Experimental Study on the Slaking Deformation of Unsaturated Laterite under Different Stress Paths

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***Abstract* — The factors that affect the soil slaking deformation test have dry density, initial water content, the gradation of test materials, test stress paths, etc.. But the different stress path research on the influence of slaking deformation is less. The slaking deformation tests of unsaturated laterite with degree of compaction 0.9 were carried out by conventional triaxial path, K0 + triaxial path and over-consolidated soil triaxial path. According to the experimental results, the slaking deformation characteristics of the laterite under different stress paths are analyzed. This result has guiding significance for the construction and design of the water immersion subgrade using the laterite.**

Keywords* — *different stress paths*; *laterite*; *slaking deformation

I. INTRODUCTION

Affected by natural rainfall, groundwater level change , water evaporation and other environmental factors, the moisture of unsaturated soil will be in the long-term changing state. After soaking the soil, under water lubrication and softening of soil particles, the soil will perform subsidence and lateral deformation because the particles are softened, broken and the relative slip and refilling of particles. The subsidence and lateral deformation of soil are called slaking deformation[1,2]. The factors that affect the soil slaking deformation test have dry density, initial water content, the gradation of test materials, test stress paths, etc.. Wang Xiaojun[3] thinks that finer particles is more easily wet if the proportion of hydrophilic mineral and viscous grains is higher through the study of expansive soil (rock) wet oxidation. Fu Xudong[4] studied relationship between material wet soil deformation and dry density. Zhang Xiucheng made slaking deformation tests of clay soil with triaxial stress-controlled apparatus under different stress paths[5]. Thus, the slaking deformation is mainly for different dry density of soil samples inferior to consolidation under wet deformation. The different stress path research on the influence of slaking deformation is less.

II. SLAKING DEFORMATION TEST METHOD

The soil material selected for this experiment is the subgrade soil near a new highway in Nanchang, which is a red brown soil. In order to obtain the physical and mechanical properties of the soil, the soil material was tested in the laboratory. The test results are shown in table I and table II. Table I shows basic physical properties of soil. Table II shows particle size distribution of soil.

In this experiment, The compaction degree of the sample is 0.9, the dry density is 1.69g/cm³, and the optimum moisture content is 15.4%.

Because of the unsaturated soil sample used in this experiment, the volume change of unsaturated sample in the wet process can not be measured by using the conventional triaxial apparatus to make slaking tests.

Therefore, the author has carried on the modification to the TSZ30-2.0 triaxial apparatus.

TABLE I. BASIC PHYSICAL PROPERTIES OF SOIL

Liquid limit (%)	Plastic limit (%)	Maximum Dry Density (g/cm^3)	Optimum Moisture Content (%)	Permeability Coefficient (cm/s)
31.5	20.3	1.88	15.4	4.58×10^{-4}

TABLE II. PARTICLE SIZE DISTRIBUTION OF SOIL

Soil Mass Percentage of Less Than One Particle Size					
Particle Size (mm)	2	1	0.5	0.25	0.075
Soil Mass Percentage (%)	100	75.32	52.10	32.78	4.32

Fig.1 shows modified triaxial apparatus. The pressure chamber of the pressure system is replaced by the anti

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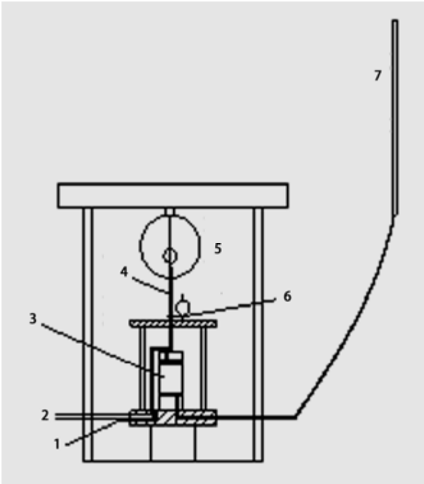

Fig. 1 Modified triaxial apparatus

1—counter pressure system,2 —volume change tube、air exhaust opening,3—soil sample,4—force transmission pole, 5—quantum ring, 6—axial displacement meter ，7—water injection tube

pressure system, which can be used to measure the volume change of the sample in the process of the double U tube. The sample is immersed in the amount of water which is connected to the base of the sample. In the wet test, the water enters the sample to achieve the effect of wetting under gravity. Keeping wet height during water injection liquid and sample center is 1.5m. Link the top cap of the specimen with the original pressure outside of the drainage tube, by this method, the gas in the sample and the water in the sample can be discharged completely to the excess water.

