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OPTIMIZATION OF DESIGN PARAMETERS AND INTELLIGENT BACK-ANALYSIS OF HIGH BENCH DUMP SLOPE IN OPEN PIT

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ABSTRACT

Dump engineering is an important part in production processes of open-pit mining. In order to complete the mine production tasks smoothly, it is necessary to make the most of land possessed by the dump in an economical and reasonable way. In the paper, we use the dump of Qidashan iron mine which belongs to Anshan Iron and Steel Group as an engineering background to achieve the aim of improving the dump capacity. Basic on the limit equilibrium method to analysis on dump slope parameters which must be inversed in the displacement and back analysis, we constructed the Knowledge Base for the inversion of slope mechanical parameters by using orthogonal experiments and numerical simulation, and substituted the in-situ monitoring data after establishing the neural network prediction model. Then we inferred the equivalent mechanical parameters of scattered particles of dump, it can provide a reliable calculation parameters for slope design, thereby maximize the dump capacity and improve the open pit's economic benefits.

Keywords: *Dump, Slope Stability, Orthogonal Design, Intelligent Back-Analysis*

1. INTRODUCTION

At present, the stacking capacity per unit area of dump in the open pit of china is very behindhand, the dump has a low efficiency and covers a large area, it also has a low-grade reclamation rate[1~4]. With the tension of land resources, as the ever-increasing land price and the continuously improving environmental protection requirements, a higher requirement has had to be proposed which has a practical significance in reducing the costs, improving the stability, and protecting the environment for carrying out more and more researches on dump Optimization. In order to conduct optimization analysis of a slope, determining the slope mechanical parameters reasonably is the firstly necessary, and the physical mechanic character of loose body is very complex problems. How to determine the value of strength parameters reasonably still is an unsolved problem. The traditional soil mechanics research method is assumed that the land is simple isotropic body, and the soil layers are uniform. But the in-stiu researches prove that this kind of test method (drilling, sampling, indoor test, theoretical formula method) for this kind of complex system of granular media cannot achieve the ideal effect. The research object of modern science is involving in some very complicated system more and more, it cannot use the traditional methods to conduct the test research any more.

This paper based on the geotechnical data of Qidashan iron mine, and combined with the data and instructions in the field survey and design of dump, then performed a sensitivity analysis to determine the main factors which can produce more influence on the slope deformation and stability. After completed the estimated job, we conducted the displacement back analysis based on the orthogonal test to determine the equivalent mechanical parameters of slope body, it can give a reasonable slope mechanical parameters, increase the dump capacity and reduce the occupancy of land. As a result, it can save the operational costs of mine.

2. PARAMETER SENSITIVITY ANALYSIS OF THE DUMP SLOPE

Sensitivity analysis first appeared in the economic evaluation of the investment project. It often served as a method to study the uncertainty factors. Until the 1990s, it was gradually used in the

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slope engineering field. Sensitivity analysis generally chooses the main parameter of rock and soil to do this kind of analysis, such as weight degree, cohesive force, internal friction angle, groundwater, slope high, slope Angle, vibration, etc. If a small change of parameter can result in a great change of slope safety factor, we can call it sensitive factor, and on the contrary, it is a non sensitive factor [5-7].

Assume the slope safety factor Fs as the function of all the affecting factors, as follow:

$$F_s = f\left(x_1, x_2, \cdots, x_n\right) \tag{1}$$

The change rate of slope safety factor to the i affecting factor η can be expressed as follow:

$$\eta = \frac{\Delta F_s}{\Delta x_i} \tag{2}$$

So the sensitivity of the i affecting factor S_i can be expressed as follow:

$$S_i = \left|\frac{\Delta F_s}{F_s}\right| \bigg/ \left|\frac{\Delta x_i}{x_i}\right| \tag{3}$$

Where $\left|\Delta F_s / F_s\right|$ is the relative variable ratio of slope safety factor, $\left|\Delta x_i / x_i\right|$ is the affecting factor's relative variable ratio.

