probability and the probability of landslide instability can be obtained:

$$P_f=P(F<1)=M/N. \tag{1}$$

software implementation process

Because the Monte-Carlo method requires plenty of repeated calculations, it is a huge workload to directly calculate the safety factor by using a number of random c,φ values. Thereupon, a program for calculating the safety factor based on the Bishop method is compiled in this paper. The general idea is to write the Bishop formula corresponding code, so that the initial value of F is 1. Through the iterative process, the safety factor that meets the convergence condition is obtained.

Import files. This program is compiled according to the Bishop method, to calculate F, need to import c, φ, w equivalent, the specific import as follows: When selecting the file, only the parameters associated with the Bishop formula can be selected, otherwise there will be (test_1.frame , "Wrong file, please choose again") reminder. Load file refers to the selected parameters into the program, open the parameter file, c, φ, w and other parameters in the same way.

produce a safety factor F value.the core of the code as follows:

sum1 = sum2 = 0; / / initialize the numerator sum1 of the formula and the denominator sum2;

F = Fi; // Assign the value of Fi to F when the absolute value of F-Fi is greater than or equal to 0.01;

for (int j = 0; j <minData; j ++) / / This cycle is F formula, landslides will be divided into several blocks in this paper , which need to superimpose several times and each time the numerator and the denominator of the respective addition of the final result of the division F;

sum1 + = 1 / mi * 0.1 * ci [i] + wi [j] * Math.tan (Math.toRadians (fai [i]))); // sum1 is a numerator corresponding to the formula;

sum2 + = wi [j] * Math.sin (Math.toRadians (allFile [m1.get ("arfai.txt")] [j])); // sum2 is the denominator corresponding to the formula;

Fi = sum1 / sum2; // numerator denominator to get a Fi;

while (Math.abs (F-Fi)> 0.01); // When the absolute value of F-Fi is greater than 0.01, the do while loop will continue. That is, when the absolute value is less than 0.01, it will exit and out put a safety factor F value;

s + = Double.toString (F) + ""; / / Save the value of F, into the string S.

According to the above code, we can get 1000 safety factor F values of two landslide surfaces in natural condition and accord with convergence condition respectively.

Xiaya River landslide example

Landslide Geological Environment Background. Baoji City, Shaanxi Province, is located at the western end of the Wei River Plain. The slope body of Xiaya River landslide forms scarps and presents a saddle shape on the plane with 290m long and 210m wide. The relative height of the landslide is about 90m. The average slope is about 20 °[9]. Human activities, construction operations, extreme weather anomalies and other effects cause many landslides collapse and cracks. According to information and relevant literature, there are 4 soil layers of Xiaya River landslide totally, with the order from top to bottom as follows: (1) middle and upper Pleistocene loess on the surface, (2) Tertiary sand gravel Stone hard clay,(3) Tertiary sand gravel layer, (4) granite rock mass [9]. There are four sliding surfaces in the landslide. Since the probability of instability is mainly considered in this paper, the sliding velocities of the sliding surfaces of the third and fourth landslides in the literature are less than those of the first and second landslides, so it is not analyzed. Both primary and secondary slip surfaces are in middle and upper Pleistocene loess [9].

landslide parameters to determine. In this paper, the first and second landslides of Xiaya River are studied, and the bodies of the landslide are divided into blocks with a width of 0.1m. Using the Bishop method, the total length of the first landslide divided into 470 blocks is about 47m long . And the second landslide is about 84m long, divided into 840 blocks. Two landslides are shown in Figure 1.

In this paper, the internal friction angle and cohesion of rock and soil are taken as the parameters of variability, and other parameters are taken as the determined values. Through consulting data, it's considered that the shear strength index cohesion c and the internal friction angle φ have a great influence on the landslide stability in many elements of the soil, and are distributed normally . [10-13] Distribution diagram of secondary slip surface shown in Figure 2. The mean and standard deviation of statistical data shown in Table 1. Meanwhile, to make the calculation result fully and truly reflect the safety status of landslide, MATLAB is used to generate c, φ random sets of 1000 first-order and second-order slip surfaces according to the distribution law of soil c and φ [9] Value, part of the data shown in Table 2.

