ISSN 2616-5872 Vol. 7, Issue 1: 12-22, DOI: 10.25236/AJEE.2025.070102

Research on the rational application of overhanging plant bags in granite stone mining areas

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Abstract: *With the state's emphasis on environmental protection, mine ecological restoration has been included as one of the main tasks of national ecological environmental protection. Our country is currently trying to optimize the ecological environment protection effect and repair environmental problems. Mine ecological restoration is a complex and challenging task, especially for granite face stope slope, which is a rock slope with a thin soil layer, low fertility, and lack of nutrients required for vegetation growth. Traditional vegetation restoration technology is difficult to apply on such slopes, and planting bag technology can be considered for ecological restoration treatment. In this study, Midas GTS/NX geotechnical finite element analysis software will be used to study the influence of overhang planting bag technology on slope stability and the feasibility of overhang planting bag technology for granite stope slope. Finally, it is concluded that applying an overhang planting bag in a granite stope slope is feasible. The influence of the overhanging bag on the slope shear force and displacement is obtained by studying and analyzing the slope stability coefficient, displacement, and maximum shear stress of the overhanging bag with different spacing. The relationship curve between the shear stress and displacement and the slope foot distance is extracted, and the optimal value of the overhanging bag layout spacing is calculated. The analysis results show that the optimal layout spacing of overhanging planting bags is obtained. When the layout spacing is 2m, the shear stress and displacement fluctuate less and are more stable. The conclusion of this study has certain applicability and aims to provide a reference for similar engineering applications.*

Keywords: *granite stope slope, ecological restoration, planting bag, numerical*

1. Introduction

With the continuous advancement of global industrialization and urbanization, mineral resources have become an indispensable resource in modern society[1-4]. However, the exploitation of mineral resources is often accompanied by the destruction of the natural landscape and the deterioration of the ecological environment, especially the abandoned land left after mining, which not only destroys the beauty of the local landscape but also may induce geological disasters, seriously threatening people's lives and property safety[5-6]. Therefore, the ecological restoration and management of mine abandoned land has become an important issue in mine environmental management and promoting sustainable development, and we need to take effective measures to solve it.

This study takes the abandoned land of granite surface open-pit stope as the research object, aiming to explore the ecological restoration and management technology suitable for this type of site. There are a large number of granite mining areas in the country, a total of 297, mainly distributed in Shandong, Beijing, Fujian, Jiangsu, Anhui, and other provinces, in addition, Sichuan, Shanxi, Inner Mongolia, Guangxi, Hebei, Henan, Liaoning, and other provinces also have rich granite resources[6-7], its mining area is widely distributed, high quality is widely used in various fields. The mining and utilization of granite minerals has provided a large amount of material wealth to the national economy and social development, but also brought a greater impact on the ecological environment, not only the destruction of forest vegetation, landscape fragmentation, excessive mining of granite may also affect the stability of the crust, thereby increasing the risk of earthquakes. The research on the comprehensive treatment and ecological restoration technology of granite face stope slope has universal reference significance for guiding China to realize the coordinated development of granite face development and ecological environment protection.

Granite stope usually has a thin soil layer, low fertility, and lack of nutrients required for vegetation growth, and ecological restoration is relatively difficult. Granite stopes often form steep slopes, which increases the difficulty of vegetation restoration, and the ecological restoration of high and steep slopes is particularly difficult. Therefore, choosing appropriate restoration measures according to specific problems is necessary to effectively solve various ecological and environmental problems. Planting bag greening is an important means of slope ecological restoration. As a landscape material, planting bags have high stability and diverse planting methods, which provide space for the selection of vegetation types on side slopes. However, for the rock slope with a large and steep slope, it is difficult to fix the planting bag on the slope, which also hinders the application of the planting bag protection technology on the tall and steep rock slopes to a certain extent. Overhanging green ecological restoration technology can effectively solve such problems.

