Study on Dynamic Characteristics of Unsaturated Strongly Weathered Sericite Schist Residual Soil

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Abstract. Sericite schist residual soils are widely distributed on the shallow surface of western Yunnan, and most of them are in an unsaturated state. In order to study its dynamic characteristics, a resonance column tester was used to target the strongly weathered unsaturated sericite schist residuals in the Dali Railway. The soil carries out dynamic characteristic test to study. The results show that the confining pressure has a great influence on the dynamic characteristics of the specimen, the dynamic shear modulus increases with the increase of the confining pressure, the phenomenon that the damping ratio decreases with the increase of shear strain is more obvious. Using the Hardin-Drnevich model can better fit the dynamic shear modulus with shear strain. The application of the improved linear equation can better describe the relationship and analyse its mechanism.

1. Introduction
The Dali-Lincang Railway is a key transportation project implemented in the “Belt and Road” initiative. Unsaturated sericite schist residual soil is distributed in a large number of strata along the line, and the engineering problems about unsaturated characteristics encountered in actual engineering are increasing, which significantly affects the actual engineering design and construction. Many scholars have been involved in the study of the dynamic characteristics of soil. The compressive strength of the unsaturated sericite schist residual soil is 10 cm thick "pulverization" phenomenon [1]. Huang Zhiquan et al. [2] used GDS resonance column to carry out dynamic characteristics test on unsaturated expansive soil, and studied the dynamic shear modulus and damping ratio of unsaturated expansive soil under different free expansion rates. Wang Zhijie et al. [3] studied the influence of soil dry density on the dynamic shear modulus and damping ratio of unsaturated expansive soil under different free expansion rates. Yuan Xiaoming et al. [4] used the resonance column free vibration test to conduct dynamic tests on domestic conventional soils, and gave the dynamic characteristics of various soils. Huang Zhiquan et al. [5] applied the Hardin-Drnevich model and the Davidenkov model to fit and compare loess of different ages, and found that the Davidenkov model was more accurate and gave the fitting parameters of the model. Li Lan et al. [6] conducted comparative experiments on the dynamic stress-strain relationship of loess under different random loads and constant amplitude cyclic loads, dynamic shear modulus and damping ratio, and concluded that the undisturbed loess under different random vibration loads the dynamic stress-strain relationship obeys the conclusion of the hyperbolic model. In summary, it can be seen that there are few studies on the dynamic characteristics of unsaturated sericite schist residual soil. The research results in this paper have important practical significance and reference value for similar projects.
2. Materials and method

2.1. Test material
The samples used in the test are taken from the strongly weathered unsaturated sericite schist residual soil in the Baishitou test section of the Dalin Railway. It is mostly grey, with a softening coefficient of $<0.75$. Its strength is almost reduced by half after contact with water. Softening with water affects surrounding rock one of the important factors of large deformation. The compactor was used to prepare a solid sample of $\Phi 50 \text{mm} \times 100 \text{mm}$.

2.2. Basic physical properties of rock samples
The sample is made of remoulded soil sample, and the basic physical performance test is carried out in accordance with the "Geotechnical Test Method Standard" (GB/T 50123-2019) \[7\]. The results of measuring its physical parameters are shown in Table 1.

| Natural moisture content (%) | Proportion $(d_s)$ | Plastic limit | Liquid limit | Plasticity index | Maximum dry density |
|-----------------------------|-------------------|---------------|--------------|-----------------|--------------------|
| 9.87                        | 2.76              | 8.15          | 20.35        | 12.20           | 2.13               |

3. Test plan

3.1. Technical index of test instrument
The test was carried out with the GZZ-50 resonance column tester produced by Jiangsu Yongchang Science and Education Instrument Manufacturing Co., Ltd., which can study the dynamic properties of soil in the small strain range (10^{-6}~10^{-4}) of the undamaged sample. The excitation form is electromagnetic, and the test is mainly obtained by free vibration test, that is, the shear modulus $G$ and damping ratio $\gamma$ under corresponding shear strain are obtained.

In order to study the influence of confining pressure on dynamic parameters, four groups of samples will be subjected to resonance column and damping tests with confining pressures of 100 kPa, 200 kPa, 300 kPa, and 400 kPa under the same moisture content and dry density. Determine the dynamic shear modulus $G$ and damping ratio $\gamma$ of the sample.

3.2. Analysis of test results
From the stress-strain relationship of the soil, the dynamic shear modulus $G$ is the dynamic shear stress $\tau$ level of the unit shear strain $\gamma$ generated by the soil under dynamic load: $G = \frac{\tau}{\gamma}$, which is a parameter reflecting the ability of the soil to resist shear deformation. Figure 1 shows the experimental relationship curve between the dynamic shear modulus $G$ and the shear strain $\gamma$ of the specimen under four confining pressures.

