CHEMICAL ENGINEERING TRANSACTIONS

VOL. 66, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866077

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

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In order to explore the effect of different rock content on shear strength and soil-rock mixture, 21 large-scale single-shear tests were conducted using advanced large-scale single shear tester. A total of 7 test samples from 0% to 80% of stone content were designed and tested at three different normal pressures of 100, 200, and 300. Based on the experimental results, the relationship between stone content and shear strength, and shear characteristics of soil-rock mixture was analysed. The experimental results show that under the same normal pressure, the internal friction angle and cohesion of soil-rock mixture increase first and then decrease with the increase of stone content. When the soil-rock mixture is between 40% and 50%, the shear strength is the highest. The results show that the shear strength of soil-rock mixture is affected by the porosity ratio of soil-rock mixture, and at the same time, the structure and dominant particles in soil-rock mixture also change with the increase of stone content. When the content of stone is between 0% and 20%, the fine aggregate dominates in the soil-rock mixture, and the soil-rock mixture is suspended and compacted structure. At this time, the shear strength of the soil-rock mixture is similar to that of the matrix particles. When the content of stone is 20%~50%, the soil-rock mixture is a skeleton pore structure. With the increase of the amount of stone, the skeleton of the soil-rock mixture gradually forms and the occlusal force between the particles increases, making the cohesion and internal friction. The horns have been significantly improved; when the amount of rock content exceeds 50%, the soil-rock mixture exhibits a dense skeleton structure, the porosity starts to increase and the fine granules begin to drastically decrease, and the fine aggregate cannot fully fill the pores between the blocks. The shear strength of soil-rock mixture began to decline.

1. Introduction

Soil-rock mixture is a kind of non-homogeneous bulk material formed by mixing soil and rock. Its shear strength characteristics are mainly affected by factors such as water content, stone content, grain gradation and compaction degree. In the large-scale indoor direct shear test, on the basis of previous studies, the impact of grading parameters was considered. By controlling the mass and volume of the sample to achieve the level of compaction required for the test, the main parameters were analysed for the shear resistance of the soil-rock mixture. The effect of strength, the test results show that: with good grading, the shear strength of soil-rock mixture increases first and then decreases with the increase of non-uniform coefficient, and the non-uniform coefficient reaches a peak around 22.99, while the curvature The coefficient has little influence on it; the shear strength of soil-rock mixture increases with the increase of stone content and compaction, but the trend of increase decreases with the degree of compaction exceeding 92.5%. For the growth, the shear strength increases first and then decreases, and reaches the peak value near the optimal moisture content. Based on the multiple linear regression analysis of MATLAB, the order of the influence of each factor on the shear strength of the soil-rock mixture is obtained. Stone content> moisture content> compaction> uneven Coefficient> curvature factor, obtained by nonlinear regression analysis formula for fitting the shear strength of each factor, and the correlation index R2 is greater than 0.9 (Abduljauwad and Gassous, 1991).

Aiming at the difficulties in the analysis and calculation of parameters and models for the high-fill earth-rock mixture engineering, the apparatus of unsaturated soil was used to carry out 36 consolidation drainage shear tests to control the matric suction and net confining pressure, and the degree of compaction and matrix were quantitatively studied. The effect of suction and mix ratio on the strength and deformation characteristics

Please cite this article as: Xu S., 2018, Study on soil-stone interaction between strength and deformation characteristics of rock-soil mixture, Chemical Engineering Transactions, 66, 457-462 DOI:10.3303/CET1866077

