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Factors Affecting Slope Reinforcement Based on Data Mining Algorithm

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ABSTRACT

To change the design complexity of the conventional pile anchored bolt retaining wall, a method based on genetic algorithm was proposed to optimize the design of the retaining wall of the soil slope. According to the basic principle of genetic algorithm, a mathematical model for the optimization of double fulcrum pile anchor retaining wall was established. Taking the comprehensive cost per meter of anchor retaining wall as objective function, various strength and structural requirements of pile-anchor retaining wall were taken as constraints. Through the engineering example analysis, it was proved that the genetic algorithm can better solve the partial solution problem of traditional optimization. The design results show that this method can not only optimize the design variables intelligently, but also get a safe, reliable and cost-effective design. It is concluded that the slope reinforcement method based on data mining algorithm has some guiding significance for the optimization design of the whole bolt support structure.

INTRODUCTION

The slope is a common surface form. According to the lithology of the slope, it can be divided into two categories: rock slope and soil slope (Baek et al. 2015, Khawaj et al. 2018, Elsayed 2017, Howlader et al. 2018). The stability of soil slope is influenced by many factors, which can be divided into internal and external factors. The internal factors include the types and properties of rock and soil composing the slope, the geological structure of the slope, the slope shape and the groundwater. The external factors include vibration effect (earthquake), climatic conditions, weathering, vegetation, human engineering activities. At present, there are many methods of slope reinforcement, such as cutting slope and reducing load, drainage and water interception measures, reinforcement measures, concrete shear structure measures, retaining measures, slope reduction measures and plant frame slope protection (Lombardi 2017, Junior et al. 2019, Rahim et al. 2018).

In the slope treatment project, the principle of comprehensive treatment is emphasized, and the stability of the slope is strengthened. With the expansion of construction scale, the increase of slope height and complexity, the requirements for the slope treatment technology are also increasing. For example, the world-renowned Yangtze Three Gorges Project, with its two-lane continuous five-stage ship lock, is the largest ship lock in the world and is located in a rock cut at the top of a hill (Sonnenberg et al. 2017, Ramli & Md Zin 2018, Ali et al. 2018). The amount of earth and stone excavation is 37 million cubic meters, the height of the slope is more than 170 meters, and the lower part is a vertical dyke wall with the length of 50~60 m. Only 180 thousand anchors are used for slope reinforcement (Lin et al. 2015, Hussain et al. 2018, Indan et al. 2018). However, due to the influence of technology and environment, failure cases of slope management are also endless, which not only seriously damages the project itself, but also destroys the surrounding infrastructure and buildings. At the same time, it endangers the people's life and safety, and causes a large amount of property loss to the country. Therefore, it is of great significance to continuously improve the measures of slope control (Ai et al. 2015, Abd Rahim et al. 2018, Lijie & Feng 2018).

DESIGN MODEL OF PILE ANCHOR BOLT BASED ON MATLAB GENETIC ALGORITHM

In row piles support, the design of crown and baffle can be solved by structural design, and the cost of this part is relatively low. Therefore, it is not included in the optimization design scope. The analysis shows that there are many parameters affecting the design of pile support, but some are not the main control effect for the optimization target. Therefore, the following design variables are selected, including pile diameter (x1), centre pile distance (x2), pile embedded depth (x3), pile reinforcement cross-sectional area (x4), fulcrum position (x5), free segment length of bolt (x6), anchorage section length of bolt (x7), anchor bar diameter (x8), anchor

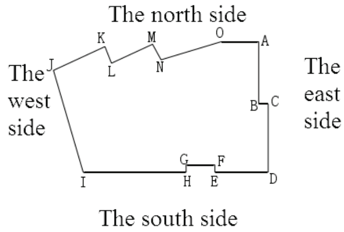

Fig. 1: Planar graph of foundation pit.

