Experimental study on Bijie Cement Improved Red-Clay

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Abstract. As there was a large amount of red clay distributed in Bijie, which is used as the foundation of building and roadbed. To study the improvement effect of cement content on the Bijie red-clay, the typical red clay in Bijie was firstly sampled and the basic physical property indexes were tested. Then, the samples with different cement ratio were made and the unconfined compressive strength test was carried out. The results indicate that the strength of cement red-clay was increasing with the cement ratio increasing, and the improved effect is obviously, but the variation curve is not linear. The peak strength appeared when the cement ratio is 10%, after that ratio, the strength was decreasing with the increase of cement ratio. The reason is that the incorporation with cement makes Bijie red-clay harden because of the hardening cement.

1. Introduction

There was a large amount of red clay distributed in Guizhou, which is the product of carbonate system. This special soil has different engineering characteristics with ordinary clay, as its water content, liquid limit and pore ratio are higher than the other ordinary clay. At present, this red clay is widely used as building materials in foundation of building and roadbed.

Cement soil is composed of cement, soil and water, which relatively have higher strength than soil only. From the end of last century, research on cement-soil in China was carried out, and also reached many great results. For example, based on the tests, the working mechanism and the influence of intensity factors were analyzed by these researchers, as Jia-zhu Zhang[1], Can Li[2] and Da Man[3]. Moreover, Xiao-quan Li[4] studied the strength development law of cement soil of Hunan red-clay, and the relevant mathematical formula was calculated. While for Guilin red-clay, the indoor tests was carried out by Zhi-kui Liu[5], the improvement effect by such as cement content and curing time were studied. Then the mechanical properties of cement soil under freeze-thaw cycling was studied on by Zhenya Zhao[6], Zhigang Wang[7], Tianliang Wang[8], Sili Chen[9]. In a word, the cement soil is researched in some areas.

But as is known, the natural soil is complex. The distribution of red clay is obviously different in regional area. So the physical and mechanical characteristics of red clay was different, because of the different regions which affected by the process of soil formation and stress history. The truth is, at present, there is no research on the properties of cement and other improved soils of red clay in Guizhou, so the paper plan to study the cement soil of Bijie.

Firstly, the physical characteristics of local soil was tested. Then, the soil disturbed completely, adding different proportions of cement, were sampled in certain specification size. The next thing to do is curing the cement soil samples, these samples will be placed in the cure box in different days. After three days, the strength of samples are tested on unconfined compressive station. Finally, based
on the test research, the paper analyzes in the strength influence factors, at the same time, the relation between cement ratio and strength is particularly analyzed.

2. Experiments content

2.1. Experiments
The first work is selecting two typical red clay in Bijie through the site reconnaissance, at the same time, the authors describes the basic characteristics of the clay such as color, buried depth, surrounding environment.

Then the soil sample is picked and taken to the lab, and a series of basic experiments are carried out, in order to obtain the basic physical parameters of the red-clay. In this part, the test includes moisture content, density, liquid and plastic limit, particle analysis. And the experiment results is listed in the tab 1.

| Red clay | water content (%) | natural density/(g/cm$^3$) | relative density | Void ratio | liquid limit(%) | plastic limit(%) | plastic limit index |
|----------|-------------------|-----------------------------|------------------|------------|-----------------|-----------------|-------------------|
| 1        | 56                | 1.63                        | 2.68             | 1.58       | 62.4            | 32.1            | 30.3              |
| 2        | 55                | 1.72                        | 2.69             | 1.45       | 65.1            | 31.5            | 33.6              |

From the table 1, Bijie red clay is characterized by high water content, high porosity ratio and high liquid limit.

2.2. Testing program
Firstly, the red-clay samples were destroyed completely and dried, then spraying water to red-clay 1 and 2, which was configured to appropriate water content, respectively 44.39% and 41.56%.
Secondly, mixing the two samples with cement ratio of 0%, 5%, 10%, 12%, 15%, 18%. And then, the samples were prepared to experiment the strength of cement soil. After mixing the red clay and cement evenly, the cylindrical sample with a diameter of 50mm and a height of 100mm is pressed by the instrument in FIG. 1, which was designed and partially made by the authors. Next, the mixed samples were placed in a standard curing box for 3 days, in the process of curing, the cement particles react with soil and water, improving the strength of soil. But the Chemical reaction process is very complex, it would also be described in the changing curves in the next section.
Finally, the unconfined compressive strength of the both clay was tested and recorded. The failure modes of samples and the instruments used are shown in FIG. 2. The automatic constant Stress test machine was used here, as the experiment progresses, the computer collects the stress and strain data of the soil sample, which is used to analyse the change law. The damage patterns of different samples are different, and these are photographed.
3. Analysis of experimental results

3.1. Strength curve of cement soil
The strength curve of red-clay with different cement content are drawn as shown in FIG. 3, based on the test data.

