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Experiments on a New Material for the Ecological Protection of Rock Slopes

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Abstract

From 2000, people use the ecological protection to reinforce rock slopes. These ecological protection methods not only can reduce the usage of concrete, but also can restore the degraded ecosystem of slopes. With the rapid development of infrastructures, many materials for ecological protection have been created. However, there are many defects in these materials, such as expensive price, weak strength in early period, easily slide or been eroded when encountered with rainfall. These defects are the problems awaiting solution in the development of slope ecological protection. In this paper, the author attempts to use cement as adhesive in a new material for the ecological protection, and carry out laboratory tests and field tests to verify the feasibility and reliability of this material. Based on existing research and the testing results, the author proposed the prescription of this new material, which can satisfy the survival requirement of vegetation on the slopes, lower costs and enhance the strength in early period of ecological protection as well.

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Key words: slope, ecological protection, new material, strength

1. Introduction

External-soil spray seeding technology is a commonly used technology in slope eco-protection, this technology is to spray the evenly mixed material formed by soil, plant seeds and some other materials in a certain proportion to the hanging wire fence of slope by high-pressure spraying seeding machine, and then to spray plant seeds. After plants have covered the slope, the well-developed root system can go deep into the joints and fissures of rock through soil, which will reinforce the slope permanently and at the same time beautify the environment. In recent years, this technology has been constantly improved and widely used, and it has already achieved good protective effects.

The main content of test is that the cement is used as a binder, and a reasonable ratio would be found out to reduce the adverse effect of its alkaline composition to soil based on the original ratio of external-

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soil spray seeding, and the intensity of external-soil spray seeding is increased under the condition that the normal growth of vegetation is ensured, so as to achieve the purpose of reducing construction cost.

2. Preparation

Three new ratios are proposed on the basis of the original external-soil spray seeding as table 1, and three-phase composition, shear strength, PH value and nutrients of the mixed materials with different ratios will be tested. The ratio that is suitable for field test is proposed according to the test results. The sample of mixed material is shown in figure 1.

(1) Cement: it is used as a binder in this study, and the 425 # cement is adopted to substitute the original PAM, so that the slope eco-protection material would have higher intensity. However, as the alkaline composition has some adverse effects on the growth of plant, the incorporation of cement should not be too large.

(2) Planting soil: as plant cannot grow without soil, planting soil is the main component of slope eco-protection material, and agricultural land is adopted in this test.

(3) Organic matter: peat is adopted as the main material of organic matter in the test, which can improve the physical properties of the material, so that the artificial mixed material can be gradually changed into the natural soil which is suitable for plant growth.

(4) Other ingredients: ①straw: it can be used to increase the mobility of the cement mixture, and at the same time to increase the porosity of the mixed material. ②long-term fertilizer: it is a kind of compound fertilizer which can provide long-term effectiveness for plant growth, and N, P and K chemical compound fertilizer is used in this test. ③water-retaining agent: it absorbs water when there is abundant water, and provides water for the plants when the weather is dry. The water-retaining agent of 400 times is commonly adopted, to ensure that the mixed material can provide adequate moisture for plant growth.

Tab.1 different ratios of the material

Component	A	B	C
Cement	3%	5%	8%
Planting soil	80%	75%	70%
Organic matter	12%	14%	15%

Fig 1 samples of the mixed material

3. Field test

3.1Situation of working site

Experimental working site locates in the Beibei District of Chongqing City. As figure2 shown, the height of slope is about 15m, the slope ratio is 1:1, and the total area is 1500 m2. In the construction process, the testing slope is evenly divided into three regions named A, B and C. The mixed materials with different ratios are adopted in the construction of each region, in order to carry out a comparison. Among which, PAM is still used as a binder in A area, 3% cement is used as a binder in B area, 5% cement is used as a binder in C area, and the ratios of the other components are the same with that of Preparation.

