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Study on Strength, Deformation Characteristics and Interaction between Soil and Stone of Soil-Rock Mixture

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Soil and rock mixture is a kind of non-uniform, discontinuous, internal structure of complex and irregular geological body. Unlike the general soil, it is a multiphase system. The mechanical properties of the various components constituting the soil-rock mixture are very different. At the same time there is a complex interaction between soil and stone. In this paper, we study the strength and deformation characteristics of soil-rock mixture and the interaction of soil and rock. With the increase of confining pressure, the shear strength of the soil-rock mixture is increased. The amount of displacement of the upper breccias is the largest. The displacement of the central breccias is small and produces both lateral and vertical displacements. The lower breccias produce almost no vertical displacement, but the outside breccias produced a significant lateral displacement. The breccias will rotate during the cutting of soil samples. And the angle of rotation is related to the size, shape, direction, spatial position, force state, and the interaction between the breccias. The breccias will be subjected to different tensile stresses by the soil during the shearing process. It will produce earth and stone off phenomenon.

1. Introduction

The soil-rock mixture has a wide distribution in nature. The widespread distribution of the soil-rock mixture provides an important place for production activities (Zhang et al., 2015). But at the same time it is different from the general soil. This mixture is composed of higher strength of the breccias and the strength of the fine soil composition. The overall stability of the geological body and the complex structure often lead to landslides, debris flows and other natural disasters (Xu et al., 2016). It is of great engineering value and theoretical significance to study the mixture of soil and rock. The rich achievements of modern soil mechanics and rock mechanics have made us have a deeper and systematic understanding of homogeneous soil and rock material. But so far on the soil and rock mixture deformation strength characteristics and seepage mechanics mechanical response test and theoretical research is very limited. The study on the variation of the mechanical properties of the soil - rock mixture under the mechanical properties of the soil - rock mixture and the different influencing factors can deepen and develop the system understanding of the properties of the soil. It is of great value for the stability analysis and deformation prediction of the accumulation slope and other landslide landslides which are prevalent in China's hydropower, transportation, railway and mine engineering (Xu et al., 2011; Rafieizonooz et al., 2017).

Early research and engineering practice, soil and stone mixture are directly classified as a kind of soil. In its calculation is also the default for homogeneous continuous material. After that, the concept of soil and rock mixture was proposed and gradually recognized by the engineering sector. In recent decades, domestic and foreign scholars in the soil and stone mixture of research have made a lot of fruitful and pioneering progress. The research methods include indoor experiment, large field experiment and numerical simulation.

In the numerical simulation, based on the Monte Carlo stochastic simulation principle, the random generation program of the soil-rock mixture structure was developed by using the program development language, and the numerical model of the soil-rock mixture was established. In the laboratory test, five typical fractal curves of soil and rock mass were obtained. The engineering properties of the soil-rock mixture can be qualitatively described according to the different types of the curve, and the fractal model of the particle size is obtained. In the field experiment, the soil and stone mixture distributed in the right bank of the Luguangxia Longpan was

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sampled, and the in-situ large-scale direct shear test was carried out under the natural condition and the immersion condition. The test yielded meaningful results. A series of horizontal shear tests were carried out for the residual slope of the Baiyuean landslide area. The shear strength parameters and deformation characteristics of the soil-rock mixture were obtained, which provided the necessary basis for the slope stability analysis in this area (Li et al., 2015).

Soil-rock mixture is a kind of complex geological body. Its internal contains large particle size, high strength of the stone. The impact of physical and mechanical properties of the factors are more. By the technical and test methods, it is difficult to accurately obtain the physical and mechanical parameters of soil and stone mixture. It is easy to cause the corresponding project construction waste of funds. Even due to the irrational choice of parameters led to the failure of construction. Indoor tests can be precise control of boundary conditions and stress conditions, but also have obvious limitations. And the indoor test has a limit on the size of the stone mixture. Field tests can overcome the shortcomings of laboratory tests. But there are shortcomings of high cost, difficulty, and can only focus on some simple clippers and press shear tests. Numerical tests are one of the methods commonly used in geotechnical engineering. But it is difficult to simulate the non-uniform and highly discrete properties of the soil-rock mixture. There is not much research on the interaction mechanism of soil - stone during the experiment (Sun et al., 2014).

In this paper, the effects of different stone contents and different blocks on the shear strength of earth and rock are analyzed. At the same time, the relationship between the spatial displacement and the angle of the rock and the shear failure is studied. The interaction between soil and rock is analyzed, which provides the basis for reasonably determining the shear strength characteristics and parameters of soil - rock mixture.

The research section of this paper is as follows. Chapter 2 describes the mechanical properties of soil-rock mixtures. Chapter 3 describes the strength, deformation, and soil-stone interrelationship of soil-rock mixtures. Chapter 4 gives the conclusion.

