Test Study on Mechanical Properties of Mixture Mass of Loess and Crushed Rocks[1]

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Abstract: Based on large-scale triaxial tests, the mechanical properties of loess and crushed rocks mixture mass of a freeway tunnel's surrounding rocks in Hebei were studied under the consideration of crushed rock's contents. The test results indicate that with the increase of crushed rocks contents, initial slope of deviatoric stress and axial strain curve increases at the same confining pressure. And corresponding axial strain decreases at the maximum partial stress value. At the same time, the mixture mass shows the characteristics of crisping deformation. Additionally, with the increase of crushed rocks contents, the internal frictional angle increases but the corresponding cohesion decreases. Therefore, the mechanical constitutive relationship of loses and crushed rocks mixture mass was simulated with double yield surface model. The method for determining the model parameters of this model was put forward at the same time.

Introduction

The "coarse phase" (also known as giant grain group or coarse grain group) and "fine particle phase", which constitute the mixture mass of loess and crushed rocks, have significant differences in physical properties and mechanical strength [1, 2]. The physico-mechanical properties of mixture mass of loess and crushed rocks are different from "fine-grained soil" and "rock" in standard [3, 4, 5]. The definition of mixture mass of loess and crushed rocks put forward by Wenjie Xu *et al* [6, 7, 8] is that formed since the quatemary period, composed of block stone with certain engineering scale and higher strength, but the research on the mixture of loess and gravel is relatively rare [7, 8].

Test analysis of tunnel's mixture mass of loess and crushed rocks

Test sample of mixture mass of loess and rocks and its physical property index. The test sample of mixture mass of loess and crushed rocks was obtained from the left line of a freeway's tunnel in Hebei near the no.K25+240 pile. Its grain size distribution curve is shown in Fig. 1. As seen in Fig. 1, the content of the particle size which more than 10mm is about 15%. In addition, the main physical properties index of the loess are obtained by the conventional soil mechanics test as shown in Table 1.

Firstly, there is 24h-isotropic consolidation under confining pressure. Then, triaxial shear test with no drainage was carried out under the shearing rate of 0.5%/min axial strain. And the test readings are r according to the frequency of 0.5% axial strain.

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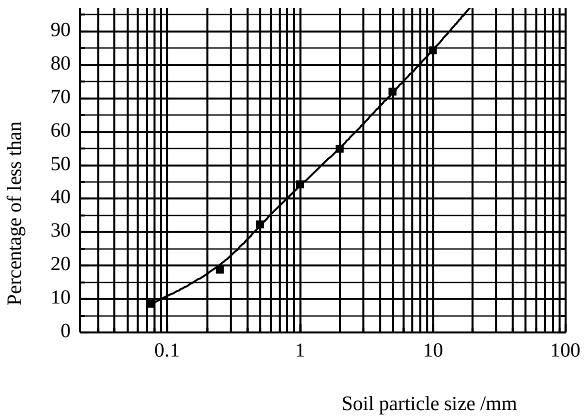


Fig.1 Grain sizes of distribution of mixture

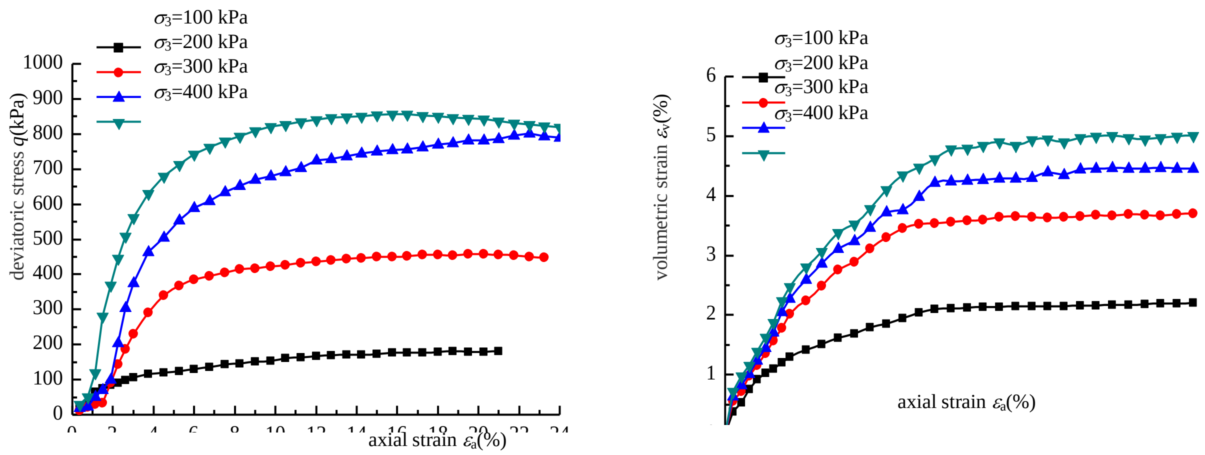
Soil sample	Natural unit weight γ (kN/m3)	Dry unit weight γ_d (kN/m3)	Natural water content W(%)	Void ratio e
mixture mass	19.21	16.95	13.24	0.57

Table 1 Physical property parameters

Test results analysis of mixture mass of loess and crushed rocks of tunnels

As shown in Fig.2 to 4, the relationship curves between axial strain and deviatoric stress as well as volumetric strain are described in triaxial shear tests with different confining pressure of three kinds of gravel content.