bar number (x9) and bolt diameter (x10). Therefore, the multidimensional optimization of 10 variables is studied, and the expression of the design variables is:

$$X=\left[x_1,x_2,x_3,x_4,x_5,x_6,x_7,x_8,x_9,x_{10}\right] \quad \ldots(1)$$

The project cost $c(x)$ of scheme X is multiplied by a certain coefficient a_t to characterize the impact of each target on the comprehensive cost C_t of engineering. That is,

$$C_t\left(X\right)=c\left(x\right)\cdot\left(a_1+a_2+a_3+a_4\right) \quad \ldots(2)$$

In the application process of genetic algorithm, a large number of programs need to be compiled for optimization calculation. Therefore, it may be inconvenient for different professionals to apply this method. MATLAB language is a highly efficient language for scientific engineering calculation. Its grammar rules are simple, and it is easy to understand learn. MATLAB software has a variety of professional toolboxes for professional applications. The genetic algorithm optimization toolbox is one of them. Among them, the more famous toolboxes are the toolbox GAOT developed by Chistopher Houck in Carolina State university of North American and the genetic algorithm toolbox GATBX developed by Peter Fleming in Sheffield University of UK. This article uses the latest MATLAB7.9.0 version released by MathWorks Company. This version adds the toolbox functionality further and adds processing for constraints. A M file that needs only a corresponding constraint function can be used to enhance its application function. The introduction of genetic algorithm and direct search toolbox based on MATLAB provides a more convenient and concise operation for solving problems in different professional fields by genetic algorithm.

There are two ways to use the MATLAB7.9.0 genetic algorithm toolbox. A genetic algorithm tool is used through a graphical user interface. The genetic algorithm function gap is called in the command line mode.

ENGINEERING EXAMPLE

General study: The project on the ground is 42 storey high-rise residential, with a total area of about 22.343325 m. The basement has three floors and the west side of the site is closed to the river. The structure form adopts the shear wall structure and the foundation form is the raft (Fig. 1). The area outside the main building adopts independent column base (Lee et al. 2017, Islam Molla et al. 2018, Khanchoul et al. 2018). The south side of the foundation ditch is the 3rd Ring Road. There is a green belt with the width of 10 m between the excavation line of the foundation pit and the road sidewalk of 3rd Ring Road. There is Fuhe River on the west side of the excavation line. The north side is a planned road and is now in a state of shut-down. The east side is Dongfeng Motor Corporation (Huang et al. 2017, Qiao 2018, Sufiyan et al. 2018), and there is a 20~15 m distance between the excavation line and the building.

The ground water is mainly the gap dive in the sand gravel layer, followed by the bedrock fissure water in the underlying bedrock. In addition, the local soil which has a small upper backwater. Ground water is mainly recharged by atmospheric precipitation and underground runoff, and is excreted by underground runoff, artificial exploitation and evaporation. During the survey, the stable water level of the ground water in the gravel layer is 4.20~5.60 m, and its water level is 484.26~484.81 m. According to the regional hydrogeological data, the ground water is abundant. The change range in the dry period is 1.5~2.5 m. The highest water level in the past year is about 2.50 m (the corresponding high level is 486.50 m).

Support design of foundation pit: In the commonly used form of foundation pit support, spray anchor support and row piles support are usually used. The ground-based information and on-site reconnaissance results show that the foundation soil of this project is based on pebble layer and backfill soil. The excavation line of the whole foundation pit is close to the planned red line. There is no slope condition. The foundation pit is 14.3 m and 13.3 m. Artificial excavation (Luo 2015, Ugwuowo et al. 2019) pile support and pre-stressed anchor cable plan and double row bolt support is adopted.

This project is mainly designed and calculated by the following methods: First, the internal force of retaining structure uses a continuous beam matrix displacement method. Second, the reinforcement calculation of bored cast-in-place

Table 1: Soil layer parameters.

