Demonstration of two methods for damming clay slaking test

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Abstract. During the initial impoundment of earth-rock dams, the slaking deformation of dam materials often leads to settlement, thus inducing cracks. The existing slaking tests are mainly applicable to coarse-grained materials, but there are few studies on the slaking tests of clay materials. In order to explore the suitable slaking test method for clay, the Single Line Method and Double Line Method were used to carry out the slaking test on the clay material of the core wall of Daxigou reservoir. The specific test principles and processes of the two methods are explained, and the test results are sorted out and plotted. The analysis of the test results shows that the test process of Single Line Method is closer to the actual immersion process of the earth-rock dam, and the test data is more accurate; If analyzed from a safety perspective, the test results of the Double Line Method also have reference value.

Keywords: Earth-rock dam safety; Clay slaking deformation; Single Line Method; Double Line Method.

1 Introduction

Slaking deformation refers to the phenomenon of deformation caused by soil particle breakage, rearrangement or structural shrinkage due to water immersion of geotechnical materials under a certain stress state, together with the reduction of friction between particles and the softening of particle minerals [1]. Slaking deformation is the additional deformation of saturated soil below the phreatic line. The phenomenon of uneven deformation and rapid stress change between dry and wet soils will lead to abnormal settlement, cracks, hydraulic fracturing and other defects [2-3]. It can be seen that considering the slaking deformation of geotechnical materials is of great significance to ensure the safety of earth- rock dams.

Slaking test is a necessary way to obtain the relevant parameters of slaking deformation. The test is mainly divided into Single Line Method and Double Line Method two test methods. Only by adopting appropriate test methods can a reasonable slaking deformation model be established, so as to accurately simulate the impact of material slaking on earth-rock dams in the subsequent numerical simulation. Nobari and Duncan believe that the two test results are similar, and the relatively simple Double Line

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Method can be used for relevant calculation [4]. The existing discussions on the two methods are mostly focused on coarse-grained materials, and the applicability of clay materials is unknown [5-6].

In this paper, the slaking test of clay material of Daxigou core wall was carried out by using Single Line Method and Double Line Method respectively. The slaking deformation law of clay materials is explored, and the applicability and rationality of the two test methods are analyzed, so as to provide reference and basis for the future slaking deformation test of clay materials and subsequent numerical simulation.

2 Slaking test method

There is no provision for slaking test of cohesive soil materials in the geotechnical test specification at present. In this study, the Single Line Method and Double Line Method were used to carry out the clay slaking test according to the GB/T 50123-2019 "Standard for geotechnical testing method" triaxial slaking deformation test specification of coarse-grained soil.

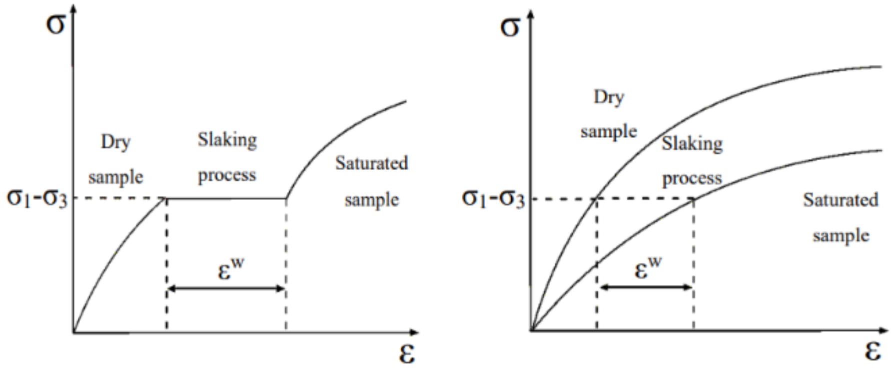
The parameters of clay used in the test are shown in Table 1:

Table 1. Parameters of clay

Clay content (%)	Permeability coefficient (cm/s)	Soil particle proportion	Optimal water content (%)	Liquid-plastic limit (%)	Plastic index	Maximum dry density (g/cm^3)	Rock compressibility (saturation) (MPa^{-1})
23.7	2.5×10^{-6}	2.72	14.5	15.0	11.0	1.80	0.103