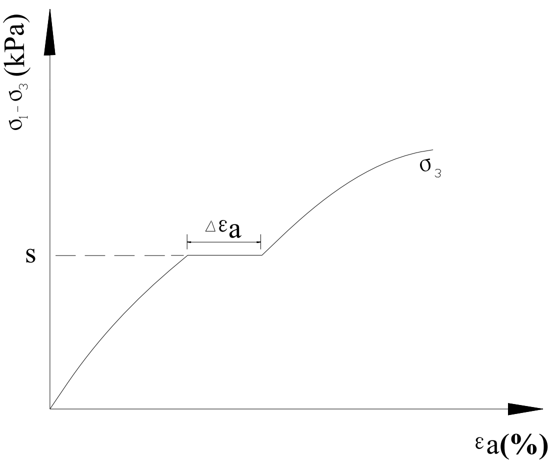

Fig.2 The single method of wetting deformation test

Δεa—slaking axial strain，εa—axial strain. s —stress level. $\sigma_1 - \sigma_3$ —deviatoric stress.

Three stress paths are carried out(conventional triaxial path slaking deformation test, K0 + triaxial path slaking deformation test and over-consolidated soil triaxial path slaking deformation test).

In order to measure true slaking deformation, single line method of slaking deformation test is used. Fig. 2 shows the single method of slaking deformation test.

A. Slaking Deformation Test by Conventional Triaxial Stress Path

Table III shows conventional triaxial stress path project. The confining pressure σ_3 is equal to 100KPa, 200KPa, 300KPa. Each confining pressure includes three tests. For each confining pressure, the dry samples(optimum moisture content) are wet in different stress level 0.25, 0.5 or 0.75. So, there are a total of 9 specimens. The whole slaking deformation test includes the shear failure stage. According to soil test procedures, the end of the shear failure axial strain required to achieve 15%. However, this article does not study the law of strength on laterite after soaking wet. So, stop test when the axial strain reaches 8%.

TABLE III. CONVENTIONAL TRIAXIAL STRESS PATH PROJECT

Soil Sample Code	Confining Pressure （KPa）	Stress Level S	Wet Point Deviatoric Stress（KPa）
CT-1	100	0.25	61.51
CT-2		0.5	123.02
CT-3		0.75	184.53
CT-4	200	0.25	98.28
CT-5		0.5	196.55
CT-6		0.75	294.83
CT-7	300	0.25	135.05
CT-8		0.5	270.09
CT-9		0.75	405.14

B. Slaking Deformation Test by K0 + Triaxial Path

Table shows K0 consolidation + conventional triaxial stress path project.

The main difference between K0 + triaxial path slaking deformation test and conventional triaxial stress path slaking deformation test is the consolidation process. Conventional triaxial slaking deformation of the consolidation process is isotropic consolidation. But this test is K0 consolidation, K0=0.55. Then according to K0=σ3/σ1=0.55, we can calculate the corresponding axial

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forces which are σ1=181.82、363.64、545.45kPa under certain confining pressure. After the completion of the sample, the sample is loaded to a certain stress level, s=0.33, 0.5 and 0.75. Then let the sample soaking wet. The shear failure criterion is the same as the conventional triaxial wet stress path.

TABLE □. K0 CONVENTIONAL +CONVENTIONAL TRIAXIAL STRESS PATH PROJECT

Soil Sample Code	Confining Pressure （KPa）	Axial Compression Under k0 Consolidation (KPa)	Stress Level S	Wet point Deviatoric Stress（KPa）
K0CT-1	100	181.82	0.33	81.82
K0CT-2			0.50	123.02
K0CT-3			0.75	184.53
K0CT-4	200	363.64	0.42	163.64
K0CT-5			0.50	196.55
K0CT-6			0.75	294.83
K0CT-7	300	545.45	0.45	245.45
K0CT-8			0.50	270.09
K0CT-9			0.75	405.14

C. Slaking Deformation Test by Over-Consolidated Soil Triaxial Path

Table□shows over-consolidated soil triaxial path project. First, the sample is loaded to the confining pressure 400KPa. Then the confining pressure is reduced to 100, 200 and 300KPa to make three sets of tests. Each test also includes 3 samples. The stress levels of the same group is 0.25, 0.5 or 0.75 respectively, then let the specimen slaking deformation. Finally, the shear failure test was carried out.