3. PARAMETER SENSITIVITY ANALYSIS OF THE DUMP SLOPE

Qidashan dump of Anshan mining company which belongs to Anshan Iron and Steel Group is located in the eastern suburbs of Anshan city in Liaoning province, about 14km away from Anshan city. The overall terrain of the diggings is high on the east and low on the west. The geomorphic unit in this area belongs to denuded hills, and the big elevation height is 202 m, the lowest elevation height is 38 m, 164 m elevation difference. Qidashan iron ore belongs to Anshan type sedimentary metamorphic ore bed of the early Sinian period, The main strata exposed in mining area are old metamorphic rock, mixed rock and some the base sex dike which belong to Anshan group of the Archean erathem and Liaohe group of the Proterozoic group.

In the dump area, the terrain is very simple; it had developed a kind of geomorphic unit called tectonic denuded hills. In the west side of the tape machine dump, the biggest soil accumulation level is 201.7 m, and the biggest soil stack height is 143.0 m. Origin time and lithologic characteristics were mainly taken into account in marking stratum, based on the rock outcrop observation, field original logging and indoor test. All the information about strata lithologic characteristics, thickness and distribution can be seen as follows: artificial accumulation, up the tape machine dump: it main stacking material is waste ore discharged from iron mine, and the main composition are quartz black mica sheet (hemp) rock, magnetic quartzite, inclined long Angle flash (film) rock and Archean gneissic granite; Plain fill: yellow soil, slightly dense, its material mainly composed of clay, sand and gravel soil, and mainly distributed in the dump slope foot. We used the Morgenstern-Price method to analysis the slope stability, we can get the stability analysis model of the slope section which is shown in figure 1, and calculation parameters see table 1:

Table 1 : Table Parameters

Name of rock and soil	Weight (kN/m^3)	Cohesion (kPa)	Angle (°)
Accumulation material	21.0	0.0	34.2
Quaternary strata	19.8	29.2	10.6
Bed rock	23.5	52.0	38.0

3.l Weight Degree Sensitivity Analysis

In the figure 1, we can know that the slope safety factor decrease gradually as long as the increase of weight degree of rock and soil. The safety factor is sensitive to the weight degree of rock and soil. The Fs-γ curve is a steep line, and the change rate of safety factor of soil is -0.008 KN/m^3, the sensitivity S has an average value of 0.162.

3.2 Cohesion Sensitivity Analysis

The figure 2 shows that slope safety factor increases slightly with increasing rock and soil cohesion. Safety factor is not sensitive to soil cohesion, Fs-c curve is approximately a straight line, the change rate is 0.0001/KPa, and the sensitivity S is 0.07.

3.3 Friction Angle Sensitivity Analysis

The figure 3 shows that slope safety factor increases with increasing rock and soil internal friction angle. Safety factor is very sensitive to soil internal friction angle, Fs-φ curve is a steep line, the change rate is 0.022/degree, and the sensitivity S is 0.46.

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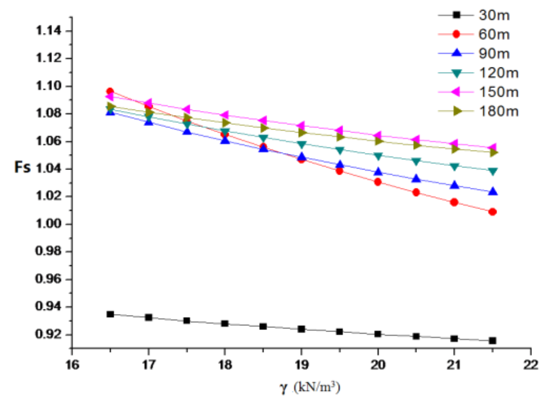

Figure 1 Fs-Γ Curve

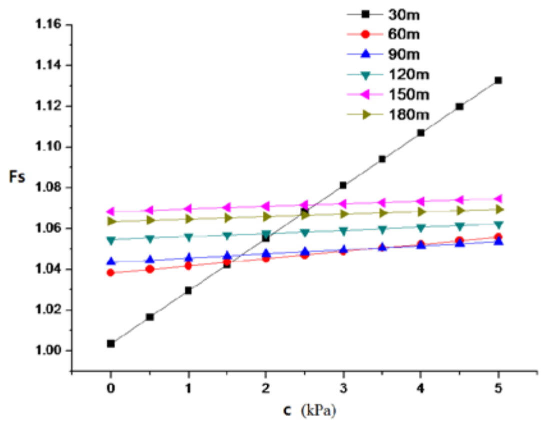

Figure 2 Fs-C Curve

We can get the conclusions as follows: each factor affects the change rate of slope safety factor quite different, the weight degree of rock and soil increase will reduces the slope safety factor, thereby reduces the degree of slope stability; however, the cohesion and internal friction angle of rock and soil increase will improve the slope safety factor, thereby increase slope stability.