mixes was established. The modified algorithm expressions for shear strength, tangent deformation modulus and tangent bulk modulus of unsaturated compacted soils were established. The test results showed that the stress and viscosity were destroyed. The cohesive force increases linearly with the increase of suction force, and the change of suction force has little effect on the effective internal friction angle; the stress and strength parameters of failure increase with the increase of compaction coefficient; the failure stress and strength of soil sample with 4:6 soil-rock ratio. For soil samples with an overall parameter slightly higher than 2:8, the effective cohesion increases with the increase of the silty clay content. With soil samples with the same mix ratio and compaction coefficient, the greater the net confining pressure or suction, the greater the strength of the sample. Large, gradual change in body deformation; in soil samples with the same net confining pressure and suction force, the higher the compaction coefficient, the strain curve gradually changes from the strain hardening type to the ideal elastic modulus type. Some soil samples tend to be under the net confining pressure Variant unsaturated soils nonlinear Incremental Constitutive conform to the corrected fill large engineering practice, it can be used to calculate the slope stability and high fill GROUND HIGH FILL modification (Aziz et al., 2016, Cai et al., 2015).

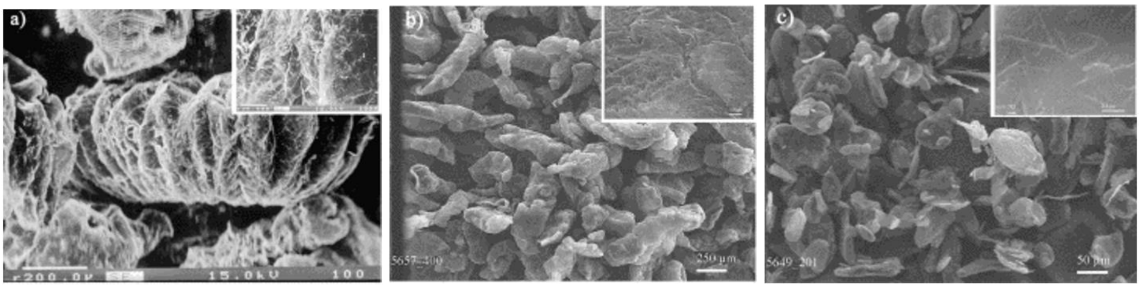

Figure 1: SEM images of TEG powder before (a) and after grinding (b, c)

2. Material and method

Soil-rock mixture is a kind of loosely-packed body with complex internal structure and a combination of block stones and soil particles formed during the Quaternary period under the dynamic coupling between the interior and exterior of the earth. This geological material has diverse material sources and complex geological origins. It is different from the general homogeneous soil and the general rock mass. It is a kind of special geological material between the soil and the fractured rock mass. Starting from the mesoscale, with the aid of mesoscopic calculation methods and mesoscopic tests, the characteristics of deformation and failure of soil-rock mixture under load are revealed, the mechanism of earth-rock interaction of soil-rock mixture is ascertained, and the deformation and fracture mechanism is essentially described. The research is the need for the current project construction, and it is also the inevitable development of the modern fine-spot rock and soil mechanics (Chakrabortyv et al., 2014).

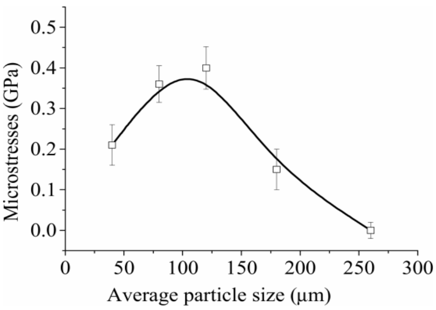

Figure 2: Dependencies of the micro-stresses on the dispersity level of TEG particles

In nature, the distribution of soil-rock mixture is very random. Even if the soil-rock mixture produced in the same area and originated from the same origin, the structure of the soil-rock mixture will show differences in the local area. The soil-rock mixture obtained based on image processing technology is also limited to the distribution of blocks in a section, and it cannot reflect the distribution of blocks in all sections of the soil-rock mixture. At the same time, even if it can truly reflect the local structural features, due to the regional differences of the soil-rock mixture, the true structure characteristics of the local areas cannot fully reflect the structure characteristics of the entire site. Therefore, the establishment of a random structure model of soil-rock mixture is more valuable than the establishment of a real scale model of soil-rock mixture, and it is more universally significant (Chakraborty et al., 2014).