TABLE □. OVER-CONSOLIDATED SOIL CONVENTIONAL TRIAXIAL STRESS PATH PROJECT

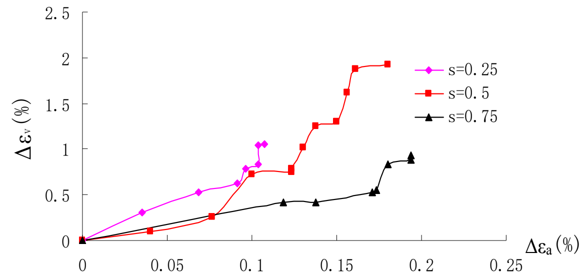
Soil Sample Code	Over-Consolid-ation Stress （KPa）	Confining Pressure （KPa）	Stress Level S	Wet point Deviatoric stress （KPa）
CGJCT-1	400	100	0.25	61.51
CGJCT-2			0.50	123.02
CGJCT-3			0.75	184.53
CGJCT-4		200	0.25	98.28
CGJCT-5			0.50	196.55
CGJCT-6			0.75	294.83
CGJCT-7		300	0.25	135.05
CGJCT-8			0.50	270.09
CGJCT-9			0.75	405.14

□. TEST RESULTS AND ANALYSIS OF SLAKING DEFORMATION UNDER DIFFERENT STRESS PATHS

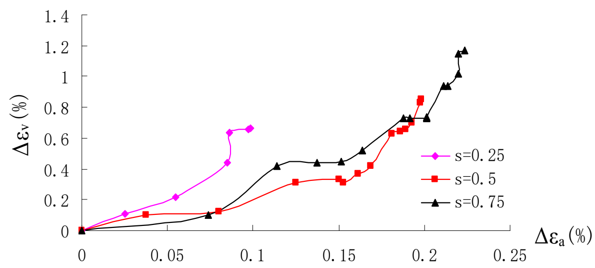
Table □ shows test results of slaking deformation under conventional triaxial stress path. In table □, $\Delta\varepsilon_a$ is slaking axial strain, $\Delta\varepsilon_v$ is slaking volumetric strain.

TABLE □. TOTAL WET STRAIN UNDER CONVENTIONAL TRIAXIAL STRESS PATH PROJECT

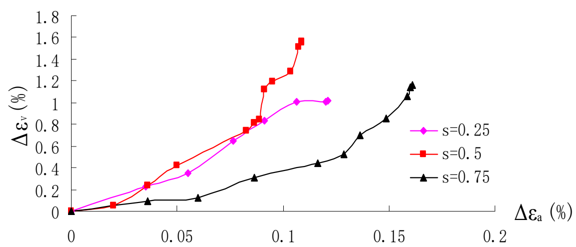
Strain	Confining Pssure					
	σ_3=100KPa		σ_3=200KPa		σ_3=300KPa	
Sress Level	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)
S=0.25	0.110	1.060	0.100	0.660	0.120	1.010
S=0.50	0.180	1.930	0.200	0.850	0.110	1.560
S=0.75	0.190	0.940	0.220	1.770	0.160	1.170



(a) σ_3 =100KPa



(b) σ_3 =200KPa



(c) σ_3 =300KPa

Fig.3 The relationship between the slaking axial strain and the slaking volumetric strain

Fig.3 shows the relationship between the slaking axial strain and the slaking volumetric strain under conventional triaxial stress path.

From fig.3,it can draw the following rules which in the wetting process of specimen under the same confining pressure, curve tilt angle of relationship between $\Delta\varepsilon_a$ and $\Delta\varepsilon_v$ curve is smaller than 45 degrees, namely the slope is slightly less than 1.

During the wet deformation later stage, the increase rate of the slaking addition volumetric strain is greater than that of the additional axial strain, and this shows the radial strain increases rapidly in the late stage.

Under different confining pressures, the slaking addition volumetric strain for the low stress level of the specimen has a larger increase rate than that the specimen with a high stress level. Under the same confining pressure, the slaking axial strain increases with the increase of the stress level.

The size of the slaking additional axial strain and the slaking volumetric strain are influenced by the confining pressure and the stress level. In the conventional triaxial slaking process, the slaking additional axial strain is smaller in low stress level, and the confining pressure has little influence on the slaking additional axial strain.

When the stress level and the confining pressure are in large, the slaking additional axial strain is also large. The slaking additional volumetric strain is smaller under lower stress level and higher confining pressure. The slaking additional volumetric strain is bigger under higher stress level and confining pressure. There is same laws under other triaxial stress path.