2.1 Test principle of Single Line Method and Double Line Method

The Single Line Method involves shearing the dry specimen to a certain stress level before maintaining it unchanged, and then saturating the specimen with water to determine the increase in volumetric strain and axial strain during the saturation process. The Double Line Method is to conduct triaxial CD tests on dry and saturated specimens respectively, and take the strain difference before and after soaking under a deviatoric stress as the slaking deformation. As shown in Figure 1



(a) Single Line Method (b) Double Line Method

Fig. 1. Two kinds of slaking tests

In Figure 1, σ represents the deviatoric stress, and ε represents the axial strain of the clay.

2.2 Single Line Method test process

Triaxial tests were carried out with strain controlled triaxial apparatus. The consolidation pressures were 200kPa, 400kPa, 600kPa and 1000kPa, respectively. Triaxial slaking deformation tests were carried out at three stress levels of 0.2, 0.4 and 0.6 under each consolidation pressure.

Each specimen is prepared according to the moisture content of 14.5%. After consolidation pressure is applied as required and stabilized, axial stress is applied to the predetermined stress level to keep consolidation pressure and axial stress unchanged. After the main deformation of the specimen tends to be stable, the specimen is soaked from the top and vented from the bottom. The axial strain and volumetric strain of the specimen are measured during soaking until the main deformation of the specimen is completed. After the slaking deformation is completed, continue to apply axial pressure to shear the specimen until the specimen is damaged or until the axial strain of the specimen reaches 15%, and the actual stress level of each specimen is calculated according to its corresponding failure strength.