3. Result and discussion

3.1 Accumulative settling characteristics of different packing slamming

The coarse aggregate in the earth and rock-filling materials can be divided into sandstone aggregates and sand and mudstone mixtures. The single point concrete tests are performed on the two source materials respectively to observe the sag and sedimentation at single points. Quantities, to study the compaction effects of different types of coarse aggregate soil-rock mixture, and determine the best number of slamming. Taking into consideration the existing construction conditions, the single-shot tamping energy of the filling body treatment test is 3000. According to experience, the virtual shop thickness is 4.0 m, and the number of slamming hits is 20 hits (Park et al., 2015; Lohani et al., 2006).

From the point of impact of on-site slamming effect, the coarse aggregate of the filler in the depth of the bottom of the pit was broken within 0.5m, and the average number of super heavy-duty gravity hits of the soil and stone mixed with sand and mudstone as the coarse aggregate was 6.4 hits. Less than the depth of the deep filling of the heavy-duty gravity hits, after the powerful ramming pit 0.5m below the padding of the super-heavy hitting the number of dynamic hits in the 7.2 ~ 8.7 hits, after the dynamic compaction to fill the foundation to reach the state of dense, deep foundation The density is greater than the shallow density. The average number of heavy heavy-duty gravity hits within a depth of 0.5m with ground-stone mixture of sandstone and coarse aggregate is 8.4 hits, and the average value is significantly smaller than that of deep-filled heavy-duty gravity hits. The number of super heavy-duty dynamic strikes hitting the following fillers was 8.7 to 13.2 hits, and the compacted land after compaction reached a dense-to-dense state. The deepness of the foundation was greater than that of the shallow layer.

$$j = \arg\max |(1-\gamma)(r_{i-1}, b_k)| \quad (1)$$

$$m = \gamma(r_{i-1}, w_k, k_b) \quad (2)$$

The increase of compactness increases the elastic modulus and deformation modulus of the filler, and the shear strength of the filler increases, which is conducive to enhancing the stability of the filling slope and reducing the deformation of the filling foundation. This chapter mainly analyses the influence of packing density on the stability and deformation of the filling body under complex terrain conditions in the mountain area. The deformation of the building is analysed by taking the two-dimensional valley filling body as an example. The deformation displacement vector of the filling soil on the centre of the valley and on the slopes on both sides of the valley is different, and the gravity of the soil around the hillside on both sides is different. In addition to the vertical displacement, there is also a horizontal displacement component. The larger the vertical displacement component, the larger the horizontal displacement component. The smaller the degree of compaction, the greater the vertical component of the displacement of the building body, and hence the greater the horizontal component. A is a double-sided slope, and b is a single-faced slope. When the compactness is small when the slope is filled, the vertical displacement component and horizontal displacement component will be larger and more unstable.

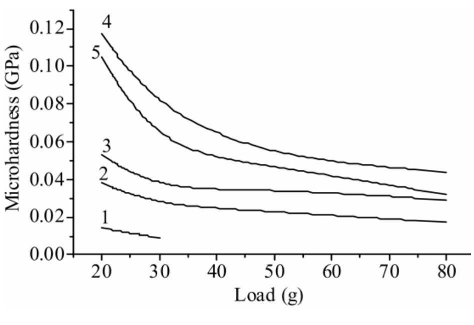

Figure 3: Micro-hardness dependencies on an applied load on indentor for the samples of initial TEG