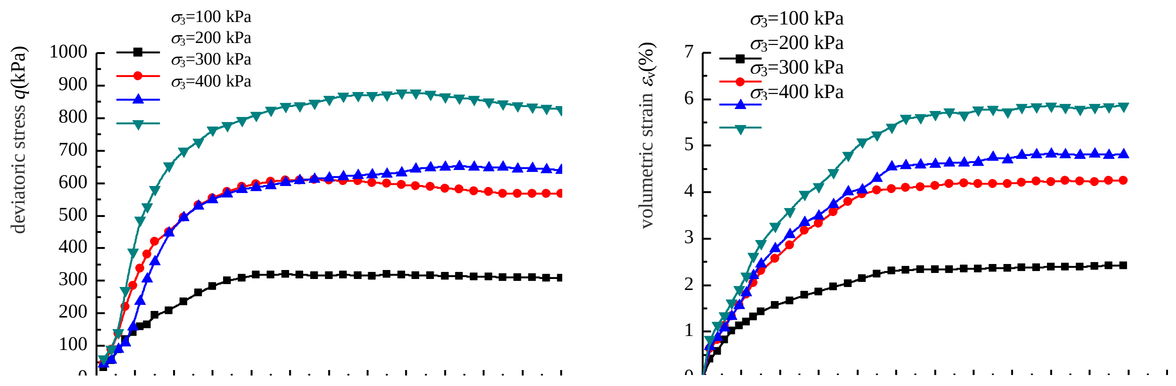
Then, the triaxial shear strength characteristic parameters (that is angle of internal friction and cohesion) of tunnel's mixture mass of loess and crushed rocks in different conditions can be obtained by the use of molar circle tangent according to triaxial shear test results with different gravel content, as shown in Table 2. In the process of increase, reduction of soil compaction porosity and distance between gravels, and change of distribution structure are the main change of mixture mass of loess and crushed rocks.



(a) deviatoric stress ~ axial strain

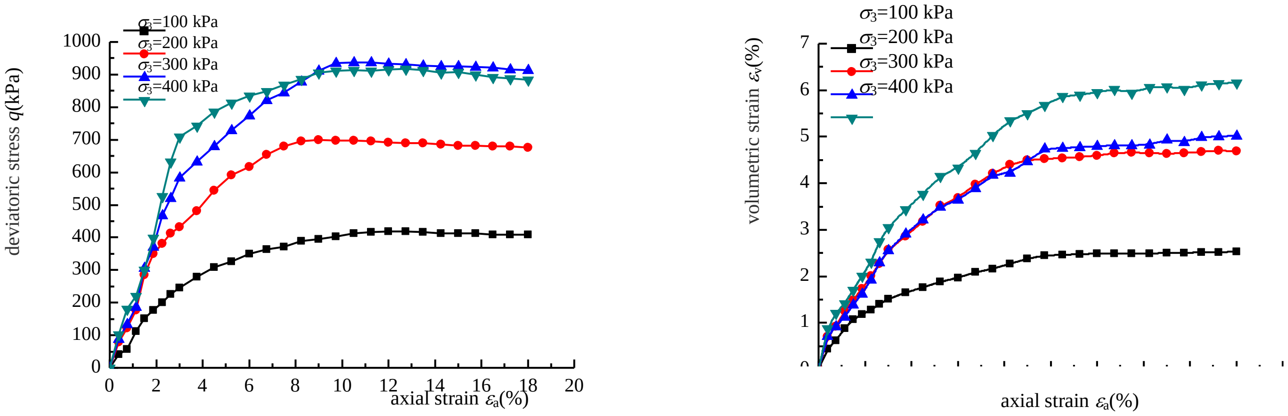
(b) axial strain ~ volume strain

Fig.2 Triaxial tests results of mixture mass with 10% crushed rocks



(a) deviatoric stress ~ axial strain (b) axial strain ~ volume strain

Fig.3 Triaxial tests results of mixture mass with 20% crushed rocks



(a) deviatoric stress ~ axial strain (b) axial strain ~ volume

Fig.4 Triaxial tests results of mixture mass with 30% crushed rocks

intensity index gravel content	normal peak intensity		residual intensity	
	internal friction angle ϕ(°)	cohesion force c(kPa)	internal friction angle ϕ(°)	Cohesion c(kPa)
10%	26.89	65.34	25.14	62.64
20%	27.67	61.12	26.43	53.21
30%	28.84	51.90	28.24	51.40

Table 2 Index of shear strength for mixture mass

Research on constitutive model of the mixture mass of loess and crushed rocks

At present, the constitutive model of mixture mass of loess and crushed rocks mainly bases on the constant elasticity modulus and Poisson's ratio. Currently, after the soil mass reaches its yield, the description of yield surface mainly contains shear yield surface and volume collapse yield surface. And double yield surface which combined by two of them is commonly used. The hardening parameter of the yield surface is plastic volume strain ε_v^p and the shear stain ε_s^p, taking the plastic shear stain and plastic shear stain into consideration. In this paper, the model of mixture mass of loess and crushed rocks is simulated by the double yield surface model.