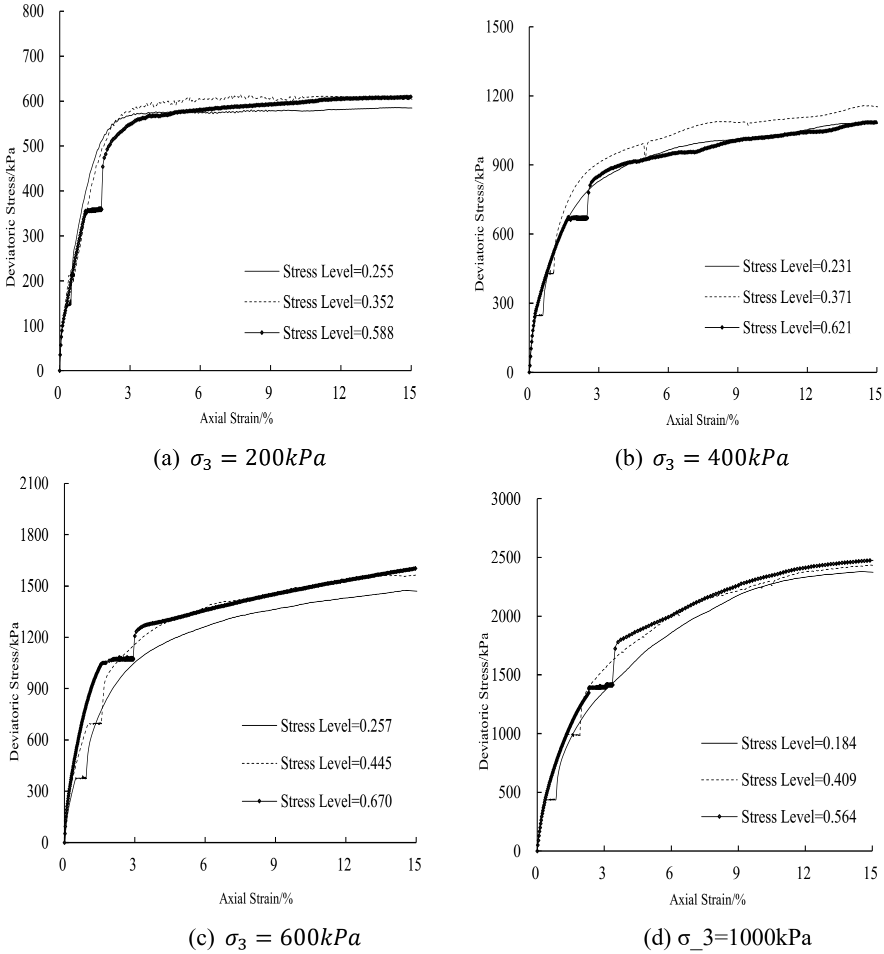
2.3 Double Line Method test process

In the Double Line Method test, after the specimen is prepared with a moisture content of 14.5%, one group carries out the triaxial consolidation drainage shear test in this state, and the other group carries out the triaxial consolidation drainage shear test after saturation.

3 Test results and conclusions

3.1 Summary of test results

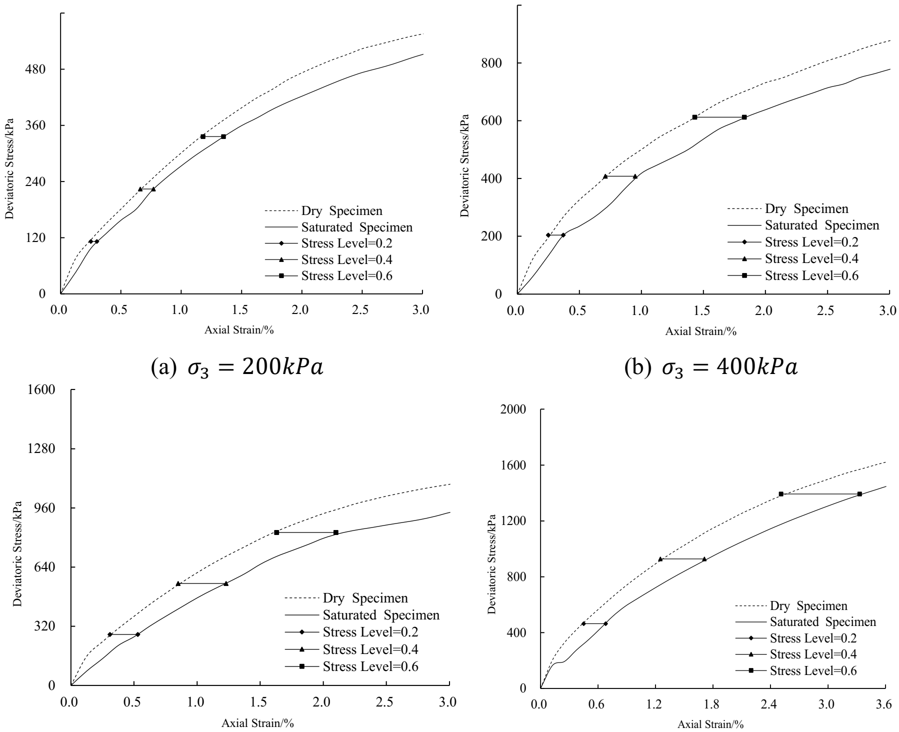
The deviatoric stress-axial strain curves drawn according to the test results of the two triaxial slaking tests under different consolidation pressures are shown in Figure 2~3. The data of the two tests are integrated as shown in table 2~3.



(a) $\sigma_3 = 200kPa$ (b) $\sigma_3 = 400kPa$

(c) $\sigma_3 = 600kPa$ (d) σ_3=1000kPa

Fig. 2. Single Line Method test curve



(a) $\sigma_3 = 200kPa$ (b) $\sigma_3 = 400kPa$

(c) $\sigma_3 = 600kPa$ (d) $\sigma_3 = 1000kPa$

Fig. 3. Double Line Method test curve

Table 2. Summary of Single Line Method test data

σ_3/kPa	Deviatoric stress/kPa	Stress level	ε_1^w/%	ε_v^w/%	γ^w/%
200	149	0.255	0.07	0.10	0.04
	216	0.352	0.13	0.13	0.09
	358	0.588	0.40	0.35	0.28
400	250	0.231	0.10	0.13	0.05
	430	0.371	0.20	0.19	0.13
	674	0.621	0.48	0.42	0.34
600	379	0.257	0.16	0.19	0.09
	696	0.445	0.33	0.33	0.22
	1073	0.670	0.62	0.60	0.41
1000	437	0.184	0.18	0.21	0.11
	995	0.409	0.34	0.35	0.23
	1398	0.564	0.58	0.56	0.39