The soil-rock mixture medium has the characteristics of high heterogeneity, significant structural effect and size effect, which makes its physical and mechanical properties complex. In this paper, according to the deformation and influencing factors of the shear band in the shearing process of soil-soil mixture, a self-developed RSM-1000 motor servo control large-scale earthwork shear strength test system is adopted to consider different stone contents (0, 30%, (50%, 70%), overburden pressure, block size (L1, L2, L3), three main structural control factors, shear deformation test of soil-rock mixture, drilling through the inside of the sample The method of wire and dry ash monitors the characteristics of the shear belt. The results show that when the content of stone is less than 30%, the deformation of the sample is less affected by the stone, and the strength mainly depends on the strength of the sand. When the content of stone reaches 50%, the skeleton structure has been formed in the sample. Affected by the block rock, the strength is caused by the joint action of the block stone and the sand. When the content of the rock reaches 70%, the block-stone overhead structure has been formed in the sample. In the case of high stone content and large grain size stone, the block stone sample with a penetrating shear plane develops with the shear deformation, and the block stone undergoes extrusion and inversion phenomenon; the sample of rock stone distributed near the shear face, With the development of the shear deformation, the block rock is dominated, and the block stone undergoes extrusion, angular shearing and misalignment. The shear deformation of the specimen can be compared with the failure characteristics of a landslide that is deformed by backwards and forwards or a composite landslide that deforms from the front to the back, that is, the trailing edge of the slope produces cracks under the action of active earth pressure, and then sinks. Compaction, slippage and slipping; creep deformation of the leading edge of the foot slope; shear loss of the rock and soil in the slope to progressive expansion of the sliding surface, the final shear plane through, the formation of the overall destruction. The research results are of great significance for revealing the formation and evolution rules of the landslide shear zone of the soil-rock mixture, the failure modes, and the disaster prevention and mitigation of landslides (Nataraj et al., 2015).

3.2 The influence of compactness on deformation of filling body

(1) Based on the heterogeneity, non-linearity, non-continuity, and other characteristics of the "soil" and "block stone" that make up the soil-rock mixture, the concept of "calculation of the mechanics of the soil-soil mixture" is proposed, and the soil-rock mixture is defined. The key scientific issues that the mechanics of scale computational mechanics must solve are that the soil-rock mixture is regarded as a three-phase composite medium consisting of a soil matrix, a block stone, and a soil-stone interface. Based on the mechanical numerical test method based on the finite element principle and damage statistical mechanics, the effects of orientation, random distribution, rock mass, and soil-cement bonding characteristics on the deformation and cracking of soil and rock are comprehensively considered, and the soil-rock mixture is analysed. Under the condition of progressively progressive failure, the damage can be divided into three grades: the failure of earth-rock interface slip, the failure of soil cracking, and the misalignment of block stone (for low-strength schist, slate, etc.) (Tsukamoto, 2006).

$$N = (1-\gamma) + \gamma W^{*} B_{r_{i-1}} \tag{3}$$

$$x_{k+1} \sim p(x_{k+1} \mid x_k, a_k) \tag{4}$$

Table 1: Statistical table of super gravity sounding test after dynamic compaction

Test setup	Buried depth 0~0.5m	Buried depth 0.5~1.0m	Buried depth 1.0~2.0m	Buried depth 2.0~3.0m	Buried depth >3.0m
Sand mud mix filler	6.6	7.2	7.2	7.9	8.2
	6.7	6.5	7.4	8.5	8.7
	5.8	7.0	7.1	7.9	7.9
Sandstone filler	7.9	8.7	9.4	11.8	13.2
	8.8	9.1	9.0	8.1	9.9

(2) Ultrasonic testing technology was introduced into the research field of soil-rock mixture. Test systems for axial and radial soil-rock hybrids were developed to study the variation of acoustic parameters under the uniaxial loading conditions of soil-soil mixture. The comparative analysis of rock acoustic test results reveals the unique characteristics of soil-rock mixture that distinguish it from “soil body” and “block stone”. Axial ultrasonic test was used to study the stress dependence of soil-rock mixture. The results show that the wave velocity, transmission coefficient and internal pore change law and the soil, block stone have obvious essential differences; at the same time, the axial compaction of soil-rock mixture is deduced. The expression of porosity reduction in the process. The radial ultrasonic test is used to analyse the damage-cracking characteristics of

soil-rock mixture, and the evolution law of the crack width in the loading process is deduced according to the change of ultrasonic velocity. The evolution equation of the segmented nonlinear damage constitutive equation is established (Youwai and Bergado, 2003).