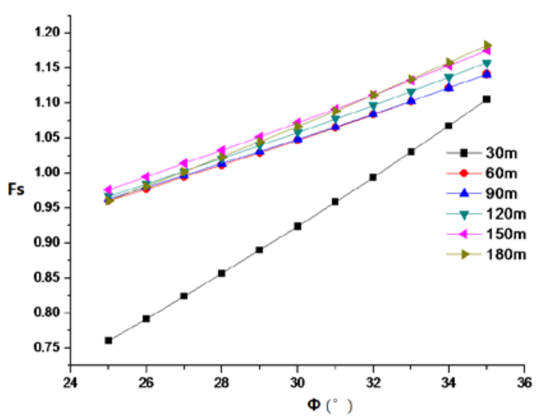

Figure 3 Fs-Φ Curve

4. INTELLIGENT BACK-ANALYSIS OF SLOPE MECHANICAL PARAMETERS BASED ON ORTHOGONAL EXPERIM-ENTAL

4.1 Orthogonal Experimental Design

Orthogonal experimental design method is an effective method used to carry out scientific arrangements and solve the problem of multi-factor test[8], it can pick out right amount of combinations which are typical and representative to arrange trial calculation from a large number of multi-parameter combinations, we can get the optimal solution by analyzing the test results got from a small number of test programs. Because the orthogonal table has the character of equilibrium dispersion and impartiality, we can find out optimal or better pilot program through a small amount of test, it very suitable for multi-factor and multi-level test. Through the parameters sensitivity analysis of the dump slope in Qidashan ore and measured data for many years that the sensitivity of the influence on slope deformation factors are elastic modulus, poisson ratio and Angle of internal friction, wait for inversion parameters variation range and value level see table 2 shows.

Table 2
Stay Inversion Mechanics Parameter Range

No	inversion parameters	Range	level			
1	E (MPa)	60-90	60	70	80	90
2	v	0.25-0.4	0.25	0.3	0.35	0.4
3	Φ (°)	32-38	32	34	36	38

4.2 Intelligent Back-Analysis

In slope stability analysis, the selection of rock mechanics parameters directly affects the results of calculation and analysis. The improper Parameters can cause the inaccurate calculation results or even diametrically opposite. The selection of mechanical parameters of rock mass have indoor rock mechanics test, in situ test and back analysis etc.[9] Indoor test results cannot be directly applied to the stability analysis of rock engineering. In situ test is reasonable, but usually affected by site conditions, and there are some unsolved technical problems, so in the actual project has not yet been widely used.[10] Through the measured data, the analysis of rock mass mechanical parameters to solve this problem is a kind of effective method. This paper considered the rock mechanics parameters of impact angle use the method of displacement back analysis study[11-12].

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Table 3: Neural Network Sample Library

No	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)
1	146.2	137.48	111.9	146.17	64.37
2	149.6	144.6	122.8	150	91.9
3	172.7	171.3	145.5	174.3	115.3
4	202.9	202.6	173.7	204.6	141.5
5	136.4	128.3	105.5	137.9	62.4
6	150.6	142.9	122.3	151.3	86.9
7	167.5	167.4	141.8	169.6	112.9
8	197.8	197.7	169.6	199.6	139.3
9	128.1	121.3	110.2	130.8	63.2
10	140.9	138.72	116.7	141.6	89.4
11	167.1	164.1	140.3	167.4	112.5
12	193.5	193.8	166.4	195.3	137.7
13	122.5	116.5	99.6	125.3	64.5
14	139.9	136.2	115.2	141.1	86.8
15	162.4	161	137.1	163.3	111.1
16	189.8	189.9	163.4	190.9	136.2

