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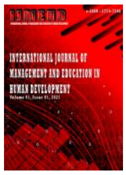

The Stability of Plant Root-Soil Slope

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ABSTRACT

In this paper, taking a highway in Guangxi as the research background, it is proposed to use the vegetation root system to reinforce the road slope. However, the design method of the vegetation root system reinforcement slope is not yet mature. Therefore, this paper attempts to carry out experimental research on the strength parameters of plant root-soil, to provide valuable experimental data for the design of vegetation-reinforced slopes. Combined with the traditional slope stability analysis method, the design calculation method of the slope reinforced by plant roots is finally obtained. Therefore, based on the climate and soil conditions in Guangxi, this paper selects suitable slope protection plants according to local conditions and then conducts a direct shear test to determine the cohesion and internal friction angle of the plant root-soil composite soil. Using the arc strip method, like Lizheng software, and the BP neural network method, the strength parameters of the root-soil are input, and the stability of the slope is checked, so the design calculation method of plant root reinforcement slope is obtained.

Keywords: *Slope Stability, Root-Soil, Direct Shear Test, Strength Parameters*

I. INTRODUCTION

Slope ecological protection is the most common form of slope protection currently used for slopes. It is widely used in various projects such as highways, railways, and water conservancy projects[1]. It is widely used in various rock slopes and soil slopes. Because this form of protection not only has the direct advantages of low cost, material saving, and short construction period, but also has great indirect effects on ecological protection, soil erosion control, and beautification of the environment, so it has been widely promoted at home and abroad[2]. The use of ecological protection slopes has been recorded since the Middle Ages, but it was not widely used until the middle of the 20th century. At present, the country with the most advanced technology is Japan, and my country is relatively late in adopting this technology[3]. Before the 1990s, my country was still using traditional ecological slope protection methods such as sowing grass seeds on slopes, sowing in holes or furrows, laying turf, and planting grass on rubble skeletons. This technology was not widely used in my country until recent decades. Although the ecological protection technology is widely used, its application in areas with steep slopes, poor soil quality and high rainfall still has certain limitations[4]. Growth and expansion, its role in slope reinforcement and mitigation of slope erosion will become more and more significant. However, this reinforcement method is limited to the shallow layer of the slope, so the research on the stability of the shallow layer has become the core content of the research on the protection form.

Plant protection is to use the covering effect of vegetation on the slope and the reinforcing effect of plant roots on the slope to protect the slope from the erosion of atmospheric precipitation and surface runoff, so as to achieve the effect of strengthening the slope and protecting the ecology[5]. Plant protection has limitations, that is, it can only prevent slope erosion and surface soil slump, and in the case of slope instability or concentrated water flow, slope slump and water damage may still occur. Plant protection must be used on the basis of slope stability, or combined with engineering protection technology.Many domestic studies have also been done on plant protection. Among them, Wang Kejun and Li Zhuofen[6] discussed the relationship between the tensile properties of tree roots, the relationship between growth direction and soil slope stability, the joint action of slope-fixing plants and artificial structures and the applicable conditions for slope-fixing plants; Yang Huilin, Li Jin et al[9] analyzed the vegetation slope protection mechanism of loess subgrade slopes, and gave the reinforced soil mechanics model of herb and woody plant roots and the calculation method of vegetation slope protection in geocells; Liang Wei, Gao Debin, etc.[10]expounded the action mechanism of three-dimensional net grass planting slope protection, and demonstrated its protective effect on the loess road cutting slope through field scouring tests. In addition, Gao Debin, Chen Zengjian, etc. [11] also analyzed the erosion mechanism of rainfall on exposed loess road cutting slopes and the slope protection effect of spraying and planting grass on thick substrates. Due to the lack of plant nutrients, the existence of dry soil layer, and the evolution of slope protection vegetation, the problems of survival rate and degradation of artificially built vegetation (especially in the Loess Plateau or areas with poor soil quality) are prevalent, plus the cost of plant protection. The continuous rise has led to an increase in the overall cost of protection. These are problems that need to be studied and solved urgently.

II. RESEARCH METHOD

Based on the climate and soil conditions in Guangxi, selects suitable slope protection plants according to local conditions, and then conducts a direct shear test to determine the cohesion and internal friction angle of the plant root-soil composite soil. Using the arc strip method (Lizheng software) and the BP neural network method, the strength parameters of the root soil are input, and the stability of the slope is checked.