Table Ⅶ shows test results of slaking deformation under K0 consolidation+conventional triaxial stress path. Table Ⅷ shows test results of slaking deformation under over-consolidated soil triaxial path.

TABLE □. TOTAL WET STRAIN UNDER K0 CONSOLIDATION + CONVENTIONAL TRIAXIAL STRESS PATH PROJECT

Strain	**Confining Pressure**					
	σ_3=100KPa		**σ_3=200KPa**		**σ_3=300KPa**	
Stress Level	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)
S=0.33 /0.42 /0.45	0.025	1.875	0.129	2.531	0.014	2.083
S=0.50	0.029	1.302	0.179	1.667	0.066	2.708
S=0.75	0.060	1.656	0.275	2.875	0.068	1.790

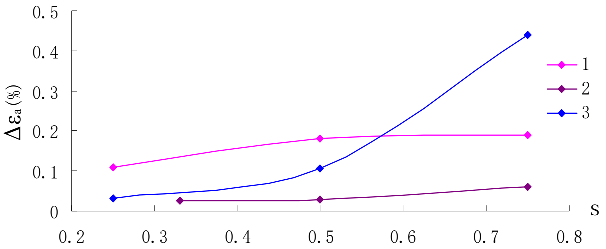
TABLE □. TOTAL WET STRAIN UNDER OVER-CONSOLIDATED SOIL CONVENTIONAL TRIAXIAL STRESS PATH PROJECT

Strain	**Confining Pressure**					
	σ_3=100KPa		**σ_3=200KPa**		**σ_3=300KPa**	
Stress Level	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)	$\Delta\varepsilon_a$ (%)	$\Delta\varepsilon_v$ (%)
S=0.25	0.0313	3.737	0.0713	4.792	0.100	1.0938
S=0.50	0.105	2.292	0.113	1.042	0.381	1.150
S=0.75	0.440	3.333	0.501	2.484	0.488	1.156

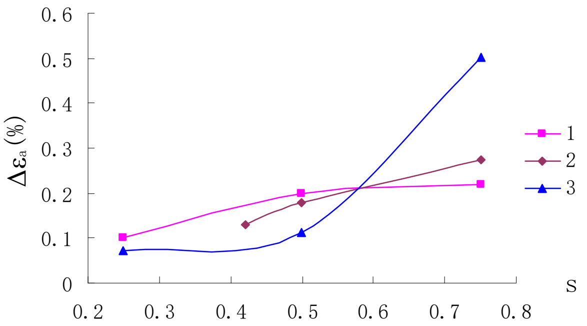
Fig.4 shows the relationship between the slaking axial additional strain and the stress level under different stress paths. Fig.5 shows the relationship between slaking volumetric strain and confining pressure under different stress paths.

From Fig. 4 and Fig. 5, these can be obtained as follows.When the specimen is in a low stress level (s=0.25~0.45), no matter what kind of wet stress path, the slaking axial strain is not more than 0.1%. As the stress level increases, slaking additional axial strain shows a trend of increase. When stress level reaches 0.75, the order of magnitude is a over-consolidation+ conventional triaxial stress path, a conventional triaxial slakng stress path and K0+conventional triaxial slakng stress path. This is not in conformity with the general slaking deformation of the over-consolidation soil. The reason may be that the confining pressure decreases. This process is similar to the stress release in the tunnel excavation, resulting in the increase of the soil sample volume. When the confining pressure is 100KPa and the stress level is less than 0.6, the stress path to produce humidifying additional axial strain is descending order of conventional triaxial slaking stress path, over consolidation+conventional triaxial slaking stress path, K0+conventional triaxial slaking stress path. When the stress level exceeds 0.6, different point from the stress level less than 0.6 is that the humidifying additional axial strain produced by over consolidated+conventional triaxial slaking stress path will exceed that of conventional triaxial slaking stress path.

