The Experiment and Research of Yunnan laterite's Shear Strength under Function of Dry-Wet Cycle

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Abstract: Environment geotechnical engineer issue is an important question which involves geotechnical structure safety and sustainable development of ecology. Aiming to Yunnan laterite's shear issue under condition of dry-wet cycle, the thesis took Yunnan laterite's shear strength under function of dry-wet cycle as research content, and the result showed that along with increasing of dry-wet cycle, cohesion of laterite would reduce gradually, among them, amplitude of attenuation after the first dry-wet cycle is smaller, and it became bigger after the second and the third dry-wet cycle, cohesion is reducing gradually along with increasing of dry-wet cycle. Relation of internal friction angle and dry-wet cycle' times are tending to be gentle, among them, amplitude of attenuation is the biggest after the first dry-wet cycle, and internal friction angle has smaller attenuation amplitude after the second and the third dry-wet cycle. Peak strength with different load after dry-wet cycle have attenuation with different amplitude, there is bigger strength attenuation amplitude from the zero to the first dry-wet cycle, and it reduced later in proper order and arrived stable status after the third dry-wet cycle. Research of thesis has important meaning for guaranteeing safety of fundamental facilities engineer and provided reference and basis of engineer construction in Yunnan.

1 Introduction

With the fast development of Yunnan economy, many large scale projects such as new roads, railway, airport, highway and others hydraulic engineer are rising quietly. Locating in low altitude region with excellent climate, lush vegetation and special landscape, which provide abundant organic matter to laterite in Yunnan plateau. Because most of regions in Yunnan located in subtropical and tropical, there are abundant heat and precipitation. Abundant precipitation continues to rush parent material with rich aluminum and iron etc. Mental ion, which resolve and run off soluble mineral, what's more, hot and humid climate speed up oxidation of iron in clay, because of low activity, iron and aluminum oxidation stayed and dye the clay in red. Therefore, laterite become normal construction material in every project and was applied widely. As a regional and special clay with distributing widely in south of our country, laterite has special nature, high natural moisture content, high plasticity, high saturation, low liquidity index, low density, high proportion, high intensity and low compressibility etc. Laterite has stronger mechanics performance but bad physical feathers [1-3].

Many projects in Yunnan, such as laterite embankment, earth dam and other hydraulic high slope put into using after the initial using phase and in unsaturated state, because of the effects of rainfall and flood, the river water level and reservoir water level elevation are higher, and slope was bared in air and backed to saturated soaking state. This process is likely to have an effect on soil strength reduction and structural deformation. With the background of global warming climate exceptionally, Yunnan has been drought since 2009, whereas in recent years, especially in 2017, because of too much rain, long time sunshine in Yunnan province, strong intensity, which exacerbated degree of the slope of the soil from the saturation status to the excessive saturation. Therefore, the effect of dry-wet cycle condition for the laterite in Yunnan cannot be neglected [4-7].

There are still some issues in research of unsaturated clay under dry-wet cycle condition, which are mainly manifested in the following aspects [8-17]:

(1) To explore how to reduce the results of saturated clay to unsaturated clay has more possibility, and research results of the unsaturated clay's basic characteristics and experimental technology are less. Many researches lack certain theoretical or experimental basis, and there is no necessary engineering test, which is not beneficial for the research and development of unsaturated clay.

(2) The nature of the laterite is different, and the mineral compositions are also different. The laterite in Yunnan has a unique representative feature, which has less research of strength deformation features under condition of dry-wet cycle.

(3) Yunnan laterite has a certain expansion and contraction feature, however, its impact always be overlooked in the actual projects. Because of effect of extreme climate in recent years, heavy rain of continuous drought in partial areas of Yunnan region threatened stability of the laterite security. It is worthy to study the expansion and contraction features of laterite in Yunnan.

Thus, the thesis combined the physical and chemical properties of the red clay and discussed the effect of the interaction between laterite and water on the physical and mechanical properties of the laterite. Also, it carried out deep research of strength and deformation properties of the laterite under the condition of dry-wet cycle, which is beneficial to understand the characteristics of the laterite. It has important significance to ensure the safety of fundamental engineer and provide reference and basis for the engineer construction in Yunnan area.