The spacing design is the key factor that affects the protective effect of overhanging planting bag technology[8]. Therefore, it is necessary to analyze the optimal spacing design method of overhang greening technology for slope protection deeply. In this paper, with the help of Midas GTS/NX geotechnical finite element analysis software, the overhang greening technology of different spacing is studied, and the slope is simulated and analyzed from the aspects of stability coefficient, displacement, and maximum shear strain[9-11].

2. Research status

The ecological restoration technology of plant bags has been widely used and developed at home and abroad, but there are still some technical problems and challenges. Relevant practitioners and scholars have conducted in-depth research and discussion in theory and practice. Xia Dong et al. put forward an ecological restoration idea composed of four links: "environmental geological disaster mechanism model - control and elimination of geological hazards - optimization of ecological restoration technical plans - dynamic monitoring and evaluation of geological hazards and restoration effects"[12-14]. Liu Kunjue et al. tested the mechanical properties of the common linen material used in the planting bag and analyzed the stability of the yellow linen planting bag on the slope combined with the conditions of the slope. It is concluded that the basic properties of yellow linen meet the requirements of the national standard for the performance of planting bags[15-18]. Lu Mingxing et al., through observation and analysis in the experimental area, concluded that the use of planting bag vegetation ecological reclamation technology not only has a short engineering period and, a relatively simple process but also has a good effect on rapid vegetation formation. For the slope with more gravel, not easy-to-cover soil, and a large slope, it is suitable to use a planting bag for treatment. The stability analysis of the slope of planting bag reclamation shows that its potential sliding surface is circular sliding surface, which not only has fast construction speed and good reclamation effect, but also can effectively reduce soil and water loss and improve the stability of the slope, and is worthy of popularization and application[19-21].

For the high and steep granite face stope slope, due to the thin soil layer and low fertility, lack of nutrients required for vegetation growth, can not meet the traditional direct planting and reclamation conditions, can consider the use of planting bag ecological restoration technology. In the future, with the continuous progress and innovation of technology and the improvement of global awareness of ecological environment protection, the ecological restoration technology of plant bags will play a more important role. Given this, this study takes the granite-clad mining slope as the research object, studies the slope stability changes under the action of overhanging planting bags, and determines the optimal distance of overhanging greening technology for slope restoration through analysis.

3. Research Methods

3.1 Basic Theory

In the process of soil deformation, elastic deformation, and plastic deformation almost occur at the same time, which is an elastic-plastic material. Therefore, the Mohr-Coulomb elastic-plastic model is selected to analyze the slope soil. Mohr-Coulomb strength criterion belongs to a typical strength concept in rock and soil mechanics. According to the Mohr-Coulomb strength criterion, material damage is often caused by shear stress. Under the influence of external forces, when a rock is shear damaged along a

ISSN 2616-5872 Vol. 7, Issue 1: 12-22, DOI: 10.25236/AJEE.2025.070102

damaged surface, the required damaged shear stress τ has some functional relationship with the normal stress σ on this side.

$$\left(\frac{\tau}{\sigma}\right)_{max} = constant \tag{1}$$

When considering the restriction of cohesion strength c, it can also be expressed as:

$$\tau = \sigma \tan\varphi + c \tag{2}$$

Where: τ is the shear stress in the soil; σ is the normal stress in soil; φ is the internal friction Angle of the soil; c is the cohesiveness of soil mass.

3.2 Numerical simulation analysis method

With the rapid development of modern science and technology, the computational analysis method based on computer finite element numerical simulation software rises in the slope stability analysis and becomes a new stability analysis method. At the same time, using numerical simulation methods to analyze and study the stability and restoration scheme of slope in ecological restoration will become the main development trend of future research and analysis. This study is based on Midas GTS NX software for numerical simulation. The finite element numerical simulation method is important in slope stability analysis. Such analysis methods can not only consider the influence of the deformation of rock and soil of slope itself on slope stability, but also calculate the stress-strain distribution in rock and soil of slope, and analyze the occurrence and development process of slope failure. It has incomparable advantages over the traditional limit equilibrium method.