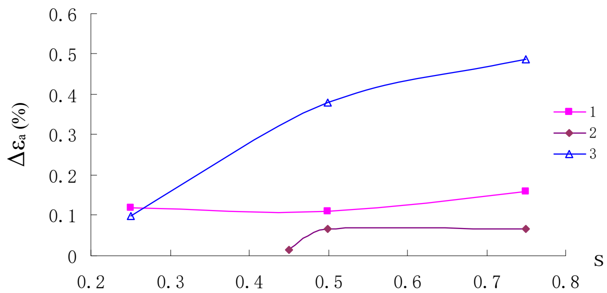
When the confining pressure is 200KPa, there is also a stress level cutoff point about 0.6. When the stress level is less than 0.6, the result is the same as confining pressure 100KPa. But when the stress level is greater than 0.6, the additional axial strain produced by over consolidation+conventional triaxial slaking stress path is the largest, the additional axial strain produced by conventional triaxial slaking stress path is the least. When the confining pressure is 300KPa, additional axial strain is descending in the order of over-consolidation +conventional triaxial slaking stress path, conventional triaxial slaking stress path and K0+conventional triaxial slaking stress path.



(a) σ_3 =100kPa



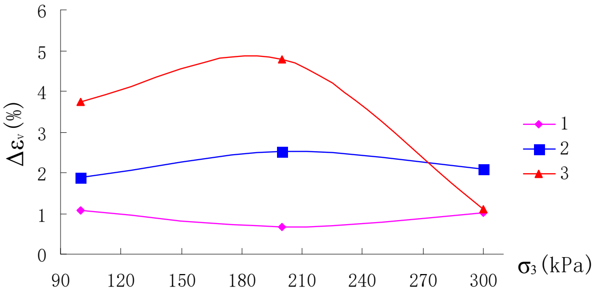
(b) σ_3 =200kPa



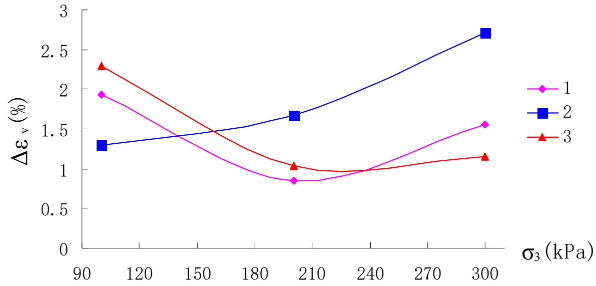
(c) σ_3 =300kPa

Fig.4 The relationship between the slaking axial strain and the stress level

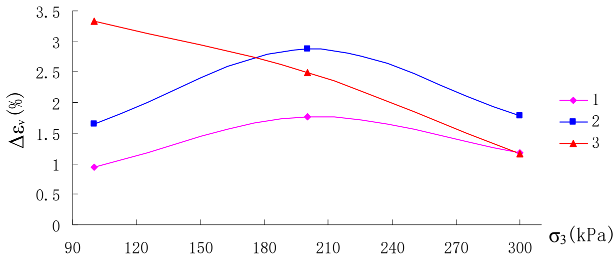
In Fig.**4**, 1—conventional triaxial stress path，2—K0 consolidation + conventional triaxial stress path，3—over-consolidated soil triaxial path.



(a) S=0.25



(b) S=0.5



(c) S=0.75

Fig.5 The relationship between the slaking volumetric strain and the confining pressure

In Fig. **5**, 1—conventional triaxial stress path, 2—K0 consolidation + conventional triaxial stress path, 3—over-consolidated soil triaxial path.

Fig.5 shows slaking additional volumetric change is in the range of 0.5～3.0% in addition to the two stress levels 0.25 and 0.75 of the over-consolidated samples. The other samples slaking additional volumetric change is in the range of 0.5~3.0%. In the low stress level of 0.25 , the slakingt deformation of the K0+ triaxial slaking stress path and the over-consolidation + conventional triaxial slaking stress path increases with the increase of confining pressure, and then decreases with the increase of the confining pressure.The additional volume of the specimen under the condition of the triaxial slaking stress path is the smallest. When the stress level is the middle level, in the normal and over-consolidation slaking stress path, the specimen's deformation increases firstly and then decreases. However, under the K0+ conventional triaxial slaking stress path, the humidification of the attached volume strain changes continuously. For the high stress level, the additional volumetric strain decreases with the increase of confining pressure under the condition of over-consolidation and normal triaxial stress path.

In the other two stress paths, when the confining pressure is greater than 200KPa, the addition volumetric strain of the sample decreases, but it has experienced a growth process before the confining pressure reaches 200KPa.

. CONCLUSION

At low stress level (s = 0.25 ~ 0.45), regardless of what kind of stress path, the axial strain of the slaking was not more than 0.1%. With the increase of the stress level, the slaking additional axial strain shows an increasing trend. In addition to the the samples of stress level 0.25 and 0.75 under the over consolidated specimens, slaking additional volumetric strain of the other samples is in the range of the 0.5~3.0%.

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