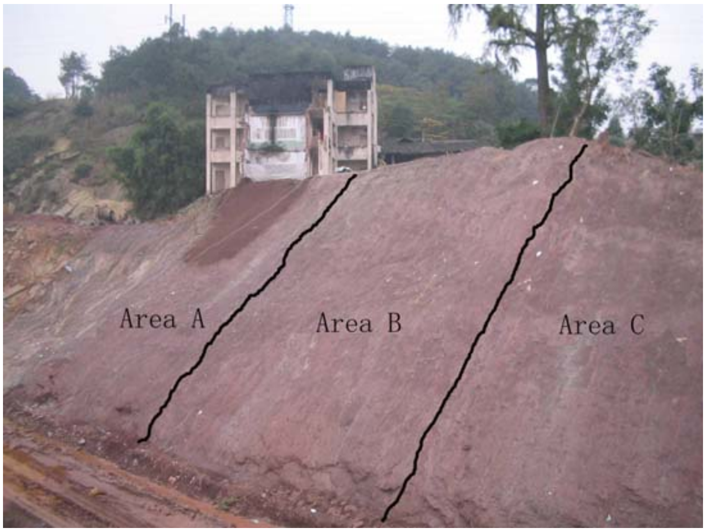

Fig 2 3 different area of worksite

3.2Data measurement results

(1) Moisture content

The curve graph that shows the changes in moisture content of the soil in different regions of slope with the time going is shown in Figure 3, and the following characteristics of different moisture content variations of the slope can be seen from the figure.① The moisture content variations of the material is significantly affected by the change of seasons, the moisture content gradually decreases with the decreasing rainfall in winter, and the moisture content of the material gradually increases with the arrival of the rainy season. ② During the same period, the moisture content of the soil with higher cement is lower, and the maximum difference between its moisture content and the moisture content of the soil without cement have reached 22.6%. ③ The water-retaining ability and water absorbing capacity of the soil with higher cement content are obviously lower, for example, the moisture content of the soil in C Region decreases rapidly during the winter, and its decreasing amplitude has reached 24.6%. Even in the rainy season, the moisture content is difficult to recover to the level at the completion.

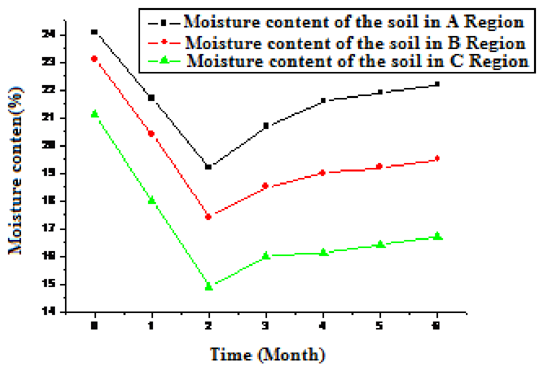

Fig 3 Curve graph of moisture content variation

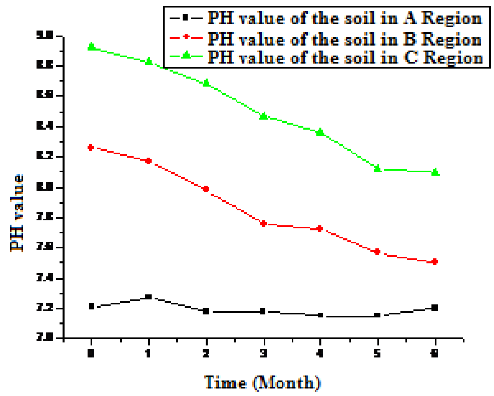

Fig 4 Curve graph of PH value variation

(2) PH value

The curve graph that shows the changes in the PH value of different regions of the slope with the time going is shown in Figure 4. It can be seen from the graph that from the construction is completed to several months after the plants have grown up and covered the slope, the PH value of the soil in A Region is always in the low volatility of 7.1~7.2 in this slope. And the PH value of the soil in C Region is 8.92 at the completion, and it is close to the range of strong base. The PH value of the soil in B Region is also relatively high, which is above 8.2 at the completion. With the time going on, the PH value of the soil in each region is gradually reduced. Six months after completion, the PH values of C Region and B Region are reduced to 8.17 and 7.52 respectively. Thus, the incorporation of cement has quite obvious impact on the PH value of soil. At the same time, in the continuous growing process of plant, the soil has a certain self-regulation function along with material exchange with the outside world, so that the PH value can be reduced to a certain extent. As the PH value which is higher than 8.0 may have adverse effects on the plant growth, it is suggested that the incorporation of cement in the soil should be less than 5%.

Tab 2 Soil nutrients of different area

Regions	N(ppm)	P(ppm)	K(ppm)	Organic matter(%)
A	9.78	53.22	79.37	2.59
B	5.67	33.07	34.43	2.17
C	6.17	29.40	37.13	1.95

(3) Nutrients

Table 2 is the soil nutrients of different regions which are determined 6 months after the completion. By comparing Table 2 and Table 3, we can see that the soil nutrients of different regions have decreased substantially in comparison with the measuring results of laboratory test. The reason is that the nutrients are consumed by plant growth and brought away by rainfall with the time going, and this leads to the gradual decrease of the organic matter and the content of N, P and K in the soil. Besides, as this slope is an independent slope, it hasn’t formed an organic whole with the surrounding vegetation and an effective supply is in lack. The nutrients are absorbed only through the plants in slope, which leads to the continuous decrease of soil nutrients. By comparing the nutrients of A Region to that of B and C Regions, we can see that the incorporation of cement still has a certain impact on the nutrients. Therefore, from the perspective of nutrients, the incorporation of cement in the soil shouldn't be too high.