The simulation process of Midas GTS NX consists of pre-processing and post-processing. The pre-processing includes establishing geometric models, generating mesh cells according to material properties, setting boundary conditions, adding static conditions, and establishing analysis conditions, and the post-processing includes running solutions and outputting calculation results.

4. Research on the application of overhang planting bag technology and slope stability

4.1 Application of Overhanging Planting Bag Ecological Restoration Technology

The main suspension material of the overhanging planting bag is the active protective net, the planting material is the permanent bag, the growth bag is loaded with nutrient soil, and the other auxiliary materials are steel bars, boards, etc. The specific uses and specifications of each material are shown in Table 1. The schematic and field drawings of the overhanging greening technology are shown in Figure 1 and Figure 2.

Table 1: Materials required for a single overhang planting bag device

serial number	name of the material	application	specification
1	active network	Used for hanging kudzu planting platform	The sheet size is 2.5m*1.2m, and it can be clipped by active mesh with an aperture of 30~40cm.
2	plank	Placed in the active mesh to support the growth bag	1m*0.5m, thickness 3cm
3	Bag of Life	Use degradable materials, contain nutritious soil, and sow seedlings	The circumference of the bag is 80cm, the length is 60cm and the soil is 50cm
4	rebar	It is used for anchoring active nets and steel strands. It is driven vertically with a rock face and the depth of the rock is 20cm.	Diameter 18mm, rebar Phi HRB400, length 20cm

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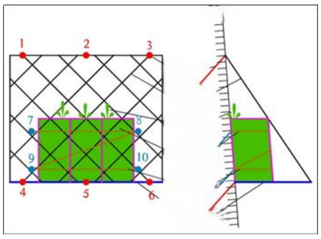

Figure 1: Schematic diagram of overhanging greening

Figure 2: Overhanging greening site diagram

Before the overhanging planting bag is arranged on the slope, the slope with gravel should be cleaned properly to ensure the smooth progress of the follow-up work. On the slope surface planting reinforcement, paving gravel, and cover the net fixed planting bag. The production process and steps are as follows:

1) Anchor into rock. According to the actual situation and field test, drill holes in 1, 2, 3, 4, 5, and 6 in a total of six positions, and require 1, 2, 3 holes, and 4, 5, and 6 holes as far as possible in the same horizontal line to ensure that the planting bag placed behind does not slip, hole spacing 50cm, drilling direction perpendicular to the slope. After the drilling is completed, the reinforced anchor rod is driven into Phi HRB400, the diameter of the steel bar is 18mm, and the rock is 20cm.

2) Hang active net. Hang the active net on the anchor rods 1, 2, and 3, and bend the lower part to the side slope according to the design. After bending, space should be reserved for placing the board, and the planting bag should be fixed through the cover net. Then according to the lower holes 4, 5, and 6 positions determine the length of the active net and appropriate cutting. The size of the single active protective net is 2.5m*1.2m. The active protective net model is RXI-075.

3) Support table installation. The board is used as the support platform, the board is 1m*0.5m, and the thickness is 3cm.

4) Planting the bag. The planting bag is made of natural materials and is composed of biodegradable growing bags, plant seeds, and cultivated soil. Place the cultivated soil in a growing bag. Place them close together in the middle of the supporting boards. Biodegradable materials are selected for planting bags. Note that the root system of the plant should not be too long to avoid affecting the stability of the planting bag.

4.2 Application scope and advantages of overhanging planting bag technology

The green bag technology is suitable for slope sites without soil because it is difficult for plants to survive in such conditions. You can use a plant bag to hold the seeds of the plant, and then fill the bag with mixed soil. Its advantages are mainly reflected in the following aspects:

1) Easy construction. The construction method is simple and the mine waste can be used on the spot. The construction process of the suspended planting bag technology is relatively simple and does not require complex equipment and a large number of labor forces.