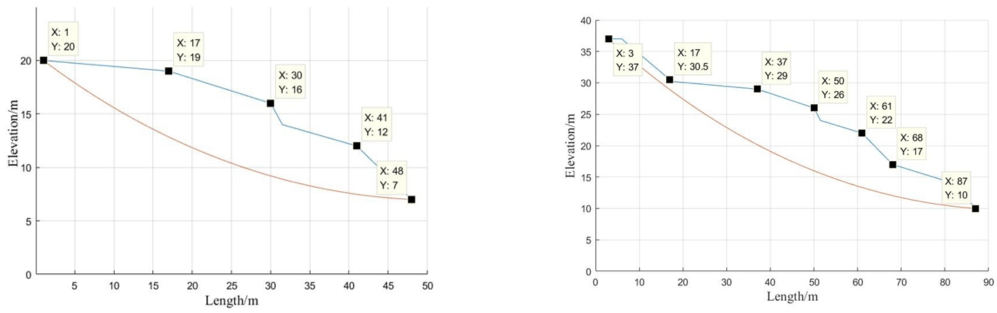

Fig.1 first-order (left) and secondary (right) slip surface of Xiaya River

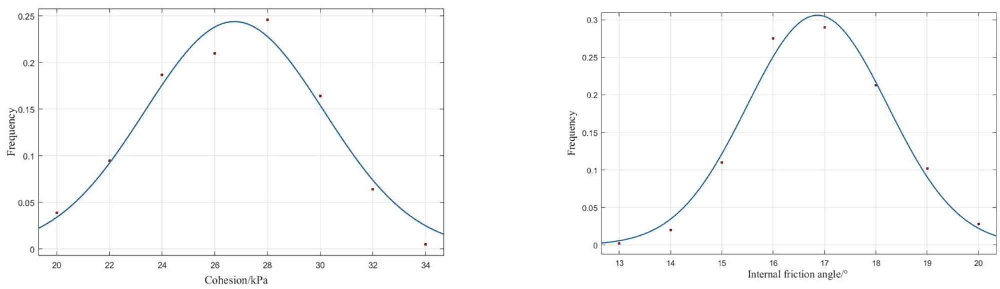

Fig. 2 Xiaya River secondary slip surface cohesion (left), internal friction angle (right) distribution

Table 1c, φ statistics of Xiaya River two slip surface

	cohesion c[kPa]		internal friction angle φ[°]	
	mean value μ	Standard deviation σ	mean value μ	standard deviation σ
first-order slip surface	29.6	5.36	16.3	1.87
secondary slip surface	27.7	3.25	17.5	1.37

Table 2 Xiaya River two slip surface part c, φ value

first-order slip surface		secondary slip surface	
cohesion c[kPa]	internal friction angle φ[°]	cohesion c[kPa]	internal friction angle φ[°]
27.973	14.356	30.860	17.499
21.286	13.100	34.037	19.171
……	……	……	……
35.019	16.224	25.225	18.825

Two-level landslide probability of failure calculation. The above analysis uses the idea of Monte-Carlo method to characterize the variability of soil parameters. Finally, the safety factor corresponding to each of the first-order and second-order slip surfaces is obtained through the Bishop formula. {F> = 1} is defined as a stable event, and {F <1} is defined as a destabilized event.

Use the formula to find the mean and standard deviation of F respectively:

$$\mu_F = \frac{1}{1000} \cdot \sum_{k=1}^{1000} F_k. \qquad (2)$$

$$\sigma_F = [\frac{1}{1000} \cdot \sum_{k=1}^{1000} (F_k - \mu_k)^2]^{\frac{1}{2}}. \qquad (3)$$

Bring the 1000 obtained safety factors into formula (1). The calculation results are shown in Table 3. The results show that first-order and the second-order slip surface instability probability is 19.4% and 13.3% respectively, to make a two-level sliding surface safety factor F value of the distribution of frequency maps, shown in Figure 3.

Table 3 Xiaya River two slip surface probability of instability

	mean value of stability (μ_F)	standard deviation of stability (σ_F)	probability of instability(P_f)	condition
first-order slip surface	1.12066	0.13701	19.4%	unstabl
Secondary slip surface	1.10026	0.08696	13.3%	unstabl

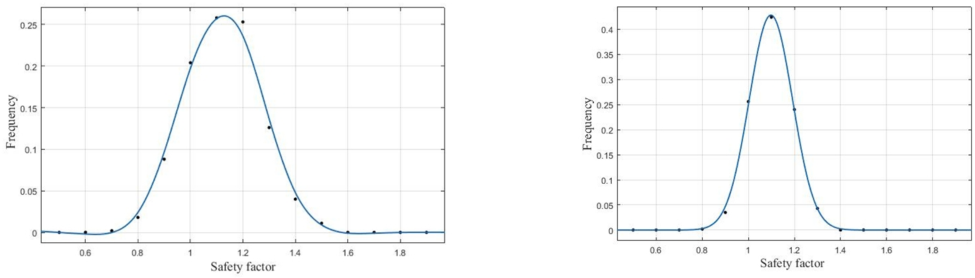

Fig. 3 safety factor distribution of
first-order (left) and secondary (right) slip surface of Xiaya River

Conclusions

1) Based on the Monte-Carlo method, this paper combines the Bishop method and JAVA language to analyze the probability of landslide instability, which greatly reduces the workload. Meanwhile, the method considers the variability of rock and soil mass and makes up for the shortcomings of ignoring the uncertainties of soil parameters when calculating the slope safety factor by traditional methods and can accurately reflect the probability of landslide accidents, which is more

practical than traditional deterministic parameter analysis method. The calculation results are more realistic and reliable.

2) It can be seen from the analysis of the calculation results in Table 4 that in the natural state, according to the mean value of the safety factors, the two-level landslide of Xiaya River is in an unstable state [2],but it's not known the unsteady specific value. Therefore,we can calculate the instability probability. It's found that there's a large risk of landslide and the probability of instability is greater than 10% for Two-level landslide, which equates with the actual slope of Xiaya River. The instability probability of the first sliding surface , which is the most dangerous one, is 19.4% and it needs to be evaluated by reference in practical engineering.

3) According to the mean and standard deviation of the stability in the calculation results, it's easy to see the mean of the stability of the two sliding surfaces are basically the same, respectively 1.12066 and 1.10026. While the standard deviations of stability are quite different, respectively 0.13701 and 0.08696. It can be seen that the safety coefficient of the second-level sliding surface is small and relatively stable under natural conditions. Meanwhile, the safety factor of the two-level landslide can be approximated as a normal distribution. The first-level sliding surface of the F distribution is more dispersed, that of second-level sliding surface is more intensive.

Acknowledgements

1, The project of the State Administration of Work Safety, key technologies for prevention of major accidents in production safety in 2017（sichuan-0004-2017AQ）

2, The key project of the education department of Sichuan Province（18ZA0407）

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