2 Basic Physical and Mechanical Nature of Yunnan Laterite

The used red clay in the experiment came from Kong gang new campus's construction site of The Oxbridge College Kunming University of science and technology, took from the surface below the 5m unsaturated zone, which is typical Yunnan laterite. To dry the laterite and placed in a 105 ℃ oven for 24 hours, after cooling to room temperature and passing 5mm sieve, carried out basic physical and mechanical features test of the laterite firstly. The basic parameters and chemical composition of the laterite were shown in Table 1 and Table 2[4-8].

The table shows:

(1) The main component of laterite for silica, alumina and ferric oxide, stable compounds, for steady chemical Compound, which also contains a small amount free material, when the basic concentration lower than the state regulations will not cause pollution to groundwater.

(2) A few heavy metals in the soil and the poisonous and harmful trace elements content, and most of the poisonous and harmful trace elements in the compound form, it is difficult to directly cause pollution of groundwater.

Therefore, the main source of contamination of groundwater contamination is from stockpiling in edaphic pollutant. When the pollutant in the poisonous and harmful trace elements by leaching of rainfall will enter into the soil, in various forms of infiltration into the groundwater, the final pollution of groundwater. The correctness is verified by the test of polluted soil test.

This test selected iron ions as pollution elements, selecting six hydrated ferric sulfate solution to carry out the test for pollutants.

Table 1 The properties of laterite

Bound water						Particle composition (%)			
Natural moisture content (%)	**Plastic limit (%)**	**Liquid limit (%)**	**Plastic limit index**	**Liquid limit index**	**Relative density**	**2-1 mm**	**1-0.075 mm**	**0.075-0.005mm**	**≤0.005 mm**
20.1	24.2	37.0	12.8	-0.32	2.78	4.2	10.3	40.3	45.2

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Table 2 The chemical composition of laterite

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	CaO	P_2O_5	MgO	Others
Content (%)	38.43	31.52	26.78	1.62	0.54	0.52	0.13	0.08	0.38

3 Experiment of Dry-Wet Cycle

3.1. Experiment Program

According to the observation results of the soil moisture content, the depth of the atmospheric impact is 0.4m-1.0m below the surface. In this layer, amplitude of fluctuation of water content is large, among them, the maximum water content is 28%.Therefore, the initial water content of experimental control of red clay is 27.1%.To observed surface change of samples clay in many times dry-wet cycles, and proceed shear experiment of sample clay with different cycles times by using direct shear apparatus and recorded analysis and result of data.

3.2 Experiment Steps

1) To select a certain number of representative clay samples, measured air-dry moisture content after air-dried, crushed, sieved, calculated the required amount of water according to the required water content.

2) To spray the amount of water in the clay material and mix it well, put it into the plastic bag, and then placed in a closed container for 24 hours, so that moisture content is advanced. Remove the clay material to measure its moisture content again. The difference value of the measured moisture content should less than 1% with the required moisture content. Otherwise, it is necessary to adjust the moisture content to meet the requirements so far.

3) The inner diameter of the barrel should be same with the diameter of sample. The diameter of the hammer should be less than the diameter of the sample and it also allowed using hammer which has same diameter with sample. It should be wiped clean before using striking cylinder wall and coated with a layer of Vaseline.

4) According to the required dry density to weigh the required soil amount. According to the sample height to stratify firmly and divided it into three layers. The qualities of soil in each layer are equal. After each layer was hit to the required height and planned hair of the surface, then added the second layer clay material. Continue to precede it until the last layer is finished. To make sample of tube at both ends leveling and carried out its amount, density difference of a group of sample should be less than $0.02g/cm^3$.

5) To stored sample clay with finish making in the incubator for 24 hours, removed it and wrapped with plastic wrap, put on the permeable stone the upper and lower sides, placed under the water pipe to 1 drop/3 seconds speed of water 12 hours. The clay was soaked and then placed in a digital blast oven for 8 hours to maintain the SV-40°and PV-60°, and the method was carried out in three different four times.

6) The shear strength was measured at different times of 0,1,2,3 times of different cycles and the cohesive force and internal friction angle of shear strength index were measured, and the compression coefficient was measured at the same time.

Fig.1the laterite sample used for direct shear strength

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3.3 Analysis of Experiment Result

According to the above steps of experiment, proceed the 0, 1, 2, 3 dry-wet cycles of red clay, and the cohesive force and internal friction of the tested soil samples were obtained under the four different vertical loads of 100, 200, 300 and 400kPa .These two types of shear strength parameters are shown in Table 3.

The relationship between the cohesive force and the strength parameters is shown in Fig 2.