Shear yield surface of mixture mass of loess and crushed rocks.

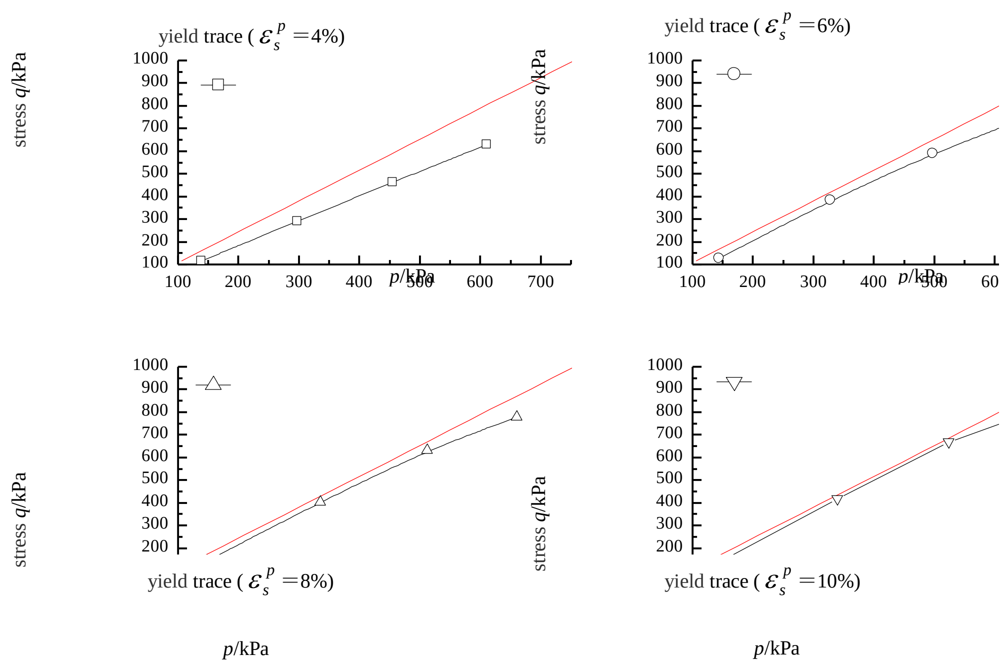


Fig.5 Trace of plastic strain change for mixture mass with 10% crushed rocks

And then the fitting results of the corresponding stress yield trace by hyperbolic function with plastic shear strain of mixture mass of loess and crushed rocks is 4%, 6%, 8% and 10% under different gravel contents in Table 3.

Soil sample	Natural unit weight γ (kN/m3)	Dry unit weight γ_d (kN/m3)	Natural water content W(%)	Void ratio e
mixture mass	19.21	16.95	13.24	0.57

parameter / **mixture mass**	shearing strain (%)	hyperbolic yield function parameters a	Hyperbolic yield function parameters b	cohesion c(kPa)	critical state line slope M
gravel content 10%	4	-0.0005	3.3479	65.34	1.1365
	6	-0.00091	1.5433		
	8	-0.00074	1.4352		
	10	-0.00034	2.243		
gravel content 20%	4	-0.0005	3.4164	61.12	1.2008
	6	-0.00042	2.6933		
	8	-0.0003	2.0475		
	10	-0.00026	1.8188		
gravel content 30%	4	-0.00026	1.845	51.90	1.3615
	6	-0.0005	3.3479		
	8	-0.00091	1.5433		
	10	-0.00074	1.4352		

Table 3 The shear yield surface parameters for mixture mass considering different contents of crushed rocks

Conclusion

An indoor large triaxial tests carried out for the mechanical properties of mixture mass of loess and crushed rocks of a freeway's tunnel in Hebei. The impact of gravel on loess mass was analyzed by changing its content. And then, the stress and strain characteristics of mixture mass of loess and crushed rocks were simulated by using double yield surface model. And main conclusions of this paper are as followed:(1) The deviatoric stress increases obviously with the increase of gravel content under the same confining pressure, especially when the gravel content increases to 30%. (2) Mixture mass of loess and crushed rocks has brittle characteristics when the gravel content gradually increases from 10% to 20% and 30%. And when gravel content increases to 30%, the internal friction angle of mixture mass of loess and crushed rocks increases by 7.3%, while the cohesion decreases by 20.6%. (3) Put forward the double yield model to simulate the mixture mass of loess and crushed rocks and determine the model parameters.

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