Experimental analysis on dynamic characteristics of unsaturated sericite schist residual soil controlled by different factors

LI Chongyang¹ᵃ, ZHANG Qingwen²ᵇ

¹School Of Civil Engineering, Southwest Forestry University, Yun Nan, 650224, china
²School Of Civil Engineering, Southwest Forestry University, Yun Nan, 650224, china
ᵃe-mail: Yoo@swfu.edu.cn
ᵇCorresponding author’s e-mail: xl@swfu.edu.cn

Abstract: Taking sericite schist residual soil widely distributed along Dalin Railway as the research object, the resonance column test of sericite schist residual soil in unsaturated state was carried out, and the dynamic shear modulus Gd under different water content, dry density and consolidation confining pressure in small strain range (10⁻⁶<γd<10⁻⁴) was studied. The test results show that water content has a great influence on dynamic shear modulus, followed by dry density and consolidation confining pressure. Gd increases non-linearly with the increase of water cut, and there is a certain critical water cut that makes Gd reach the maximum, and then Gd gradually declines with the increase of water cut; \(D \sim \gamma_d\) curves tend to overlap under high confining pressure and high water content. Under the same dynamic shear strain amplitude, Gd increases with the increase of dry density. Under different consolidation confining pressures, the increasing of Gd follow-up shear strain \(\gamma_d\) tends to decrease.

1. Introduction.

The dynamic shear modulus and damping ratio of soil, as important parameters to describe the dynamic characteristics of soil, are indispensable to analyze and evaluate the dynamic stability of structures. Based on this, some scholars have made in-depth research on the dynamic parameters of saline soil, expansive soil and loess. Zhao Futang et al[1]. carried out indoor dynamic triaxial tests on saline soil of subgrade, studied the change law of dynamic stress-strain and dynamic shear modulus of saline soil under the condition of indoor temperature change, and pointed out that the change of temperature and the increase of dynamic load frequency have great influence on the dynamic characteristic parameters of saline soil. Liu Bin et al[2]. measured the dynamic parameters and dynamic constitutive relation of unsaturated loess under repeated load through indoor dynamic triaxial test, and pointed out that the dynamic stress-strain relation can be expressed by hyperbolic model, and the influence of various factors has great influence on dynamic elastic modulus and damping ratio. Wen Shaojie et al[3]. analyzed the influence of moisture content and consolidation confining pressure on the dynamic shear modulus and damping ratio of undisturbed loess in Haidong area under cyclic loading, and found that the moisture content and consolidation confining pressure have a significant influence on its dynamic parameters when the number of cycles exceeds a certain number. Wang Zhijie et al[4]. studied the influence of dry density on dynamic shear modulus and damping ratio of remolded loess under the action of pre-shear stress. Huang Zhiquan et al[5]. used GDS resonant column to test the dynamic characteristics of...
unsaturated expansive soil, and studied the dynamic shear modulus and damping ratio of unsaturated expansive soil under different free expansion rates. Chen Guoxing, Liu Xuezhu, etc.[6-7]. studied the dynamic characteristics of newly deposited soil in Nanjing area by resonance column test, and discussed in detail the influences of confining pressure, shear strain level, soil particle composition and structure on soil shear modulus and damping ratio, and gave the test curves of dynamic shear modulus ratio, damping ratio and dynamic shear strain. Bai Yu et al[8]. studied the variation of dynamic shear modulus and damping ratio of two kinds of clay with shear strain and consolidation confining pressure by using resonance column test, and compared with previous studies by combining hyperbolic model, which verified the correctness of the test. Cai Huiteng et al[9]. conducted indoor resonant column tests on six typical soils in Fuzhou, and discussed in detail the effects of soil properties and consolidation confining pressure on their dynamic parameters.

As for sericite schist residual soil, it is mainly composed of granular metamorphic quartz and dolomite, and its physical and mechanical properties are different from other residual soils. At present, the dynamic characteristics of sericite schist residual soil in unsaturated state are not clear. Based on this, this paper conducts indoor resonance column test on sericite schist residual soil distributed in Grand White Rock test section of Dalin Railway, measures its dynamic parameters, studies the influence of different moisture content, dry density and consolidation confining pressure on dynamic shear modulus and damping ratio, and explains the influence mechanism from the unsaturated microscopic point of view, providing theoretical basis and technical reference for subsequent engineering site design and seismic safety assessment.