Layer number	Soil name	Layer thickness	Density	Float density	Cohesive force	Internal friction angle	Anchor solid Frictional resistance	Cohesive force Underwater	Internal friction angle Underwater	Soil and water
1	Miscellaneous fill	1.65	17.0	10.0	5.00	15.00	17.0	5.00	15.00	
2	Plain fill	2.90	17.0	10.0	5.00	15.00	17.0	5.00	15.00	
3	Silt	1.60	19.0	10.0	45.00	20.00	40.0	45.00	20.00	
4	Fine sand	2.10	20.0	10.0	0.00	25.00	40.0	0.00	25.00	Separated calculation
5	Pebble soil	5.60	20.0	10.0	5.00	35.00	40.0	5.00	35.00	Separated calculation
6	Sandy soil	11.50	23.0	10.0	17.00	50.00	40.0	10.00	50.00	Separated calculation

pile adopts the segmented reinforcement method along the circular section and the length direction according to the bending moment. Third, the design of anchor bolt mainly includes the selection of anchor type and material, the section area of anchor, the length of anchorage section, the calculation of free section length and the stiffness calculation of anchor bolt. Forth, the Swedish strip method is used to calculate the overall stability. Fifth, the anti-overturning, anti-slip, anti-uplift and anti-piping operation are carried out.

In this paper, the north side slope is taken as an example, which is calculated as Fig. 2. The project does not do slope treatment. The pre-stressed anchor cable and pile support are used. The main soil parameters are shown in Table 1. The working condition coefficient of anchorage solid and stratum bonding is $\xi_1 = 1.33$. The slope engineering importance coefficient is $r_0 = 1.1$. The working condition coefficient of anchorage resistance is $\xi_2 = 0.92$. The strength grade of cement mortar is M30, and the grade of pile core concrete is C25. The design value of the bond strength between the steel strand and the mortar is $f_b = 2.95$. The pile reinforcement adopts HRB335. The strength standard value of steel strand is $f_{ptk} = 1860 N/mm^2$. The anchor angle is $\theta = 15°$.

Cost information: The comprehensive unit price of concrete is 380 yuan/m^3. The comprehensive unit price of column reinforced bar is 4000 yuan/ton. The integrated unit price of anchor bars is 5500 yuan/ton. The unit price of drill hole grouting is 150 yuan/m.

Optimization of analysis steps: Step 1: Based on the Prandtl earth pressure theory, the corresponding soil pressure calculation module is developed by MATLAB.

Step 2: The continuous beam method is used to prepare MATLAB pile internal force calculation module.

Step 3: The genetic algorithm toolbox (GADS) is used to optimize the pile retaining wall.

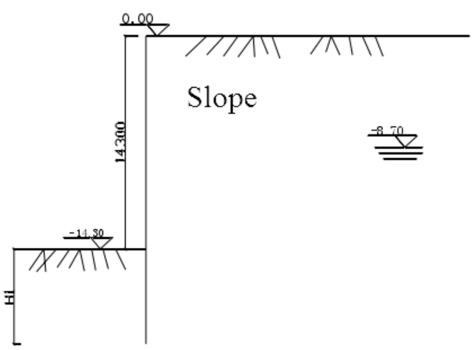

Fig. 2: Calculation sketch of soil pressure on the south side slope of foundation pit.

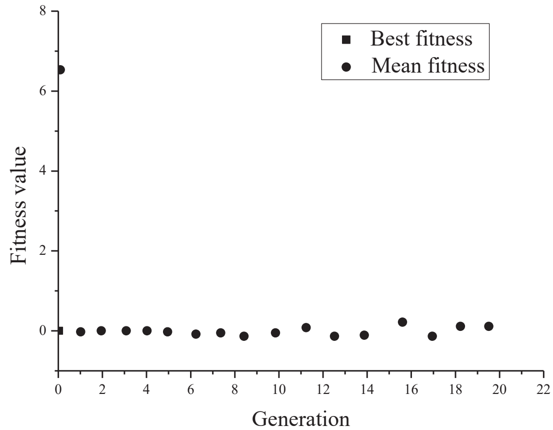

Fig. 3: Optimization of graphic output interface by genetic algorithm.