2) Strong adaptability. Overhang planting bag technology can be applied in a variety of complex terrains and environments, such as rock slopes, exposed parts after landslides, soilless sand and gravel slopes of highways and railways, and vertical cliff parts. These areas are often difficult to restore by traditional greening methods, and overhanging planting bag technology can solve these problems well.

3) Ecological environmental protection. The planting bag in the hanging planting bag technology is made of environmentally friendly materials, has good air permeability and water drainage, and can provide a suitable growing environment for plants. At the same time, the high-quality mother soil and

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fertilizer filled in the bag can ensure the survival conditions of plant seeds, thereby improving the survival rate of plants. In addition, as the plants in the bag continue to grow, their roots firmly hold the soil of the slope, further enhancing the stability of the slope.

4) High survival rate. The planting bag material used in the hanging planting bag technology is degradable and will not cause pollution to the environment. At the same time, the technology can improve the ecological environment and the ecological function of the slope through vegetation restoration and ecological restoration. This is of great significance for protecting the natural environment and promoting ecological balance.

5) Excellent stability. Overhanging planting bag technology is an effective method widely used in slope ecological restoration. It not only has a high landscape value but also performs well in terms of stability, can resist the erosion of rain, and reduces the risk of soil erosion and landslides of the slope.

From the perspective of taking into account the greening effect and economy, it is suggested that this vertical greening restoration technology can be used in the embankment slopes with high scenic spots or landscape requirements, that are not suitable for plant growth, and in the skeleton, frame or parapet of the coarse aggregate embankment slopes and rock cutting slopes which are not suitable for plant growth.

4.3 Research on slope stability under the action of overhanging planting pocket

4.3.1 Model simplification principles

The reliability of software simulation results largely depends on the reasonableness of model establishment and the reasonableness of loading mode. Based on ensuring that it conforms to the actual situation of the project, the calculation model is simplified as much as possible. The object of this simulation is 5m steps of the granite face stope slope with different spacing overhanging greening, which can be treated as the plane strain problem, so only the plane model is established for simulation. To reduce boundary effects, each model has a large enough size. The left and right boundary conditions of the model restrict only horizontal displacement and allow vertical displacement. The lower boundary is set as a rigid constraint, allowing no horizontal and vertical displacement. The surface of the engineering slope is a free boundary. The mohr-Coulomb model is used to simulate the constitutive relation of rock mass, and the ideal linear elastic model is used to simulate the constitutive relation of steel bolts and wood slabs. The boundary conditions and loading of the model are shown in Figure 3.

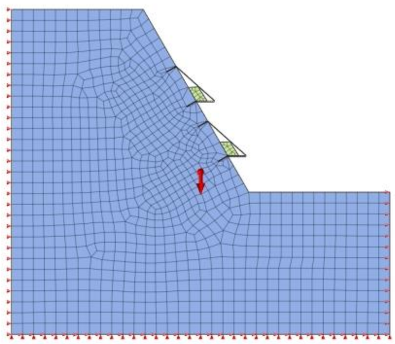

Figure 3: Calculation model diagram

4.3.2 Material parameter selection

The simplified two-dimensional model is used to simulate the section numerically. The correct selection of physical and mechanical parameters of slope soil mass determines the authenticity of slope stability evaluation. Based on the comprehensive consideration of local engineering experience, the material parameters are shown in Table 2.