It can be seen from Figure 1 that the relationship curve between the dynamic shear modulus $G$ and the shear strain $\gamma$ of the soil sample shows an attenuation trend. When the shear strain $\gamma$ is small, the dynamic shear modulus $G$ first decreases slowly with the increase of the shear strain, and the attenuation amplitude of the curve is small. When the shear strain $\gamma$ increases to a certain extent, the attenuation amplitude of the dynamic shear modulus and the shear strain curve increases. Under the same confining pressure, as the shear strain increases, the dynamic shear modulus decreases. At the same strain level, as the confining pressure increases, the dynamic shear modulus gradually increases. Under the same strain level, the greater the confining pressure of the sample, the greater the dynamic shear modulus.
3.3. Hardin-Drneovich model

At present, there have been many research results on the stress-strain relationship equation of the soil skeleton. In order to study the application of the existing model to the strongly weathered unsaturated sericite schist residual soil in this experiment, the data of this experiment is now fitted. For the dynamic shear modulus, the widely used Hardin-Drneovich model is used for fitting. It is an empirical model developed on the basis of the nonlinear backbone curve and the Masing rule, and it is also one of the first to be applied. This model [8] assumes that the curve of the specimen under dynamic load conforms to the hyperbolic law, and its expression is

\[
\tau = \frac{\gamma_d}{a + b\gamma_d}
\]

In the formula, \(a\) and \(b\) are test parameters.

The dynamic shear modulus of soil is defined as:

\[
G_d = \frac{\tau_d}{\gamma_d}
\]

Then there are:

\[
G_d = \frac{1}{a + b\gamma_d}
\]

which is:

\[
\frac{G_d}{G_{max}} = \frac{1}{1 + \frac{\gamma_d}{\gamma_r}}
\]

In the formula, \(G_d\), \(G_{max}\) is the dynamic shear modulus and the maximum dynamic shear modulus respectively, \(G_{max} = \frac{1}{a}\), \(\gamma_d\) is the shear strain, \(\gamma_r\) is the reference shear strain, and its value is \(\frac{a}{b}\).

3.4. Damping ratio \(D\)

The damping ratio of soil is one of the important characteristic parameters of soil dynamics, reflecting the hysteresis of soil dynamic stress-strain relationship. It is produced by the energy consumed by
internal friction when the soil is deformed, and reflects the nature of energy consumption due to the internal resistance of the soil under dynamic load [9]. And the hysteresis is gradually manifested in the process of plastic deformation after the elastic deformation of the soil.

Figure 2. D-γ relationship curve of samples under different confining pressures

Analyzing Figure 2, it can be seen that the damping ratio increases with the increase of the shear strain. Under the same confining pressure, as the shear strain increases, the damping ratio gradually increases. And at the same strain level, the greater the confining pressure, the smaller the damping ratio. The curve trend shows three stages: basically unchanged, increasing rapidly and slowly increasing. At the beginning, the sample was not damaged. At this time, the friction between the soil particles is smaller and the energy consumption is less. As the shear strain increases, the soil gradually deforms, and the energy loss also increases. When the shear strain is large enough, soil deformation and energy loss gradually stabilize.

4. Analysis of test results

Figure 3 shows the Hardin-Drnevich model fitting curve between the dynamic shear modulus G and shear strain γ of the unsaturated strongly weathered sericite schist residual soil under four confining pressures. Table 2 shows the parameter values after fitting, where a and b are the experimental fitting parameters, and Gmax is the maximum dynamic shear modulus value. R² is the correlation coefficient of the fitting equation. The closer its value is to 1, the better the curve fit.

Analyzing Figure 3, Table 2, we can get that: the experimental scatter points have a great coincidence with the fitted curve, and the average value of R² after fitting the G-γ relationship under four kinds of confining pressure conditions using formula (3) reaches 0.9713, which shows that the model can describe the dynamic characteristics of the dynamic shear modulus and shear strain of the strongly weathered unsaturated sericite schist residual soil. It can be seen from Table 2 that under the same strain level, the values of parameters a and b decrease as the confining pressure increases.
Figure 3. Fitting curve of G-\(\gamma\) relationship of samples under different confining

Table 2. H-D Model fitting parameters.

| Sample number | Confining pressure | Test fitting parameters | \(G_{max}\)/MPa | \(R^2\) |
|---------------|--------------------|-------------------------|-----------------|--------|
| 1             | 100                | 0.00555 13.38718 180.0213 | 0.96907         |
| 2             | 200                | 0.00462 14.96897 220.2787 | 0.96192         |
| 3             | 300                | 0.00390 11.12475 261.0406 | 0.97035         |
| 4             | 400                | 0.00353 8.42350 286.2772 | 0.98387         |

5. Conclusion
In this chapter, the resonance column test is used to study the dynamic characteristic parameters of the strongly weathered unsaturated sericite schist residual soil, and the relevant test data are analysed. The following conclusions are obtained:

1. The dynamic shear modulus decreases with the increase of shear strain, and the magnitude of decrease in dynamic shear modulus increases with the increase of shear strain. The Hardin-Drnevich model is used to fit the \(G-\gamma\) relationship curve, and it is found that the model can better describe the trend of dynamic shear modulus \(G\) with shear strain \(\gamma\).

2. The confining pressure has a great influence on the dynamic shear modulus. Under the same strain level, the greater the confining pressure, the greater the dynamic shear modulus. And the
maximum dynamic shear modulus increases with the increase of the confining pressure. There is a good non-linear relationship between dynamic shear modulus $G_{\text{max}}$ and confining pressure.

(3) The damping ratio shows a fluctuating upward trend with the increase of shear strain, and its curve shows three stages: basically unchanged, increasing rapidly and slowly increasing. Under the same strain level, the damping ratio decreases with the increase of confining pressure. The larger the confining pressure, the smaller the damping ratio. Under the same confining pressure, the damping ratio increases with the increase of the shear strain. A linear equation can be used to express the relationship between the damping ratio $D$ and the shear strain $\gamma$.

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