2. Mechanical properties of soil - rock mixture

The soil - rock mixture has its own characteristics and mechanical mechanism in stress - strain relationship, hardening softening, shear - shear shrinkage, strength characteristics, shear failure morphology and so on. Mainly there are stress-strain relationships, hardening softening rule, shear shrinkage shear, strength characteristics and shear failure morphology.

In order to accurately evaluate the deformation and strength characteristics of rock and soil, it is necessary to establish stress-strain relationship through mathematical expression. According to the boundary conditions and initial conditions of the project, the strain, stress and displacement in the rock mass are obtained by analytic method or numerical method. But the soil-rock mixture is a non-homogeneous, discontinuous material. The contact friction between the stone content and the rock and soil will have an effect on the stress-strain relationship of the soil-rock mixture.

In the soil and rock mixture, the internal structure of the rock and stone mixture shows obvious structure, and the strength of the specimen is increasing and the strain is hardened due to the occlusion between the blocks. After the peak, the stress increases with the increase of strain is not obvious. This is mainly due to the structural characteristics of the soil and stone mixture. The interaction between soil and stone did not show softening. Under the condition of low confining pressure, the soil-rock mixture is softened and the high confining pressure is hardened.

In the process of shearing, the stone is not only the relative horizontal displacement and the rotational motion, but also the vertical displacement occurs in the direction perpendicular to the shear zone due to the occlusal and friction between the blocks. The soil and rock mixture is different from the ordinary rock and soil due to the complexity of its composition. The shear shrinkage and shear shrinkage are obviously affected by the content of stone in the mixture of soil and stone. The stone content and morphology have an effect on the dilatancy.

From the Coulomb shear strength theory we can see that the shear strength of soil is composed of two parts, namely, friction strength and cohesion strength. It is generally believed that there is no cohesive strength between the coarse-grained soil particles. However, due to the soil and stone mixture from the soil, stone two parts, the strength of the size and coarse soil or fine soil is different.

The stochastic distribution of the crushed stone in the soil-rock mixture makes the stress distribution and deformation uneven and complex. In the study, it was found that the earth-rock mixture with dense earth-rock mixture had more contact with the gravel. It causes the contact surface to climb. May first appear fissure. In the areas with spare gravel, cracks appear late. With the test of the cracks gradually connected together to form a complex failure surface, accompanied by a number of secondary cracks.

3. Strength, deformation and soil - stone interrelationship of Soil - rock mixture

3.1 Soil - rock mixture strength

The earth-rock mixture is a special geological body. The different contents of the breccias make the structure of the soil and stone mixture change greatly. When the content of gravel is less rock and stone mixture sample is denser. The breccias are embedded in the soil. The contact between the gravel is relatively small. The mechanical properties of the soil-rock mixture mainly depend on the soil particles. When the amount of breccias increases, the breccias become the main skeleton of the earth-rock mixture. Increased contact between the gravel, easy to form a bite in the soil mixture. At this time, its mechanical properties mainly depend on the spatial distribution of the breccias. Studies have shown that when the breccias content is less than 30%, its characteristics are mainly determined by the nature of the soil. When the amount of stone is between 30% and 70%, the characteristic is determined by soil and breccias. When the stone content is more than 70%, the strength characteristics of the soil and stone mixture are mainly determined by the breccias.

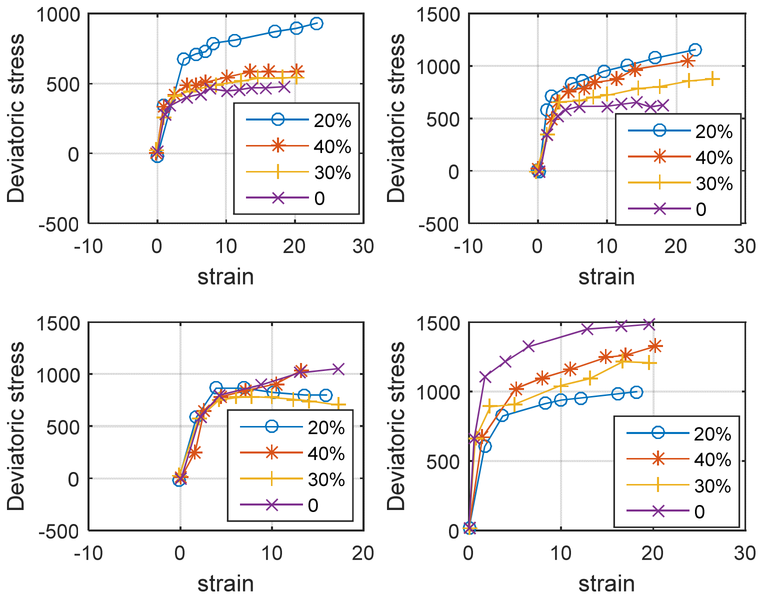

Figure 1: Stress - Strain Curve with Different Stone Content in the Same Pressure