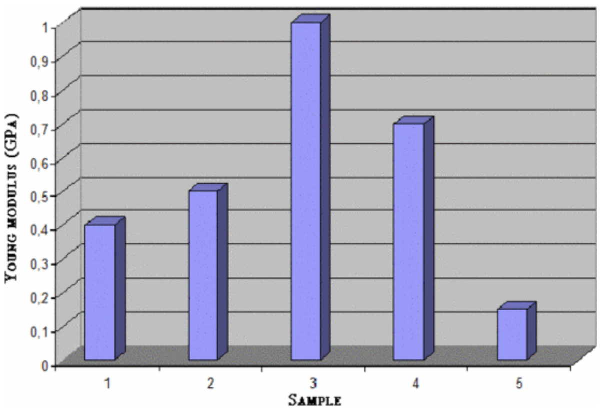

Figure 4: The young modulus diagram for the samples of compacted TEG with average particle sizes

Complex landforms in mountainous areas often have strong restraining effect at the bottom of valleys, which is conducive to stability. As the height of valley increases, the restraint effect weakens. Although there is a weak silty clay layer at the bottom of the area, due to the strong constraints, the bottom of the gully has good stability; due to the weak constraint, the displacement of the upper part of the gulch centre elevation of 330m is relatively large. Potential slip. In the process of filling the upper part of the elevation of 360.0m, due to the self-gravity and the constraints of rock slopes in the downhill slope, the amount of slip on the high-speed side to the high-speed side of the upper filling body is large, and the elevation is 360.0m below the elevation. The slope has an effect.

Table 2: Result of compactness test

Coarse aggregate type	Average dry density(g/cm^3)	Maximum dry density(g/cm^3)	Average degree of compaction	Solid volume rate
Sand mud	2.258	2.376	95.5%	84.4%
	2.257	2.376	95.4%	84.4%
	2.258	2.376	95.3%	84.3%
Sandstone	2.227	2.331	95.3%	84.7%
	2.228	2.331	94.8%	84.7%

3.3 Effect of compactness on deformation and stability of fill building

(1) The results of comprehensive axial ultrasonic testing and radial ultrasonic testing confirmed that the stone content is the most important index affecting the mechanical properties of soil-rock mixture. The P-wave velocity decreases with the increase of stone content, and the attenuation characteristics increase with the increase of stone content. With the increase of stress, the coupling effect between soil and rock becomes stronger, the wave-like velocity of axial wave velocity and transmission coefficient increase slowly; the radial relative wave velocity decreases with the increase of stress, and the cumulative width of cracks in the sample increases continuously.

(2) Using the combination of the uniaxial compression test and the real-time CT scan test of the macroscopic soil-rock mixture, the CT number characteristics of the region of interest (ROI) inside the sample are quantitatively analysed, and the damage cracking of the sample is further clarified. Mechanism; In addition, based on mathematical morphology statistical principles to extract the crack geometry and analysis of its spatial distribution characteristics, the crack length, area and average width of the quantitative description, more conducive to the sample deformation cracking mechanism and research, It also helps to further establish the mesoscopic damage evolution equation.

(3) In order to overcome the defect that the porosity value is uncertain due to the threshold value segmentation method, starting from the CT image itself, the porosity of the sample is calculated by mining the variation law of the number of CT images, and the porosity extraction is proposed. Gray level method. The gray value of the whole CT image is divided into two parts: the matrix and the pore. Through the determination

of the matrix and pore CT number threshold, the porosity of the sample can be quickly calculated to analyse the damage cracking mechanism from the perspective of mesoscopic pore evolution.

(4) Based on CT number-based damage variable definition method, the damage characteristics of soil-rock mixture samples under uniaxial loading are analysed, and the damage evolution equation and damage constitutive model of soil-rock mixture are obtained. The calculation shows that the damage variable and the principal strain have an exponential function in the loading process of the soil and rock samples, and the calculated results of the theoretical prediction model are in good agreement with the measured results.