Table 2: Material parameters table

lithology	c(kPa)	φ(°)	E(kPa)	γ(kN/m3)	μ
clay	9	12	150	18.0	0.3
Aeolian granite	490	39	1×105	25.0	0.3
rebar	-	-	2.06×105	25.0	0.3
plank	-	-	1×105	10.0	0.3

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4.3.3 Analysis of Slope Safety Factor

The slope finite element model was established by MIDAS GTS NX with a self-weight load and boundary constraint. In this study, the slopes of 60°, 70°, and 80° will be modeled and analyzed respectively, and the bare slopes under the three gradients will be compared with the components with a spacing of 1.5m, a spacing of 2m, and a spacing of 2.5m. By analyzing the safety factor of slope, the safety and rationality of overhanging green bag planting technology are judged comprehensively. Slope stability analysis and solution type choose slope stability (SRM) model. The slope stability coefficient obtained through the analysis model is shown in the following table.

Table 3: Slope safety factor table

	Slope 60°	Slope 70°	Slope 80°
Bare slope	3.53	3.23	3.06
1.5m component spacing	2.88	2.53	2.26
2.0m component spacing	3.05	2.77	2.49
2.5m component spacing	3.21	3.02	2.78

By pertinent technical specifications, including the “Technical Code for Slope Engineering of Non-coal Open-pit Mines”(GB 51016-2014) and the”Technical Code for Slope Engineering of Buildings”(GB 50330-2013), it is stipulated that for Class I slopes, the permissible safety factor for stability calculations is [K] = 1.25, as indicated in Table 3. The calculated safety factors in this analysis exceed the minimum allowable threshold, confirming that the slope remains stable under the influence of suspended vegetation bags. When the slope is 60°, the slope safety factor decreases from 3.53 of the original slope to 2.88, 3.05, and 3.21, respectively, by 18.2%, 13.6%, and 9.06%, under the density of 1.5m, 2.0m and 2.5m of overhanging planting bag layout spacing. When the slope is 70°, the safety factor of the slope decreases from 3.53 to 2.53, 2.77, and 3.02, respectively, by 28.3%, 21.5% and 14.4%. When the slope is 80°, the safety factor of the slope decreases from 3.53 to 2.26, 2.49, and 2.78, respectively, by 35.9%, 29.4% and 21.1%. The placement of overhanging planting bags on the slope can significantly reduce the safety factor of the slope. According to the changing trend, the decrease in safety factor is negatively correlated with the layout spacing density. The smaller the spacing, the more obvious the reduction effect on the slope safety factor.

4.3.4 Shear stress analysis of slope

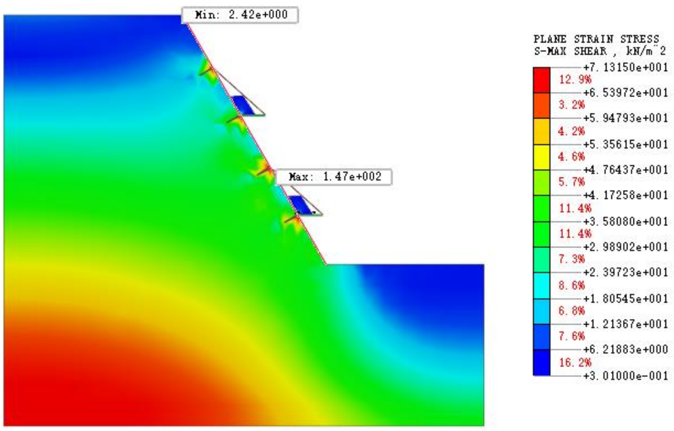

Figure 4: Cloud map of maximum shear stress under overhanging planting pocket

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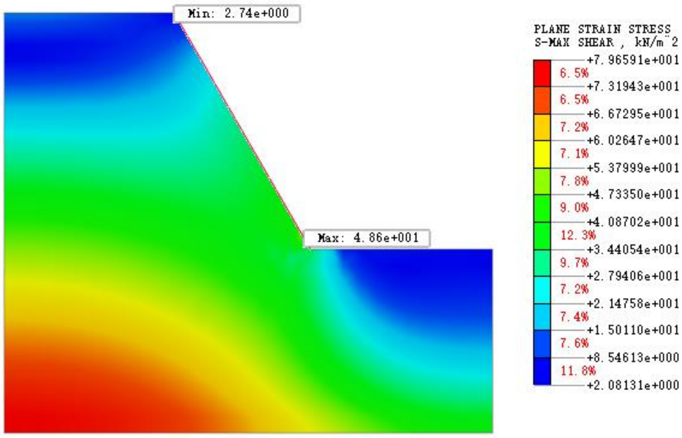