It can be clearly seen from Fig. 2 that the cohesive force decreases gradually along with increasing of the number of wet-dry cycles, which has small attenuation amplitude 16.7% after the first wet-dry cycle, and large attenuation amplitude in the second and third dry-wet cycles, which arrived to 34.8% and 50.5%.Although the

Table 3 The results of direct shear test under dry-wet cycles

The number of wet-dry cycles	C/kPa	φ/(°)	The peak strength at different vertical pressures /kPa			
			100	200	300	400
0	56.9	24.8	103	149.1	195.3	241.4
1	47.4	19.8	80	126	153.3	191.2
2	30.9	19.6	62.4	109.3	135.6	172.3
3	15.3	19.2	43.1	95	121.3	150.6

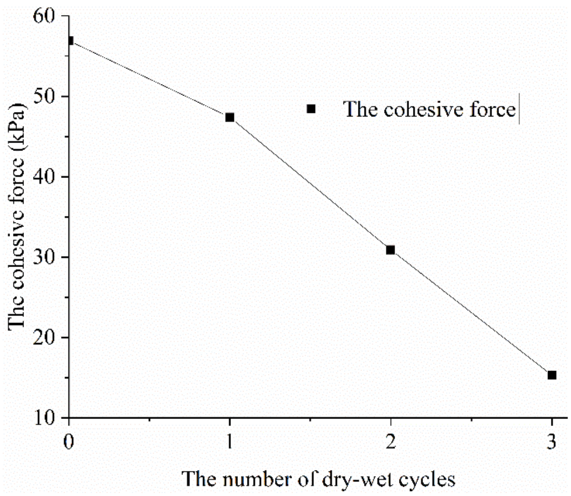

Fig.2 The relationship between the cohesive force and the number of dry-wet cycles

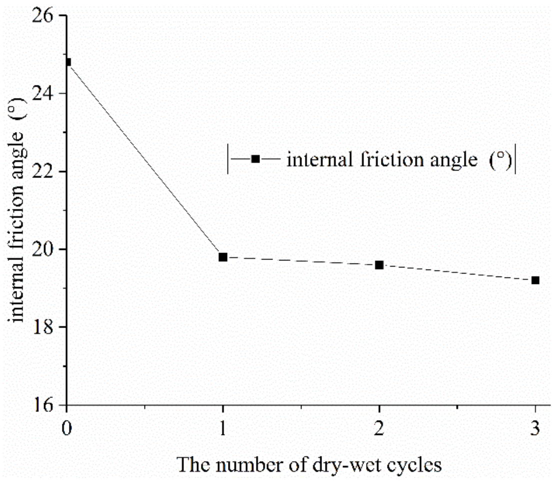

Fig.3 The relationship between internal friction angle and the number of dry-wet cycles

Test was completed only three times trunk cycles tests, but it easy to see from test results that the cohesive force is reducing gradually along with the number of dry-wet cycles gradually increased, the second and third officers have large attenuation amplitude ,after the third clay, cohesion reduced to 15.3kPa, basically reached the minimum. It can be thought approximated that after three times the wet-dry cycle, the cohesive force attenuation tended to be steady. The cohesive force after the third wet-dry cycle can be obtained after the attenuation of the stability of cohesion is 15.3kPa, so as to get dry-wet cycle after the clay’s cohesion attenuation rate is 73.1%.

From Table 3, it could be drawing he relationship between the internal friction angles and intensity parameters is shown in Fig. 3.

It can be seen clearly from Fig. 3 that the curve of the internal friction angle and the number of dry-wet cycles tended to be gentle gradually, among them, the maximum attenuation is 20.2% after the first wet-dry cycle. The internal friction angle of the second and third dry-wet cycles is smaller, the internal friction angle curve is close to the parallel horizontal axis, and the maximum attenuation angle of the inner friction angle is 1% and 2%. After the first dry-wet cycle, the internal friction angle is stabilized. The internal friction angle after the second and third dry-wet cycles can be obtained to 19.4°after the attenuation of the internal friction angle, so that to get attenuation strength parameters of the friction angle in high liquid clay is 21.8% after dry-wet cycle.

From the experimental data in Table 3, it can obtain relation of peak intensity with different load and the number of wet-dry cycle curve shown in Figure 4.