It can be seen from the figure 1, in the same confining pressure under the sample, the greater the amount of stone, the higher the peak strength. When the stone content is different, the strength and deformation mechanism of the sample are different. When the stone content is low, the larger diameter of the corner is embedded in the soil, which can`t form a skeleton effect. The initial deformation of the specimen during loading is mainly due to the compressive deformation of the soil. The external load is mainly borne by the soil. The shear strength of the specimen depends on the soil particles themselves. At the same time, the skeleton does not form a skeleton easy to drive under the action of the surrounding soil deformation. It exacerbates the disturbance of the soil structure, resulting in a lower strength of the rocky mixture of low rock content. When the amount of stone is high, the interior of the specimen is not suspended in the soil. The spacing between the breeds is small, and even contact with each other, the soil filled in the corner between the breccias, which forming a dense skeleton structure. As the axial stress increases, the crushed stone rotates, translates and slides. The gap between the crushed stone is reduced and the upper load is shared by the crushed stone and the soil.

Table 1: Shear strength parameters

Stone content/%	0	20	30	40
Internal friction angle φ/°	18.0	/	33.8	25.6
Cohesion c/kPa	124	/	120	86

Table 1 shows the shear strength indices for different rock-laden mixtures. It can be seen that the addition of the breccias causes the cohesion of the sample to decrease and the internal friction angle increases. The strength of the soil-rock mixture is the result of the interaction between the soil particles and the breccias. When the amount of stone is small, the strength parameter of the soil-rock mixture is mainly determined by the soil. The contact between the soil and the breccias increases, so that the internal friction angle increases. The presence of the breccias has a disturbing effect on the soil, so that the soil-stone mixture becomes loose. Its cohesion significantly is reduced.

3.2 Deformation of soil and stone mixture

The internal breed movement of the soil-rock mixture is closely related to the macroscopic mechanical properties. The soil and the breccias are in contact with each other in space to form a more stable granular structure system. Due to the large difference in the size of the breccias, there is an overhead phenomenon. The distribution of the breccias and the distribution in the long axis direction are highly random. During the compression process, the location of the adjacent breccias and soil will be adjusted. The contact between the breccias and the soil is changed. Therefore, the deformation of the soil and stone mixture is the result of the combination of the position of the breccias and the deformation of the soil. It is important to study the movement law of the breccias under the action of load.

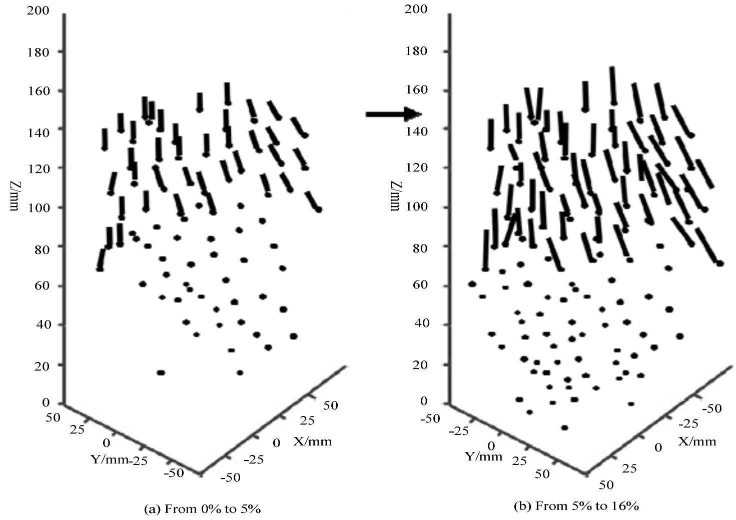

Figure 2: The movement vector of the breccias space

Figure 2 shows the motion vector of the breccias centroid space. The left graph shows the motion vector of the strain from 0% to 5%. It can be found that the displacement of the upper part of the specimen is the largest, and the downward movement is the main. The displacement of the central breccias is small and produces both lateral and vertical displacements. The lower breccias are almost free of displacement. The right figure shows the motion vector of the strain from 5% to 10%. Compared with the left figure, it can be found that the breccias in the sample produce a significant amount of displacement. The upper part of the breccias has the maximum displacement and the direction of movement has changed. The center of the breccias is still the main movement down. Near the outside of the breccias produced a significant lateral displacement, which is mainly related to the occurrence of lateral deformation and deformation of the soil. The lateral displacement of the central breccias is also more pronounced than that of the strain. The amount of displacement at the bottom of the breccias is very small.
Table 2 and table3 show the Corresponding Relationship between the Inclined Surface and the Horizontal Strain and the Axial Strain.