(4)Shear strength

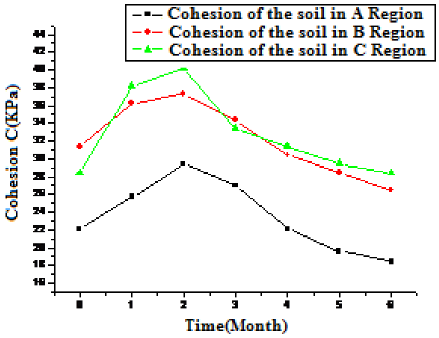

Fig 5 Variation diagram of cohesion

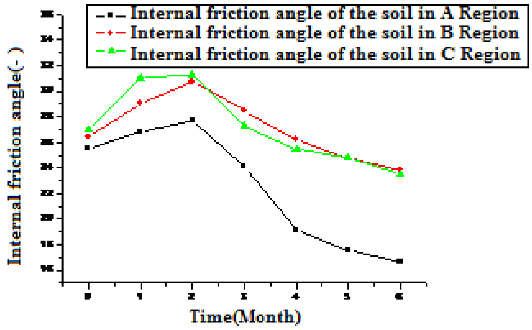

Fig 6 Variation diagram of internal friction angle

Figure 5 and Figure6 are respectively the variation diagrams of cohesion and internal friction angle of the soil in different regions. It can be seen from the figures that: ① high intensity can be attained by using cement as bonding material; the consolidation of cement gradually came into effect when the construction was completed, and the cohesion and the internal friction angle of soil are significantly enhanced with the increasing incorporation of the cement in mixed material. A month later, the cohesion of C Region is 52.3% higher than that of A Region, and the internal friction angle of C Region is 15.2% higher than that of A Region. ② The cohesion and the internal friction angle of the soil in C Region are slightly higher than that of B Region 3 months after completion, but the differences are gradually narrowed with the time going. And especially 3 months later, the internal friction angle of C Region is slightly lower than that of B. The possible reason may be that the continuously developed plant root penetrates through the soil and changes the internal structure of soil, which resulting in the similar soil strength of the two regions.③ the shear strength of the soil presents obvious seasonality in all regions. According to the variation diagram of moisture content (Fig. 6), we can see that both of the cohesion and the internal friction angle decrease with the increasing moisture content of soil.

(5) Growth condition of plants

Fig.7 3 months after completion

Fig. 7 6 months after completion

Figure 7 and Figure 8 are the photos of the slope at different periods of time. The plants begin to germinate 20 days after completion; they have completely covered the slope 3 months after completion; the plant growth on slope approximates stabilization 6 months after completion, a large number of wild plants have invaded, which occupy over 50% of the total plants on the slope, the growth conditions of the plants in A, B Region and C Region have no significant differences. According to the local meteorological records, there have been five rainfalls over storm intensity within 6 months after completion, a small amount of alluvial deposits can be seen at the foot of the slope in A Region, and no alluvial deposits can be seen in B Region and C Region (Figure8). This shows that the soil of B Region and C Region can meet the needs of plant growth, and also has higher strength and anti-erosion resistance. It also confirms that the adoption of cement as a binder is not only feasible, but also can effectively improve the strength of soil.

4. Summary

This paper studies the strength, stability and suitability of plant growth of carrying soil under the condition that the cement is used as a binder, in order to find a new kind of slope eco-prevention material. A large number of experimental data and monitoring data are attained through laboratory tests, field tests and tracking observations. Based on the above findings, the following conclusions can be drawn:

(1) The ratio of new material screened from the laboratory test can fully meet the needs of plant growth, maintain its stability on the slope, and it is also proved to be qualified with high anti-erosion ability through the verification of field construction. As the low-cost cement is adopted as a binder, the cost of raw material is reduced, thus the purpose of reducing construction cost is achieved.

(2) The incorporation of cement would have adverse effects on the PH value and the nutrients of soil. The test results shows that the soil with higher incorporation of cement has lower nutrients content and higher PH value, which would have adverse effects on the plant growth. Therefore, a reasonable incorporation of cement is the key factor to effectively improve the strength of carrying soil. According to the research results of this paper, the incorporation of cement should be between 3% and 5%.

(3) The field test results are the growth condition of vegetation and the stable condition of ecological soil within six months after completion, a long-term tracing observation need to be conducted on the test slope, in order to examine the continuous water-retaining ability, fertilizer-retaining capacity and anti-erosion ability of the soil, and also the long-term growth condition of plants.

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