Figure 5: Maximum shear stress cloud diagram of bare slope

Under static conditions, the maximum shear stress cloud diagram of the slope under the action of the overhanging plant pocket and the maximum shear stress cloud diagram of the bare slope are shown in Figure 4 and Figure 5. Through the analysis of the cloud diagram of the maximum shear stress, it is found that the maximum shear stress of the bare slope is at the bottom of the slope, and the slope with an overhanging planting bag is the same as that of the bare slope, and the maximum shear stress is at the bottom, indicating that the overhanging planting bag has little influence on the position of the maximum shear stress of the slope. However, the shear stress increases obviously around the position where the anchor rod of the overhanging planting bag is inserted into the slope. The lower bolt mainly bears the pressure from the dead weight of the planting bag, and there is an obvious area of increasing shear stress under the bolt. There are increasing areas of shear stress above and below the upper bolt. If the arrangement is too dense, the shear stress affected area of the upper anchor rod in the lower overhanging planting bag overlaps with that of the lower anchor rod in the upper overhanging planting bag, which may cause excessive shear stress and cause slope failure.

The maximum shear stress of the slope in the model is selected as the research object, and the maximum shear stress of the slope with the overhanging green bag spacing of 1.5m, 2.0m, and 2.5m is compared with that without overhanging green bag, to clarify its influence on the slope. The slope shear stress curves were drawn under three spacing conditions with overhang planting bags and without overhang planting bags. The curves took the edge slope foot as the origin, the horizontal coordinate was the longitudinal distance from the slope foot, and the vertical coordinate was the maximum shear stress. FIG. 6- FIG. 8 shows the comparison of shear stress under the slope of 60 °, 70 °, and 80 °respectively.

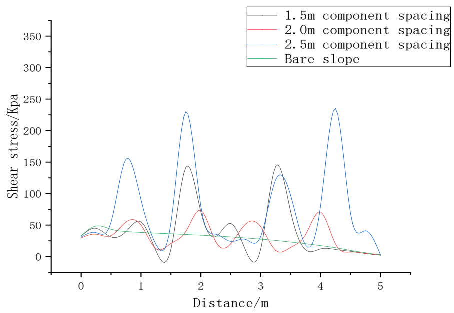

Figure 6: Comparison of shear stress of 60 °slope

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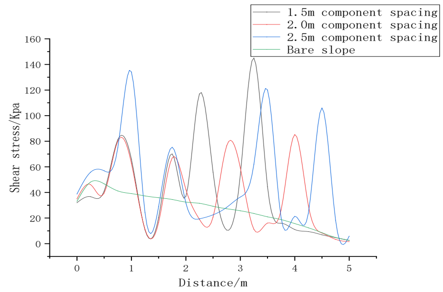