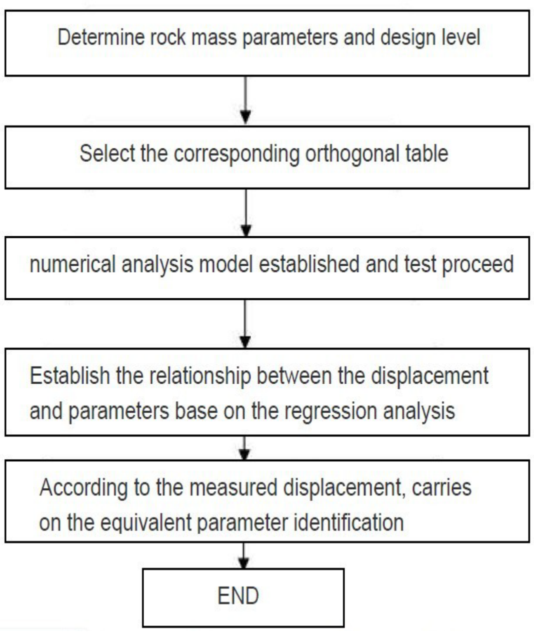

Figure 4: The Equivalent Parameter Identification Steps Based On The Orthogonal Numerical Test

This paper use genetic algorithm optimization, consider the nonlinear neural network capacity, combining these and forming the method of evolutionary neural network. Calculation process as follow: first of all, according to the QiDaShan iron ore mine engineering geological and exhaust soil conditions, create a three-dimensional numerical analysis model for constructing orthogonal test sample to calculate the slope surface displacement changes when the slope dump height is from 120 to 150m segmentation, tectonic neural network learning samples; Secondly, by means of genetic algorithm optimization of neural network structure, use learning good neural network of rock mass mechanics parameters optimized inversion; Finally, based on the actual measurement results as target, optimized the rock mass mechanics parameters. In order to validate the correctness of the mechanical parameters, compared dump dumps level 180 m in between the measured results and the surface displacement using the optimized mechanics parameter calculation results, evaluate its effect.

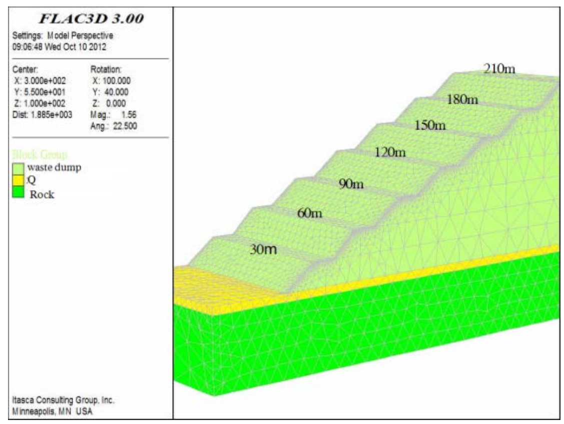

Figure 5: Calculation Model Diagram

Adopting the calculation procedures FLAC3D test and simulate the slope Heightening to 120 ~ 150m, the calculated results are shown in shown in the monitoring points A-E of Table 3.

Standardized sample data processing for the [0.2, 0.8] interval data, standardized algorithm:

$$x_i' = 0.2 + 0.6 \cdot \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \tag{4}$$

Where x_i' is Standardized data, x_i is the original data. $x_{\min} = \min\{x_i\}$, $x_{\max} = \max\{x_i\}$.

Using the genetic algorithm searching for optimal neural network model, obtain network inspection error function is:

$$\mathrm{F}(x) = \sqrt{\frac{1}{n}\sum_{1}^{n}\left\{\sum_{1}^{m}\left| f_{ij}(x) - u_{ij}\right|\right\}^2} \tag{5}$$

Type of $f_{ij}(x)$ is the j network output in the sample of i (i=1, 2… n, n is the total test sample). u_{ij} for the j sample expected output, m for the network output node number.