III. DISCUSSION

3.1 Selection of slope protection plants

3.1.1 Requirements for ecological slope protection plants

The conditions that the road slope vegetation should have: ① Adapt to the local climate and have strong drought resistance. ②The root system is developed and the expansion is strong. ③It is resistant to barrenness and extensive management. ④The seeds are abundant, the hair pressure is strong, and it is easy to update. ⑤ Long green period, perennial. ⑥ It is easy to raise seedlings and can multiply in large numbers. ⑦The period of sowing and planting is longer.

3.1.2 Common slope protection plants in different regions

According to the adaptability of various grass species to seasonal temperature changes, it can be divided into warm season type and cool season type. Cool-season grasses are more cold-tolerant, but less heat- and cold-tolerant. The warm-season grasses are more heat-resistant and drought-tolerant, but not cold-resistant. They use underground stems or stolons for winter, and their management is more extensive than that of cool-season grasses.

Table 1 Main Slope Protection Plants

Area	Cool Season Lawn Plants	Warm Season Lawn Plants
North China	Reed fescue, woodland grass, grass grass, Canadian grass grass, small crown flower, white clover	Zoysia
Northeast	Bison grass, purple fescue, stolon grass, woodland grass, grass grass, Canadian grass	Zoysia
Northwest	Bison grass, purple fescue, fescue, reed fescue, woodland grass, grass grass, white grass, Canada grass, grass grass, small bran grass, stolon clipping grass, different ear moss grass, small crown flower, white clover	Zoysia, bermudagrass (warm place)
Southwest	Fescue, reed fescue, purple fescue, grass grass, Canada grass, grass grass, well-off grass, perennial ryegrass, small crown flower, white clover	Bermudagrass, False Thrift, Zoysia
East China	Purple fescue, grass cooked grass, grass cooked grass, small bran grass, stolon clipping	bermudagrass, shamrock, zoysia, zoysia serrata, zoysia sinensis, manila grass, bahi grass
Central China	Fescue, purple fescue, grass cooked grass, grass cooked grass, small bran grass, stolon clipping, small crown flower	bermudagrass, shamrock, zoysia, zoysia serrata, manila zoysia, bahi grass
South China	no	Bermudagrass, Zoysia serrata, Carpetgrass, Pseudomonas, Zoysia, Manila Zoysia, Zoysia sinensis, Bahi grass

3.1.3 Suitable plant species

(1) Fescue

Figure 1 Fescue Diagram

Herbs perennial, densely clumps, intrathecally branched. Its culm is ribbed, slender, erect. Fescue lawn is a more popular cool-season lawn. Fescue has deep root system, medium green color and soft leaves. It not only has strong adaptability and high ornamental value, but also is resistant to drought, trampling/pruning, long green period.

(2) Bermudagrass

Figure 2 Bermudagrass Diagram

Bermudagrass has a strong rhizome spreading power, and it is widely spread on the ground. It is a good soil-retaining plant whcih often used to build bermudagrass lawns or fields. It is a harmful weed that is difficult to eliminate when it grows in orchards or cultivated land. It is found in warm regions of the world. The rhizome can be fed to pigs, and cows, horses, rabbits, chickens, etc. like to eat its leaves; the whole plant can be used as medicine, which has the effects of clearing blood, antipyretic and muscle regeneration. The bermudagrass has a well-developed root system and a large number of roots, which is a good soil and water conservation plant.

(3) Zoysia

Figure 3 Sketch Of The Knot

Perennial herb. With transverse rhizomes, fibrous roots are thin. The culm is erect, 120 cm high, and often has persistent withered leaf sheaths at the base. Zoysia grass has the advantages of resistance to trampling, good elasticity, strong regeneration, less pests and diseases, easy maintenance and management, and long life. It is widely used in sports lawns all over China.

3.1.4 Comprehensive selection

According to the actual situation of a highway slope in Guangxi, Zoysia japonica is selected as the slope protection plant. The advantages of Zoysia as a slope protection plant are that the root system is developed, it is convenient for on-site construction, it is suitable for the local climate, and it is a perennial herb with a long green period.

3.2 Root shear resistance test

3.2.1 Different kinds of soil tests

Experiments were carried out with different soils to find out the best soil types under the combined action of plant roots.The soil samples used in this experiment were laboratory sand (100g as quantitative), laboratory red clay (using the ring knife sampling method), and natural soil (ring knife sampling).

3.2.2 Experiment preparation stage

1) Collection of samples

Zoysia, natural soil collected near school

Figure 4 Soil Sample And Sketch Map

(2) Treatment of Zoysia Root

Figure 5 Zoysia Root System Diagram

The root length of Zoysia japonica was measured and the result was 5-16cm. Cut the root system to a length of about 2cm with a ring knife and set aside for later use.