Figure 7: Comparison of shear stress of 70 °slope

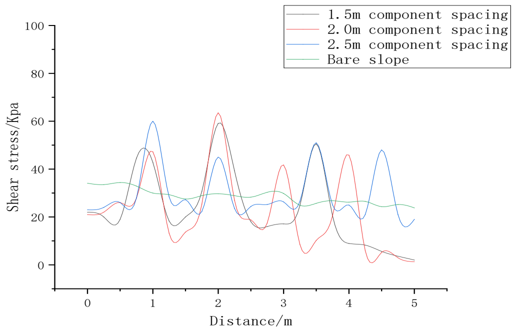

Figure 8: Comparison of shear stress of 80 °slope

As can be seen from FIG. 6-8, when no overhang planting bag is used, the shear stress of the slope is relatively stable and declines gently from the foot to the top of the slope, and the maximum shear stress is located at the foot of the slope. When the overhanging planting bag is used, there are four shear stress surges, all of which are four anchor rods embedded in the slope soil area, and the shear stress of the bare slope as a whole increases from about 40kN/m2 to 100 kN/m2 to 200 kN/m2. Under the action of overhanging planting bags, it is shown that the shear stress effect can be significantly increased when the anchor bolt is embedded in the specific area of the soil center. According to the comparison diagram of the shear stress of three slopes with different slopes, the shear stress is relatively stable and the fluctuation is small when the spacing is 2.0m.

4.3.5 Slope displacement analysis

Under static conditions, the maximum shear stress program and the displacement program of the bare slope under the action of an overhanging plant pocket are shown in FIG. 9 and FIG. 10. It can be seen from the figure that the total displacement of the undisturbed slope gradually increases from the bottom to the top. Under the action of the overhanging planting pocket, the displacement nebulogram has no obvious change, indicating that the overhanging planting pocket has little influence on the total displacement of the slope.

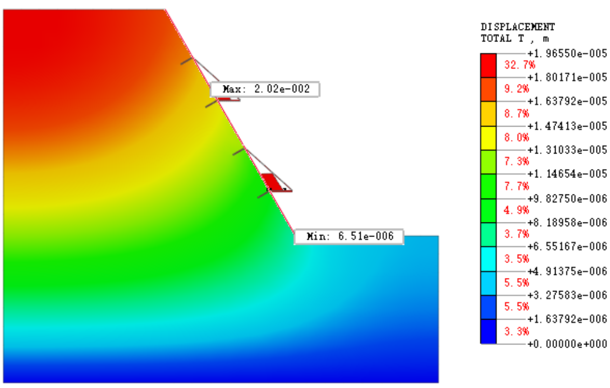

Figure 9: Displacement cloud image under the action of overhanging planting pocket

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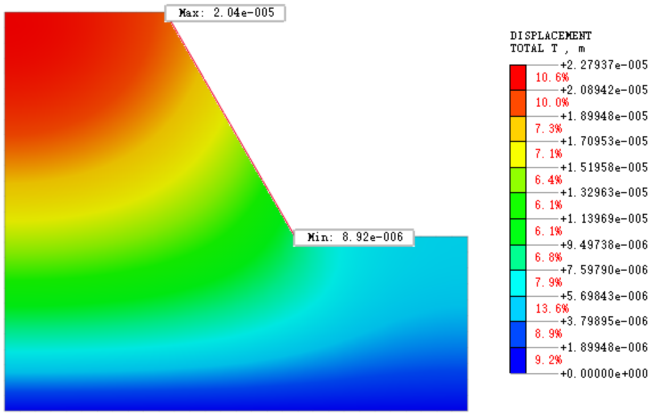

Figure 10: Displacement cloud image of bare slope

The total displacement of the slope in the model is selected as the research object, and the displacement of the slope with a vertical spacing of 1.5m, 2.0m, and 2.5m is compared with that of the bare slope without an overhanging planting bag, to clarify its influence on the maximum displacement of the slope. The slope displacements under three different spacing conditions were plotted, with the edge slope foot as the origin, the horizontal coordinate as the longitudinal slope foot distance, and the vertical coordinate as the displacement deformation. FIG. 11- FIG. 13 shows the comparison of maximum displacements under slopes of 60 °, 70 °, and 80 °respectively.