2. Testing program

2.1. Test soil samples and physical and mechanical parameters

According to the regional geological records of Yunnan Province, the parent rock of the sericite schist residual soil belongs to the lower Paleozoic Lancang group sericite schist and sericite quartz schist intercalated with carbonaceous sericite schist. It is mainly composed of quartz, muscovite and other minerals. It feels soft and greasy when touching water, and has greasy, waxy or silky luster.

The samples are from the strongly weathered sericite schist residual soil in baishitou test section of Dalin railway in Yunnan Province, and most of them are gray. The scanning electron microscope of Sericite schist residual soil shows that the quartz has recrystallized completely and appears as other granular with wavy extinction, and the grains are inlaid with each other. The lamellar texture is composed of lamellar meta crystalline muscovite and chlorite, which are intermittently and continuously aligned, and the heteromorphic granular dolomite is unevenly distributed among quartz grains. The sampling diagram and scanning results of electron microscope are shown in Figure 1.

![Fig.1 Sericite schist residual soil and its natural state SEM image](image)

According to the Standard for Geotechnical Test Methods (GB/T 50123—2019), the basic physical and mechanical tests are carried out on the residual soil of sericite schist, and the physical properties are shown in Table 1.
### Table 1 Basic physical parameters of Sericite schist residual soil

| natural moisture content (ω%) | Specific gravity of soil particles (Gs) | Liquid limit (ωL) (%) | Plastic limit (ωpl) (%) | Plasticity index (Ip) | Maximum dry density (ρd) (g/cm³) | size composition (%) |
|------------------------------|----------------------------------------|-----------------------|------------------------|---------------------|----------------------------------|---------------------|
|                              |                                        | 14.59                 | 22.31                  | 7.72                | 2.10                             | >2mm                |
|                              |                                        |                       |                        |                     |                                  | >0.5mm              |
|                              |                                        |                       |                        |                     |                                  | >0.075mm            |
|                              |                                        |                       |                        |                     |                                  | ≤0.074mm            |
| 9.87                         | 2.76                                   | 14.59                 | 22.31                  | 7.72                | 2.10                             | 32.20               |
|                              |                                        |                       |                        |                     |                                  | 45.32               |
|                              |                                        |                       |                        |                     |                                  | 19.13               |
|                              |                                        |                       |                        |                     |                                  | 2.35                |

### 2.2. Testing program

Under the condition of controlling water content and dry density, the dynamic shear modulus of soil samples was measured by loading different consolidation confining pressures. See table 2 for the test scheme.

### Table 2 Trial protocol

| Sample No. | Water content (ω%) | Dry density (ρd) (g/cm³) | Consolidation confining pressure (σ₀) (MPa) |
|------------|--------------------|--------------------------|--------------------------------------------|
| 1 #        | 8.55               | 2.10                     | 0.1→0.2→0.3→0.4 Step by step loading      |
| 2 #        | 8.55, 9.87, 11.36, 15.77 | 1.83                   |                                            |
| 3 #        | 2, 4, 6, 8, 10, 12, 14, 16, 18 | 1.83                   |                                            |
| 4 #        | 8.55               | 1.83                     |                                            |
| 5 #        | 8.55               | 2.01                     | 0.2                                        |

### 3. Experimental results and analysis

#### 3.1. Influence of consolidation confining pressure on dynamic shear modulus

Fig. 2 shows the relationship curves between dynamic shear modulus (Gd) and dynamic shear strain (γd) under four confining pressures.

Fig. 2 Curves of the relationship between Gd and γd under various consolidation confining pressures.