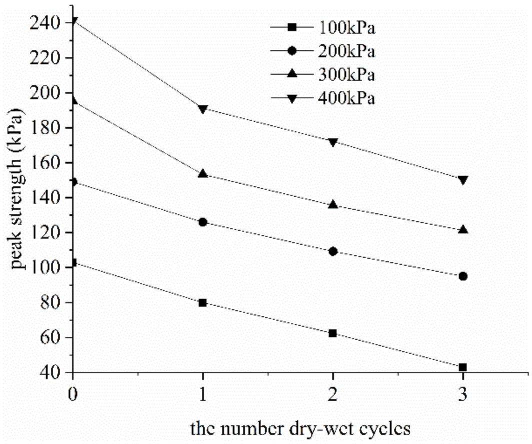

Fig.4 The relationship between peak strength under different load and the number of dry-wet cycles

It can be seen clearly from Fig. 4 that the peak intensities have different amplitudes under different loads after wet-dry cycles, among them, the intensity attenuation is large after the 0th to the first wet-dry cycles and then decreases in proper order and achieve a stable status from the third dry-wet cycle. From the vertical pressure changes, change of 400kPa peak intensity is the most obvious, which has the largest attenuation.

4 Analysis of Mechanism

The change of water content in red clay under the function of wet-dry cycle changed the shear strength of red clay. Humidification is a process that hydrophilic clay mineral water absorption disintegration and its result is that in the case of unconsolidated case the body is wet and disintegrated into a crushed granule, which is an irreversible process. The moisture loss of the red clay improved its moisture absorption pressure, a large number of cracks and pores filled with air, when the dry expansive clay soaked, because of the role of moisture absorption, the water along the fissure channel infiltration quickly , the air is squeezed into the internal Compressed. With the increasing of external water immersion, the internal air pressure rises, which leaded to the gradual collapse of the mineral skeleton along the weakest surface. The presence of hydrophilic minerals and micro fractures is a prerequisite for wetting, and the moisture absorption pressure is the power of wetting, and the time of overcoming the strength cementing bonds also reflected the difficulty of wetting the red soil.

During the repeated processes of wet-dry cycle, the water content in the red clay is fluctuating repeatedly, and the fine structure inside the clay is damaged due to the complex and changeable physical and chemical reactions during the dry-wet cycle, and the distance within the micro particles become larger , therefore the porosity ratio also increased. The pores of the laterite can be divided into two types: the aggregates and the intergranular pores. The classification pore size is 0.1-0.2μm. During the humidification process of the wet-dry cycle, the pore water pressure increased because of increasing of the water content, and the expansion pressure is formed. When the expansion pressure reaches a critical value, the bond structure between the soils of the partially red clay is irreversible destruction, which leaded to aggregates dispersing and form loose structure, therefore, aggregates quickly increased between the holes. During the process of dehydration and drying, the volume of aggregates decreased, and the concentration of aggregates increased, and some of the micro-aggregates are dispersed in the process of humidification, and the intergranular pores are transformed into aggregates. Because of the re-aggregation of the micro-aggregates and the non-uniformity of the red clay shrinkage caused by the micro-aggregates, the microstructure of the red clay is fissured or forms part of the aggregates, which leads to the decrease of the clay shear strength.

5 Conclusion

The shear test of red clay was proceeded inside by using direct shear apparatus, researched variation of shear strength of clay with function of dry-wet cycle, and the following conclusions were drawn below:

(1) The cohesive force decreased along with the increasing of the number of wet-dry cycles, and the attenuation is small after the first wet-dry cycle, and the attenuation is large after the second and third dry-wet cycles. The increasing of the number of dry-wet cycles is reduced gradually , and the cohesive force of the laterite reached the minimum value after the third time, and it can be approximated thought that the cohesive force attenuation tended to be stabilizes after three wet-dry cycles.

(2) The relationship between the internal friction angle and the number of dry-wet cycles tended to be gentle gradually, among them, it arrived the maximum attenuation after the first wet- dry cycle, and amplitude of internal friction angle is small after the second and third wet-dry cycles, basically, it can be thought that internal friction angel is tended to be stabilized after the first wet-dry cycle.

(3) The peak intensity with different load after wet-dry cycle has different attenuation, among them, the intensity attenuation is larger from the 0th to the first wet-dry cycle, and then decreased in proper order and achieve a stable status after the third dry-wet cycle. From changes of the vertical pressure, 400kPa peak intensity is the most obvious and its attenuation is the largest.