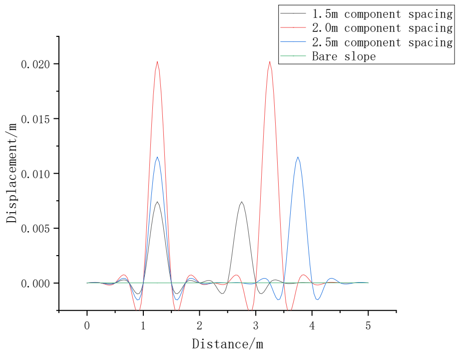

Figure 11: Comparison of slope displacement at 60 °

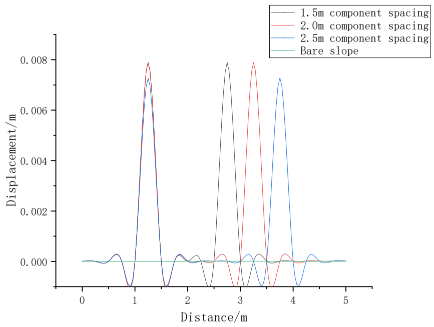

Figure 12: Comparison of slope displacement at 70 °

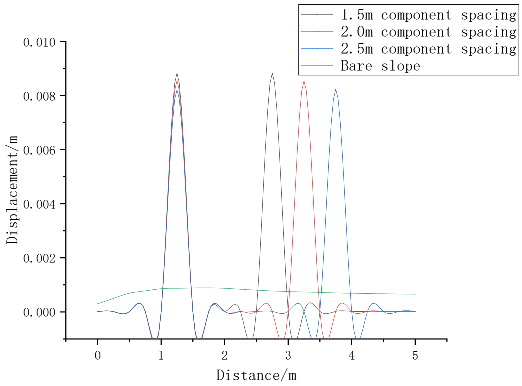

Figure 13: Comparison of slope displacement at 80 °

As can be seen from FIG. 11-13, when no overhang planting bag is used, the displacement and deformation are relatively stable, with a maximum displacement of about 1mm, rising gently from the foot of the slope to the top of the slope, and the maximum displacement is located at the top of the slope. When the overhang planting bag is used, there are two places where the displacement spikes, both of which are the rebar embedded in the slope soil, the displacement is about 8mm, and the value is relatively stable, indicating that the displacement mutation is the implanted rebar, and the soil displacement is not a big change. The results show that the displacement and deformation of the side slope will not increase significantly in the specific area where the overhanging planting bag is embedded.

5. Results and Prospects

As an important means of ecological restoration, the principle of overhanging planting bags is that the anchor rod plays a fixed role, and the planting bag on the board is responsible for the slope greening. The spacing design of overhanging planting bags is related to the overall stability of the slope. Too dense layout may lead to the instability of part of the slope, and too sparse layout will also make the slope ecological restoration effect not ideal. Based on the numerical simulation method, this paper studies the influence of overhanging plant pockets on the stability of the slope and discusses the internal relationship between the maximum displacement and shear stress of the slope. The main conclusions are as follows:

(1) The strength reduction method and Midas GTS NX software were used to calculate the influence of overhanging planting bags on slope safety stability coefficient under different slope conditions, and the correlation between safety stability coefficient and layout spacing was obtained. It is concluded that for the slope with 60 °, 70 °, and 80 °slopes, the stability of the slope can be ensured when the overhanging planting bag is used, but the use of the planting bag will have a certain negative impact on the stability of the slope. And the smaller the spacing, the more obvious the reduction effect on the safety stability coefficient of slope.

(2) A calculation model was established considering the different spacing of overhanging planting bags. According to the contrast curve of shear stress and displacement, the optimal spacing of overhanging planting bags was obtained. When the spacing is 2m, the shear stress and displacement fluctuate less and are more stable. It can be used as a reference in the ecological restoration of granite stope slope.

As an environmentally friendly slope protection method, planting bag technology conforms to the green, low-carbon, and sustainable development concept of modern engineering construction. Through vegetation restoration and soil improvement, the self-repair and sustainable development of the ecosystem are realized. The research results can be applied to practical engineering projects to guide the treatment of granite stope slope and vegetation restoration and improve engineering safety and ecological benefits.

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