By observing the law of this curve, it can be obtained that: the curve is a curve with low and high middle on both sides. With the increasing of cement ratio, the strength of cement soil increases, but it decreases at later stage. Specifically, cement soil is strongest when incorporation ratio is 10%. When incorporation ratio increases, cement-soil strength decreases.

The reason for this phenomenon is that when the cement is mixed in relatively low, the cement-soil water binder surface area is small, and the contribution to the increase of cement-soil strength is limited; When more cement is added, more cement particles are hardened with water and mineral glue, forming a stronger cement and soil structure; However, when more cement is added, the water in the soil is limited, and the completion of the cementation will cause the excess cement particles to exist alone, making the soil appear "powdery" and the strength will be reduced.

Therefore, it is not that the more cement is added, the higher the strength of the soil. In practical engineering, the best purpose is to get cement mixed with low specific but high strength cement soil, so as to obtain greater strength at lower cost. The purpose of this experimental study can provide a reference.

3.2. Destruction patterns of cement soil
According to the pictures collected during the experiment, the destruction patterns of cement soil were analyzed. In the strength test, all samples have been damaged, the cylindrical cement soil was firstly destroyed from the upper part, but there was no obvious damage in the lower part.
4. Conclusion
In this paper, by testing the basic physical properties of red clay, the relative basic parameters are obtained and analyzed.

The results show that the red clay has high water content, high liquid limit and high plasticity, through the basic physical test. The material composition of soil is the material basis for forming the engineering properties of soil, the structure of soil is the existence form of material composition, and the physical mechanical properties of soil are jointly influenced by components and structures. The engineering property of red clay is determined by its special material composition and structural characteristics.

The strength curves of cement red clay mixed with different amounts of cement were drawn through the strength experiments of cement red clay. The cement mixing ratio-strength curve is a curve with a low middle height on both sides. It is concluded that under the same water content of red clay, the strength of cement admixture increases, and after the increasing of cement admixture increases, the strength decreases, and the optimal cement admixture ratio is at 10 \% obtained according to the cement admixture ratio-strength curve.

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References
[1] Zhang J.Z., Cheng Z., Yu J.H. (1996) Experimental Study on Properties of Cement soil. Geotechnical Engineering Technique,03:38-40
[2] LI C., Zhou H.Q., Zhao S.Y., Zhang Y.T., Wang Q.X. (2019) Experimental Study on Early Strength Characteristics of Low-content Cement Soil. Contemporary Chemical Industry, 48(01),13-16
[3] Man D., Pang W.T., FAN Z.C., Pang W.T. (2019) Research on the Stress-strain Constitutive Model of Composite Cement Soil. Bulletin of the Chinese Ceramic Society, 38(01), 99-102
[4] Li X.Q., Ma S.C., Qu C.A., Zhang X.W. (2007) Experimental Research on Strength of Cement Red Clay. Highway Engineering,06:49-52.
[5] Liu Z.K., Guo T., Wang J. (2017) Effect of the fly ash and lime fly ash on the mechanical properties of red clay in Guilin. Hydrogeology & Engineering Geology,44(03),86-92
[6] Zhao Z.Y., Shen X.D. (2012) Experimental Study on Frost-resistance of Red Clay Cemented Soil. Bulletin of the Chinese Ceramic Society, 31(03):702-705+710

[7] Wang Z.G. (2016) Study on mechanical properties of modified red clay under the action of freeze-thaw cycles. Journal of Transport Science and Engineering, 32(01):12-16

[8] Wang T.L., Liu J.K., Tian y.h. (2010) Dynamic properties of cement- and lime-improved soil subjected to freeze-thaw cycles. Chinese Journal of Geotechnical Engineering, 32(11):1733-1737.

[9] Chen S.L., Shi J.J., Yu T., Huang J. (2014) Effect of Freezing-thawing Cycle on the Mechanical Behaviors of Cemented Soil. Journal of Basic Science and Engineering, 22(02):343-349.