Table 3. Summary of Double Line Method test data

σ_3/kPa	Deviatoric stress/kPa	Stress level	ε_1^w/%	ε_v^w/%	γ^w/%
200	112	0.2	0.06	0.07	0.04
	224	0.4	0.09	0.25	0.01
	336	0.6	0.15	0.36	0.03
400	204	0.2	0.13	0.11	0.09
	408	0.4	0.21	0.26	0.12
	612	0.6	0.40	0.39	0.27
600	276	0.2	0.20	0.16	0.15
	551	0.4	0.35	0.28	0.26
	827	0.6	0.56	0.49	0.40
1000	464	0.2	0.23	0.18	0.17
	928	0.4	0.47	0.51	0.30
	1392	0.6	0.78	0.93	0.47

In Figure 2~3 and Table 2~3, σ_3 represents the consolidation pressure on the soil sample during consolidation, ε_1^w represents the slaking axial strain, ε_v^w represents the slaking volumetric strain, γ^w represents the slaking shear strain. The slaking shear strain γ^w in the table is calculated from the strain relationship under triaxial conditions. The specific relationship is as follows:

$$\gamma^w = \sqrt{\frac{2}{9}[(\varepsilon_1^w - \varepsilon_2^w)^2 + (\varepsilon_1^w - \varepsilon_3^w)^2 + (\varepsilon_2^w - \varepsilon_3^w)^2]} = \varepsilon_1^w - \frac{1}{3}\varepsilon_v^w$$

ε_2^w and ε_3^w in the equation represent the slaking lateral strain of two vertical directions.

3.2 Analysis of test results

There are some differences between the results of the two test methods, but the deformation trend is the same. When the consolidation pressure is low, the Double Line Method can hardly reflect the slaking shear strain of clay, and the overall measured values of slaking axial strain and slaking volumetric strain are less than those of the Single Line Method. When the consolidation pressure is 400~600kPa, the test results of Single Line Method and Double Line Method are similar. Under the condition of high consolidation pressure, the overall measured value of the Double Line Method is slightly larger than that of the Single Line Method. Considering that the test process of the Single Line Method takes into account the stress conditions of the soil sample during soaking, which is more in line with the real state of the internal geotechnical materials of the earth-rock dam when the water level suddenly rises, it is considered that the

Single Line Method can more accurately reflect the slaking deformation of the clay materials [7].

By comparing the data of this clay slaking test with the existing test results of some coarse-grained materials, it can be seen that the slaking deformation of clay is generally less than that of coarse-grained materials, but the change trends of both are similar, and generally increase with the increase of consolidation pressure and stress level [8-10].

4 Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

(1) There are some differences between the measurement values of the Single Line Method and the Double Line Method slaking deformation tests of clay, and it is believed that the measurement values of the Single Line Method are more accurate. Considering that the total amount of slaking deformation under low consolidation pressure is relatively small, although there are differences in the measurement values of the two test methods, the impact of small magnitude differences on the overall deformation can be ignored according to actual engineering needs; Under the condition of high consolidation pressure, the overall measured value of the Double Line Method is slightly larger than that of the Single Line Method. At this time, the slaking deformation calculated by using the test data of the Double Line Method is larger. Therefore, from the perspective of partial safety, the conclusion of the Double Line Method can be considered to calculate the slaking deformation of clay.

(2) Because the slaking deformation trend of clay material is similar to that of coarse-grained material, the slaking deformation model of coarse-grained material can be used to describe the slaking deformation of clay. Due to the large differences in clay particle composition, chemical composition and other factors in different regions, the slaking deformation of clay needs to be further explored.

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