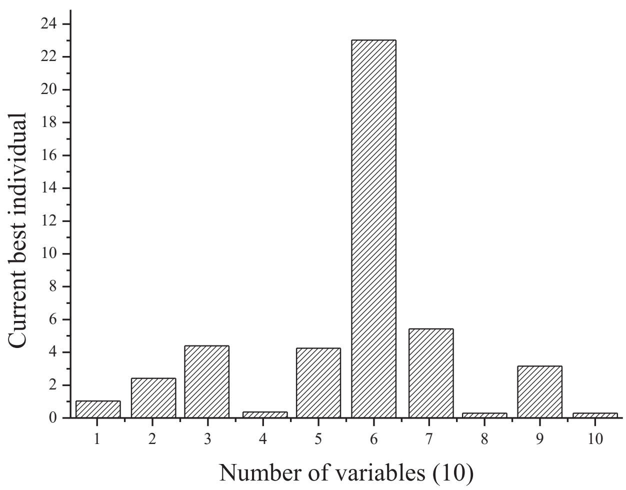

Fig. 4: Optimization of graphic output interface by genetic algorithm.

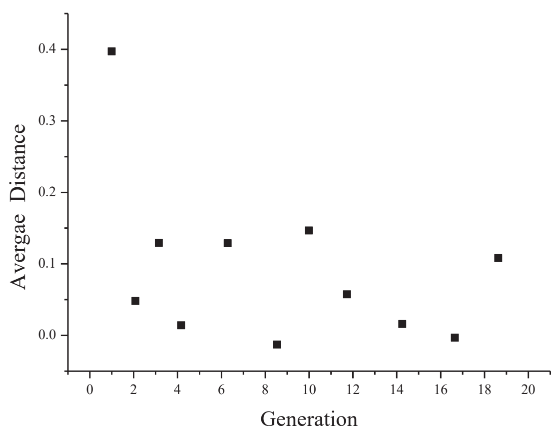

Fig. 5: Average distance between individuals.

Table 2: Optimization result comparison.

	x1 (m)	x2 (m)	x3 (m)	x4 (m)	x5 (m)	x6 (m)	x7 (m)	x8 (m)	x9 (number)	x10 (m)
Original design	1.00	3.00	4.00	0.0069	4.00	15.00	10.00	0.015	5	0.15
Optimal design	0.90	3.00	4.30	0.0058	4.50	22.92	5.78	0.016	3	0.15

Optimization results: The optimization results are shown in Figs. 3-5. The results of the optimization and the original design are compared in Table 2.

The comparison results show that compared with the original design, the pile diameter decreases. Although the embedded degree increases a little, the pile reinforcement is correspondingly reduced due to the reduction of the maximum bending moment of the pile under the fulcrum position. Compared to the original design, the free segment length of anchor increases, the anchorage length decreases more. In addition, the decrease of anchor reduces the engineering cost greatly.

By adjusting and optimizing the fulcrum location, row diameter, embedded depth and anchorage length, the comprehensive cost can be saved, and the internal force of pile body can be optimized. The optimization results are in good agreement with the measured data, which show that the optimization of the genetic algorithm for the pile anchor retaining wall is successful.

CONCLUSIONS

In this paper, a new soil pressure calculation theory is introduced and the Prandtl sliding surface formula for calculating the soil pressure is derived. The earth pressure calculation method is combined with the continuous beam matrix displacement method for calculating the pile-anchor supporting structure. The MATLAB programming is used in engineering examples to calculate the internal force of row piles. Finally, with the combination of MATLAB genetic algorithm, the optimization design of pile bolt retaining wall is realized by MATLAB genetic algorithm toolbox. After a series of calculations, the following conclusions are drawn. The Prandtl sliding surface formula for calculating the soil pressure is a supplement to the classical earth pressure theory, which can be more accurate to calculate the actual conditions of soil pressure. The internal force of the supporting structure calculated by this method is less than the result calculated by the traditional soil pressure method, and the optimization aim is also achieved to a certain extent. The support structure optimization of pile anchor retaining wall with the engineering cost as a goal is a multi-objective problem. Based on the analytic hierarchy process, the weight coefficient is introduced, and the support structure optimization is transformed into a single objective optimization problem, which achieves the purpose of comprehensive cost optimization. Compared with the traditional optimization method, the genetic algorithm has a large search range and is not easy to fall into the local optimal solution. This optimization can not only save the cost, but also reduce the internal force and displacement of the pile. It is an effective method to optimize the design of slope support structure.

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