(4) The change of water content in red clay under the function of wet-dry cycle changed the shear strength of red clay. During the repeated wet-dry cycle, the water content in the red clay is fluctuating repeatedly, and the fine structure inside the clay was damaged because of the complex and changeable physical and chemical reactions during the dry-wet cycle, and the distance between the micro particles became larger , the porosity ratio also increased. The increasing in porosity of the clay leaded to decreasing in the original cohesion of the red clay until the original cohesion reached a new stable status. Owing to the re-aggregation of the micro-aggregates and the non-uniformity of the red clay shrinkage which caused by the micro-aggregates, the microstructure of the red clay had fissure or formed part of the aggregates, finally it leaded to the decreasing of the clay shear strength.

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References

[1] Peng Liu, Ying Huang, Min He. The migration mechanism of arsenic Ions under the effect of temperature in Yunnan laterite[J]. Earth Sciences, 2015.04.15, (02).
[2] Peng Liu, Ying Huang, Study on Effect of Different Size Fraction Laterite Particles on Adsorption of As[J]. Scholars Journal of Engineering and Technology, 2015.03.12, (05).
[3] Liu Peng ,Huang Ying, The test study of iron ion migration characteristics on pollution laterite[J]. Earth Sciences, 2014, 3(6): 132~136.
[4] Liu Peng, Huang Ying,(#)The Simulation to Water Transport in Unsaturated Soils[J]. Physical and Numerical Simulation Of Geotechnical Engineering, 2012, 12(9): 79~83.
[5] Ying Huang, Peng Liu, Kesheng Jin, Zulian Zhang, Bichang Fu, Study of the migration characteristics of iron ion in laterite in water[J]. Sustainable environment and transportation, 2012, 10(2): 411~418.
[6] Liu Peng, Huang Ying, Gao Wenxin, The Study of Transportation Regularity for Pollution

Laterite[J]. WREP 2014,HongKong, 2014.6.7-2014.6.9.

[7] Liu Peng, Jin Juanjuan, The Study of Transportation Regularity for Different Element[J]. ISWREP2011, Xi'an, 2011.5.20-2011.5.22.

[8] Liu Peng, He Min, Jin Juanjuan, The Study of Transportation Regularity Consider Temperature[J]. 2010International Symposium on Multi-field Coupling Theory rock and Soil Media and Its Applications, ChengDu, 2010.10.10-2010.10.11.

[9] Liu Peng, Huang Ying, The Simulation to Water Transport in Unsaturated Soils[J]. International Forum on Porous Flow and Applications, wuhan, 2009.4.24-2009.4.26.

[10] LU Haibo, ZENG Zhaotian, ZHAO Yan-lin, LU Hao. Experimental studies of expansive soil in drying and wetting cycle[J]. Rock and Soil Mechanics, 2009, 30(12): 3797~3802.

[11] TANG Xiaowu, LIU Jingjing, WANG Yan. Adsorotion behavior and mechanism of loess soil towards chromium ion[J]. Rock and Soil Mechanics, 2013.34(8):2136~2142.

[12] ZHOU Xiong, HU Haibo. Study on Shear Test of High Liquid Limit Clay under Dry-wet Cycles[J]. Highway Engineering, 2014, 39(5): 352~355.

[13] Yanyan Shi, Zhao Zhang, Jingxin Su, Fahe Cao, Jiangqing Zhang. Electrochemical noise study on 2024-T3 Aluminum alloy corrosion in simulated acid rain under cyclic wet-dry condition[J]. Electrochimica Acta, 2006, 51: 4977-4986.

[14] CAO Hao-rong, LI Xin-ming, FAN You-jie, WANG Yong. Experimental study of pavement performances of lime-treated laterite soil considering drying-wetting cycle paths[J]. Rock and Soil Mechanics, 2012, 33(9): 2619~2624.

[15] WANG Hai-long, DONG Yi-sen, SUN Xiao-yan, JIN Wei-liang. Damage mechanism of concrete deteriorated by sulfate attack in wet-dry cycle environment[J]. Journal of Zhejiang University(Engineering Science), 2012, 46(7): 1255~1261.

[16] Abdelmalek Bouazza, Stephan Jefferis, Thaveesak Vangpaisal. Investigation of the effects and degree of calcium exchange on the Atterberg limits and swelling of geosynthetic clay liners when subjected to wet-dry cycles[J]. Geotextiles and Geomembranes, 2007, 25: 170~185.

[17] WANG Jai-jun, YIN Zong-ze. Experimental Study on Long-time Deformation of Rockfill under Wetting-drying Cycle Effect[J]. Journal of Disaster Prevention and Mitigation Engineering, 2012, 32(4): 488~501.