4. Conclusion

Soil-rock mixture is a complex geotechnical material composed of two materials with different properties (soil medium and block stone), showing a strong non-uniformity, non-continuity, macroscopic mechanical properties and the amount of stone contained in the block stone. The structures such as morphological characteristics and spatial distribution are closely related. This paper takes the establishment of the mixture structure model as the starting point, and mainly completes the following work and obtains the following conclusions: Through the image acquisition device, the digital image data of the block stone is collected, and the image processing technology is used to identify the boundary pixels of the block stone, and then With the concept of "straight-forward music", a geometric method for obtaining linear boundaries and corner points of block stones was proposed, which not only eliminated the jaggedness of the boundary, but also obtained the boundary shape of block stones without losing the shape information of block stones. Two new parameters for the shape of block stone are proposed: the area difference ratio CPS, the angular index AI, and its effect on the mechanical properties of the soil-rock mixture. The study shows that when the content of stone is 50%, the shear properties of the soil-rock mixture are determined by the fine material and the block stone. The area difference CPS and the angular index AI indicate the surface shape characteristics of the block stone, and the mechanics of the soil-rock mixture. Less impact on performance. Based on the idea of "substituting an arc for straightness" and the principle of "allowing particles to overlap", an algorithm for filling irregular block stones (MCOS algorithm) was proposed, and the control conditions for filling accuracy were proposed, and a block suitable for discrete elements of particles was established. Stone basic unit.

Reference

Abduljauwad S.N., Al-Gassous K.A., 1991, Soil deformation and shear strength characteristics of the Sana'a soil, Yemen Arab Republic, Engineering Geology, 31(3-4), 291-314, DOI: 10.1016/0013-7952(1)90013-B

Aziz M., Towhata I., Irfan M., 2016, Strength and Deformation Characteristics of Degradable Granular Soils, Geotechnical Testing Journal, 39(3):20150209

Cai G.H., Liu S.Y., Yan-Jun D.U., Zhang D.W., Zheng X., 2015, Strength and deformation characteristics of carbonated reactive magnesia treated silt soil, 22(5), 1859-1868, DOI: 10.1007/s11771-015-2705-5

Chakraborty D., Watts C.W., Powlson D.S, Macdonald A.J., Ashton R.W., 2014, Triaxial Testing to Determine the Effect of Soil Type and Organic Carbon Content on Soil Consolidation and Shear Deformation Characteristics, Soil Science Society of America Journal, 78(4), 1192-1198, DOI: 10.2136/sssaj2014.01.0007

Hou T.S., 2012, Influence of expanded polystyrene size on deformation characteristics of light weight soil, 2012, 19(11), 3320-3328

Lohani T.N., Matsushima K., Aqil U., Mohri Y., Tatsuoka F., 2006, Evaluating the strength and deformation characteristics of a soil bag pile from full-scale laboratory tests, Geosynthetics International, 13(6), 246-264, DOI: 10.1680/gein.2006.13.6.246

Matsushima K., Tatsuoka F., Mohri Y., Aqil U., 2008, Shear strength and deformation characteristics of geosynthetic soil bags stacked horizontal and inclined, Geosynthetics International, 15(2), 119-135, DOI: 10.1680/gein.2008.15.2.119

Nataraj M.S., Mcmanis K.L., 2015, Strength and Deformation Properties of Soils Reinforced With Fibrillated Fibers, Geosynthetics International, 4(1), 11-19.

Park C.S., Park I.B., Mok Y.J., 2015, Evaluation of resilient moduli for recycled crushed-rock-soil-mixtures using in-situ seismic techniques and large-scale resonant column tests, Ksce Journal of Civil Engineering, 19(6), 1-9.

Tsukamoto Y., 2006, Undrained deformation and strength characteristics of soils from reclaimed deposits in Kobe, Soils and Foundations, 38(Special), 47-55.

Youwai S., Bergado D.T., 2003, Strength and deformation characteristics of shredded rubber tire-sand mixtures, Canadian Geotechnical Journal, 40(2), 254-264, DOI: 10.1139/t02-104