As shown in fig.2, Gd decreases with increasing γd under different consolidation confining pressures. In a small strain range, Gd does not change with the increase of γd when 10⁻⁶<γd<10⁻⁵, but decreases rapidly with the increase of γd when γd>10⁻⁵. This is because when the strain amplitude is small, the soil is in elastic deformation state; With the increasing of dynamic shear strain, the stress-strain relationship of unsaturated sericite schist residual soil gradually transits to nonlinear, and the attenuation trend of dynamic shear modulus suddenly increases.

When γd is the same, Gd increases with the increase of consolidation confining pressure. This is mainly due to the fact that the void ratio of soil first decreases slowly with the increase of consolidation.
confining pressure at all levels, and then decreases rapidly when the soil reaches the yield strength. The flaky structure in sericite schist residual soil is easy to break with the gradual increase of consolidation confining pressure, which leads to the reorganization of internal soil particles, the gradual increase of consolidation confining pressure, the gradual increase of bite force and cementation area between soil particles, the increasingly dense soil, and the difficulty of relative dislocation between soil particles, thus enhancing the shear resistance of soil. In addition, with the increase of consolidation confining pressure, the relative density of sericite schist residual soil increases, the pores between soil particles decrease, and the propagation speed of stress wave between particles increases, thus increasing the dynamic shear modulus.

3.2. Influence of water content and dry density on dynamic shear modulus

As shown in fig. 3, when the water content is low, $G_d$ is small; The water content increases gradually, and $G_d$ increases gradually. $G_d$ reaches the maximum when it reaches the limit moisture content. After that, with the increase of water content, $G_d$ gradually declined.

![Fig.3 Effect of moisture content on $G_d$](image)

The influence trend of this type of soil moisture content on dynamic shear modulus is quite different from the research results of some scholars. The reason is that there is wet suction between soil particles, which is different from matrix suction which characterizes negative pressure potential of soil. This suction and structural suction of soil particles together constitute the suction between soil particles. For sericite schist residual soil, when the water content is low, the wet suction force acting on the capillary water of suspended holes between soil particles is small, and the resulting total effective stress is small. Because the residual soil of sericite schist has a flaky structure inside, when the water content gradually increases, its internal pore channel develops rapidly, and the suspended capillary water can be connected into a cable-like water-gas migration channel. At this time, the wet suction force increases with the increase of the advancing contact angle, and the total effective stress of the soil gradually increases, thus improving the shear strength. It can be seen from Figure 3 that the dynamic shear modulus of residual soil under 4-level confining pressure peaks between the water content of 6%–10%, and the water content corresponding to the peak is defined as the critical water content $\omega_{\text{lim}}$, and the wet suction is the maximum, at which time the dynamic shear modulus reaches the maximum. After that, the dynamic shear modulus decreases monotonously with the increase of water content, which is due to the fact that the soil sample is mainly composed of granular metamorphic quartz and flaky metamorphic muscovite. With the gradual increase of water content, the soil is wet and destroyed, and the shear
resistance decreases gradually.

4. Conclusion
In this paper, the strongly weathered sericite schist residual soil in Grand White Rock test section of Dalin Railway is taken as the research object, and the effects of water content, dry density and consolidation confining pressure on dynamic shear modulus and damping ratio are studied and analyzed by using GZZ-50 electromagnetic excitation resonant column tester. The results show that:

1) In the small strain range ($10^{-6} < \gamma_d < 10^{-4}$), the dynamic shear modulus $G_d$ of sericite schist residual soil decreases with the increase of shear strain $\gamma_d$ under different consolidation confining pressures, and $G_d$ increases nonlinearly with the increase of dry density when $\gamma_d$ is the same. The water content has a significant influence on $G_d$, and there is a limit water content $\omega_{lim}$. When the water content is less than $\omega_{lim}$, $G_d$ gradually increases with the increase of water content, and when it reaches $\omega_{lim}$, $G_d$ gradually decreases with the increase of water content.

2) Hardin-Drnevic model and damping ratio empirical model can well reflect the variation of dynamic shear modulus ratio $G_d/G_0$ with $\gamma_d$. Due to the damage of soil microstructure and the weakening of intergranular structure suction, the $D-\gamma_d$ relationship curves tend to overlap at high confining pressure and high water content.

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