3.2.3 Experiment development stage

1) Laboratory sand

① Sieve, pass the laboratory sand through a 2mm sieve for use ②Weigh 6 parts of laboratory sand with a mass of 100g and divide them into two groups of three. ③Put 6 parts of sand into the ring knife to level the surface. It was found that the 100g mass soil sample was just put into the ring knife.④ Insert the roots of Zoysia japonica into three soil samples, each with 20 roots. The insertion method is vertical insertion. ⑤ Carry out the direct reduction test, fix the soil sample without root system in the ring knife to the instrument, and carry out the direct reduction test of 50Mpa, 100Mpa and 150Mpa vertical pressure respectively. ⑥ Carry out the test on the soil samples containing the roots of zoysia japonica by the same procedure. ⑦Record data.

Figure 6 Sand Sample Map

(2) Laboratory red clay

① Hammer the laboratory red clay part into small clods. ② Put the red clay into the laboratory drying apparatus to dry for a whole day and night for use ((The dryer can only be opened at a high temperature, that is, the set 100 degrees celsius, and cannot be dried by wind). ③ At this time, the soil moisture content is 0. After drying, the soil samples were hammered and crushed as much as possible. ④ Pass the soil through a 0.5mm sieve. ⑤ Calculate the amount of water added. The detailed steps are as follows:

Query the geological prospecting report: local water content ω=20.46% The formula for calculating moisture content is:

$$\omega = \frac{m_w}{m_s}$$

After drying, the soil moisture content is 0, and the measured mass is 5912.8g. Then it can be calculated that the amount of water added is 1209.76g

⑥ Use a watering can to evenly humidify the soil, completely seal the humidified soil sample with a plastic film, and leave it for a day and night for use. ⑦ Take samples with a ring knife, take 6 parts, and divide them into two groups, one group of three. ⑧In the same way as above, insert it into the root system of Zoysia japonica, and carry out the direct reduction test of 50Mpa, 100Mpa and 150Mpa. ⑨ Record data.

Figure 7 Experimental Measures Diagram

(3) Natural soil

①Sampling with a ring knife at the root system of Zoysia japonica. (Three servings with roots, three servings without roots) ②Weigh the quality of the ring knife (with soil) to ensure that the quality of each soil sample is similar. ③ Carry out the test directly, the steps are the same as above. ④Record data.

Figure 8. The Natural Root System Collected By The Ring Knife

3.2.4 Data processing stage

Record the experimental data into a table and fit it into a curve through Excel, you can clearly see the changes in the cohesion and friction angle generated by the combination of different soils and plant roots.

(1) Laboratory sand（Data are as follows:）

Table 2 Laboratory sand experiment data sheet

Natural soil Ring knife sampling M4642 c=1.941			
1) Direct shear test of rootless soil		2) 20 zoysia roots inserted vertically	
vertical stress	Displacement meter reading	vertical stress	Displacement meter reading
50	9	50	10
100	13	100	18
150	18	150	20

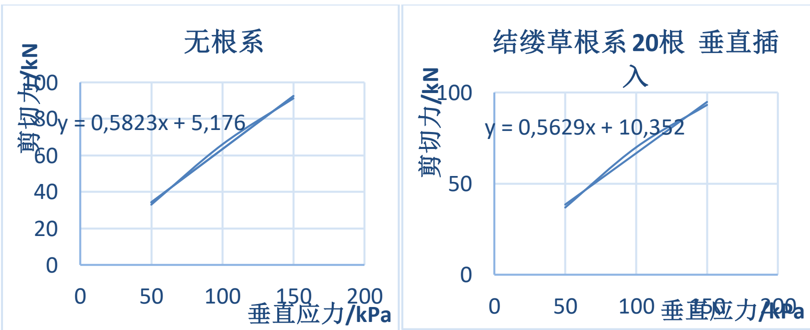

Figure 9/10 Laboratory Sand Experiment

The slope of the trend line is the tan value of the internal friction angle, the tan function is a monotonically increasing function in a fixed period, and the intercept is the cohesion c. Then we can see that the cohesion c value of the soil inserted into the root system increases, while the internal friction angle decreases. By fitting the data, we can get that when no root system is added, the cohesion of the sand is 5.176KN, and the tangent of the friction angle is 0.5823.Similarly, the cohesion of sand with 20 zoysia roots is 10.352, and the tangent of the friction angle is 0.5629. Investigating the reason, looking for relevant information, it is found that the cohesion of the laboratory sand increases, while the internal friction angle decreases because the sand is relatively dispersed and cannot form a frictional relationship with the root system.