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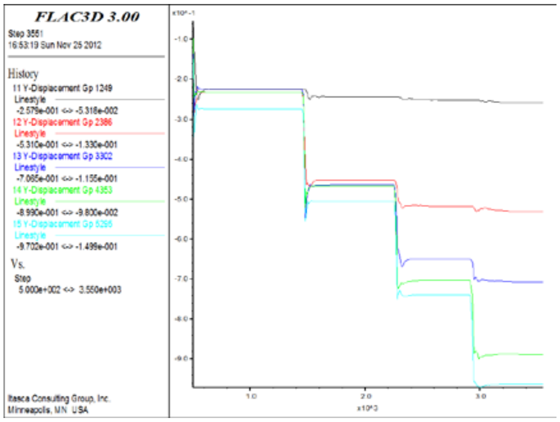

Figure 6: Monitoring Point Vertical Deformation Curve

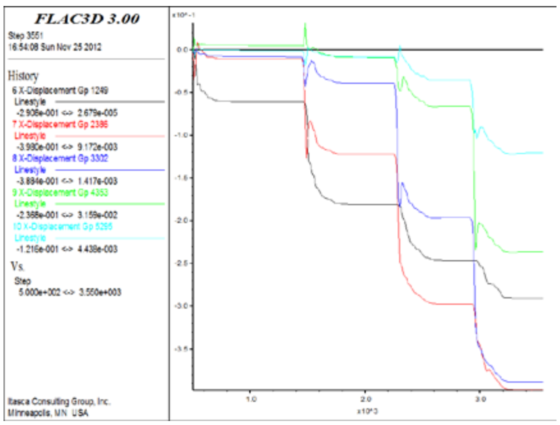

Figure 7: Monitoring Point Horizontal Deformation Curve

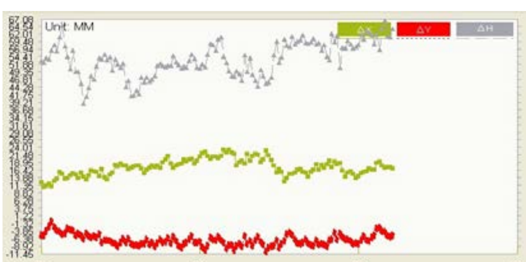

Figure 8: Field Monitoring Point A Deformation Curve

After Substituting the normalization of the training sample generation into the neural network, through the genetic algorithm search, found that structure for the 5-15-18-3 BP network to mapping relations approximation the best effect. Will the results generation into the BP neural network in train in until the network output error can satisfy the convergence criteria? After 275 times training, get dump are 68.56 MPa elastic modulus, poison's ratio 0.32, Angle of internal friction of 35.25°, the network output mean square error of 9.899 × 10-5, and the network error convergence speed faster, obtained with neural network model extrapolation, the optimization inversion mechanics parameters test.

Table 4

Mechanics Parameter Inversion Result Error Analysis

Monitoring point	A	B	C	D	E
Measured values (mm)	175.3	164.4	155.8	178.6	105.2
Calculation results (mm)	185.4	174.2	136.4	166.7	94.9
Relative error (%)	5.7	5.9	6.4	6.7	9.8

5. CONCLUSIONS

(1). Reasonable selection slope rock mass strength parameter is a crucial problem during the designing of slope. When the slope rock mass geological condition is a relatively complex problem, it is difficult to use the conventional methods to obtain the slope reinforcement mechanics parameter. On the contrary, using the mathematical statistic of orthogonal test to design with the corresponding numerical model for slope rock mass strength parameter inversion analysis, is a feasible method to solve the problems

(2). Thought the analysis of the degree of geotechnical weight, cohesive force and internal friction Angle sensitive factor, the internal friction Angle of soil slope row is the most sensitive, the cohesion have little influence in the slope stability. Therefore, dealing with the landslide, should pay more attention on the influence for slope body friction Angle on the slope safety factor, when necessary, can use support means, well blasting shock absorption measures to reduce the exhaust soil disturbance, ensuring the slope body friction Angle not great changes have taken place.

(3). By means of genetic algorithm for the optimization of neural network structure, with learning good neural network for rock mass mechanics parameters optimization inversion, the actual measurement results as target, the rock mass mechanics parameters optimization, through compared the dumps level 180 m in between the measured results and the surface displacement using the optimized mechanics parameter calculation results, to test the reliability of the optimization inversion mechanics parameters.

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