Table 2: The angles of breccias with 30% stones

Strain/%	Breccias number						
	1	2	3	4	5	6	7
0	-33.38	-37.66	28.66	50.74	57.73	-52.72	48.74
5	-32.66	-38.53	34.55	53.21	54.21	-53.81	43.21
15	-25.86	-38.06	38.52	48.67	49.57	-50.67	43.67
20	-25.88	-37.38	34.58	48.97	49.27	-45.93	45.86

Table 3: The angles of breccias with 40% stones

Strain/%	Breccias number									
	1	2	3	4	5	6	7	8	9	10
0	-13.58	-57.36	-2.26	36.74	-50.72	82.72	46.74	-36.67	38.66	56.79
5	-12.64	-58.33	-3.78	22.24	-50.54	73.61	43.22	-34.55	38.65	53.32
15	-15.36	-48.03	-3.54	18.68	-49.58	70.68	40.47	-33.96	38.86	50.44
20	-15.85	-47.35	-43.28	48.89	-49.26	70.83	35.88	-34.42	40.62	55.68

3.3 Soil - rock interaction

Because of the great difference in the physical and mechanical properties between the soil and the breccias, the contact interface between the soil and the breccias under the external load becomes the stress concentration part of the soil and stone mixture and the weakest zone. The perturbation and soil cracking between soil and the breccias affect the macroscopic mechanical properties and their damage morphology to a great extent. Therefore, the study of the interaction between soil and stone for the analysis of soil and rock mixture strength and deformation characteristics, the interaction between soil and stone is very meaningful. We can see the development of shear fissures, some local first cracks. However, due to uneven distribution of soil and stone mixture, it will be associated with some secondary cracks. The soil-rock mixture first destroys between the intersection of the breccias and the soil, or between the narrow crevices. With the axial strain of the force mouth, the plastic zone gradually extended to the soil inside the figure marked part of the line. And then the destruction of different parts of the soil, and the destruction of the area connected to each other, the ultimate occurrence of the overall shear damage. It can be seen that the soil is cracked by the percussion. This is due to the loading process of soil and stone mixture within the breccias at the corners of the stress concentration, resulting in rotating torque. Two breccias, promote the surrounding soil in the opposite direction of movement, causing the middle of the soil cracking.

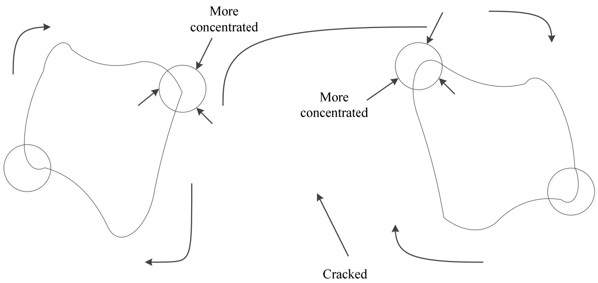

Figure 3: Soil - rock interaction

When the shear band passes through the angle, there may be three cases. The first case is encountered a higher strength of the corner, the destruction of the area around the breccias, causing the shear damage surface deflection. The second case is a two-way around the breccias, will cause the appearance of the sliding surface of the fork, and even cause a multi-slide phenomenon. The third case is the destruction of the area to cut the relatively low intensity of the breccias, most of the defective weak breccias. In this test, we can see that the first two shear bands bypass the breccias. In addition, from 20%, 30% and 40% of the figure can be seen when the stone content is less prone to shear zone. The increase of the breccias content will hinder the development of the shear zone, and it is difficult to form the shear fracture.

4. Conclusion

Soil and rock mixture is a kind of non-uniform, discontinuous, internal structure of complex and irregular geological body. Unlike the general soil, it is a multiphase system, and the mechanical properties of the various components that make up the soil-rock mixture are very different. At the same time there is a complex interaction between earth and stone. Therefore, the mechanical properties, such as failure modes, stress transfer and so on, are different from homogeneous materials. And to a large extent, depends on the internal structure of the soil and stone mixture, such as particle size composition, breccias distribution, breccias arrangement and so on.

In this paper, the effects of stone content and confining pressure on deformation and strength characteristics of soil-rock mixture are studied. Through the qualitative and quantitative method, the change of breccias displacement and the rotation of the attitude during the shear process are analyzed. And the interaction between the earth and stone mixture during the shearing process was studied.

The effect of confining pressure on the strength of soil and rock mixture was studied. The stress - strain curves of the soil - rock mixture show obvious nonlinearity. With the increase of confining pressure, the shear strength of the soil-rock mixture is increased. In the case of low confining pressure, the peak intensity decreases first and then increases with the increase of stone content. When the confining pressure increases, the peak intensity increases with the increase of the amount of stone.

The upper part of the breccias has the maximum displacement with the downward movement. The displacement of the central breccias is small and produces both lateral and vertical displacements. The lower breccias produce almost no vertical displacement.

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