(2) Laboratory red clay（The experimental data are as follows:）

Red clay Ring knife sampling M4642 c=1.941			
1) Direct shear test of rootless soil		2) 20 zoysia roots inserted vertically	
vertical stress	Displacement meter reading	vertical stress	Displacement meter reading
50	23	50	23
100	43	100	50
150	64	150	68

Table 3 Experimental Data Table Of Red Clay

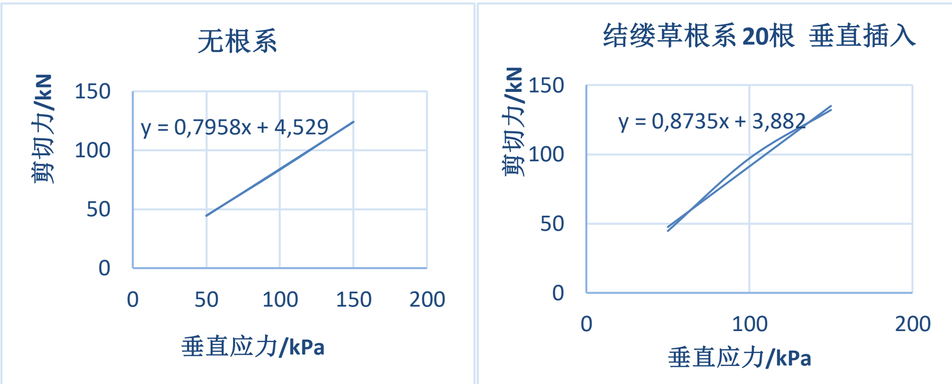

Figure 10/11 Experimental Map Of Red Clay

By fitting the curve in the figure, the equation of the fitting curve is obtained, from which it can be seen that the cohesion c value of the soil inserted into the root system decreases, while the internal friction angle increases. By fitting the data, we can get that the cohesive force of the red clay is 4.529KN and the tangent value of the friction angle is 0.7985 when no root system is added.Similarly, the cohesion of the red clay with 20 zoysia roots is 3.882, and the tangent of the friction angle is 0.8735. The cohesion is doubled and the internal friction angle is slightly reduced. Experimental results of laboratory red clay showed that the root system shifted along the shear direction. The reason is that the soil cannot anchor the root system.

(3) Natural soil（The experimental data are as follows:）

Table 4 Data sheet of natural soil experiment

Natural soil Ring knife sampling M4642 c=1.941			
1) Direct shear test of rootless soil		2) 20 zoysia roots inserted vertically	
vertical stress	Displacement meter reading	vertical stress	Displacement meter reading
50	9	50	10
100	13	100	18
150	18	150	20

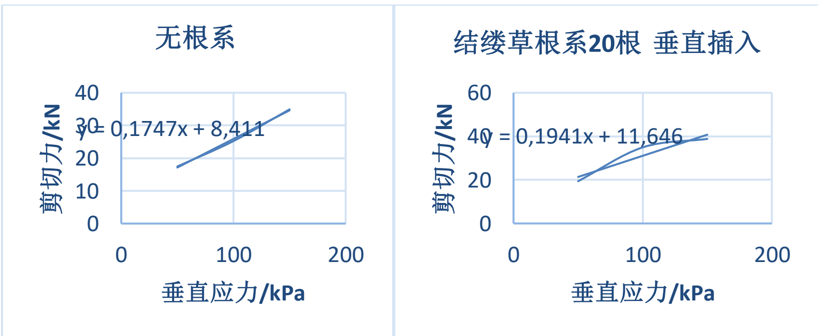

Figure 12/13 Natural Soil Experiment Map

An equation is obtained from the figure, in which the intercept represents the cohesion c, and the coefficient in front of the independent variable represents the tangent of the friction angle. It can be seen that the soil cohesion c value inserted into the root system increases, which internal friction angle increases. By fitting the data, we can obtain that the cohesion of the natural soil is 8.411KN and the tangent value of the friction angle is 0.1747 when no root system is added. Similarly, the cohesion of the red clay with 20 zoysia roots is 11.646KN, and the tangent value of the friction angle is 0.1946. The internal friction angle and cohesion increased at the same time, especially the cohesion increased by about 40%, and the root system of Zoysiagrass significantly improved the shear resistance of the soil.

3.3 Slope stability calculation

The experimental data of adding 20 g of zoysia root system to red clay is used as the basis for the calculation of slope stability, and the combination of Lizheng software and MATLAP-BP neural network will be used to verify each other and make the calculation results more real and reliable. The root soil layer parameters are used: γ=19, the cohesion is 11.646KN, the internal friction angle is 11° (tangent value is 0.1946), and the slope height is 14.66m.3.3.1 Optimize the training mode of professional nursing talents

3.3.1 Correction software calculation results

The safety factor is calculated by the arc sliding method, and the calculation result of the safety factor is 1.6589.

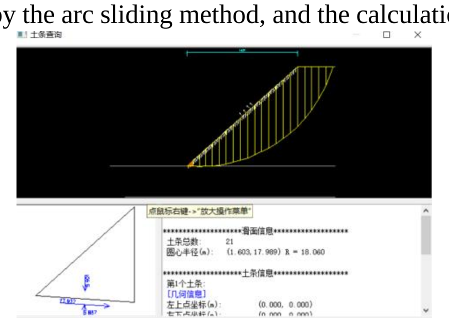

Figure 14 Calculation Results

3.3.2 MATLAB-BP neural network calculation results

BP neural network is a kind of multi-layer feed-forward neural network, the main feature is that the signal is transmitted forward and the error is back-propagated. In the forward pass, the input signal is processed layer by layer from the input layer through the hidden layer until the output layer. The neuron state of each layer only affects the neuron state of the next layer. If the output layer can't get the expected output, it turns to backpropagation, and adjusts the network weights and thresholds according to the prediction error, so that the predicted output of the BP neural network is constantly approaching the expected output. The calculation result is shown in the following figure:

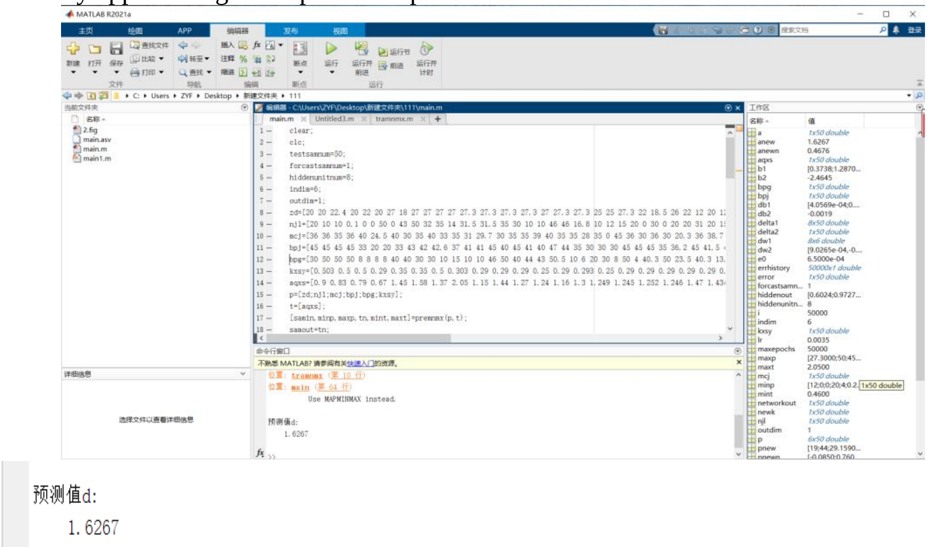

Figure 15 Calculation result of BP neural network

As can be seen from the above figure, the safety factor at this time is 1.6267, which is greater than the 1.35 required by the specification, and the slope is in a stable state. In conclusion, the error of the slope stability coefficient calculation results calculated by Lizheng and MATLAP is small (less than 1.8%), indicating that the calculation results are reliable. From this, the design calculation method of plant root reinforcement slope is obtained.

IV. CONCLUSION

1. Zoysia grass has the advantages of resistance to trampling, good elasticity, strong regeneration, less pests and diseases, easy maintenance and management, and long life. It is widely used in sports lawns all over China.
2. The cohesion of the sand is 5.176KN, and the tangent of the friction angle is 0.5823. The cohesion of sand with 20 zoysia roots added is 10.352 KN, and the tangent value of the friction angle is 0.5629. After inserting 20 zoysia grass roots, the cohesion of sandy soil doubled, while the internal friction angle decreased slightly.

3. The cohesion of natural red clay is 8.411KN, and the tangent value of the friction angle is 0.1747. The cohesion of the red clay with 20 Zoysia roots added is 11.646KN, and the tangent value of the friction angle is 0.1946. The internal friction angle and cohesion of the red clay inserted into 20 zoysia root systems increased at the same time, especially the cohesion increased by about 40% . This shows that the root system of Zoysia japonica significantly improves the shear resistance of red clay。
4. The experimental data of adding red clay to 20g Zoysia grass root system were input into Lizheng software and MATLAP-BP neural network. The error of the slope safety factor calculated by the two methods is small (less than 1.8%), indicating that the calculation results are reliable . From this, the design calculation method of plant root reinforcement slope is obtained.

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