Research on Improvement of Red Clay in a Highway Engineering

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Abstract. Red clay generally has a high liquid limit and is easy to shrink due to water loss. It is easy to cause some engineering accidents. If red clay is used as subgrade filler, it must be studied. This paper studied the red clay properties of a highway in southwest China and improved the red clay by adding quicklime. Research results show that the red clay is high liquid limit soil and the CBR does not meet the specification requirement. It can’t be directly used as filler for highway. After improved by adding quicklime, the red clay changed from high liquid limit soil to non-high liquid limit soil and the CBR increased rapidly. In the supporting project, red clay was improved by adding 5% quicklime. Then the liquid limit and CBR of the modified red clay meet the specification requirements. And the red clay’s water loss cracking has also been greatly improved.

1. Introduction
Red clay is a kind of clay formed by laterization of carbonate rock outcrop [1]. It is brown red or yellow brown clay with high plasticity, low compressibility and high strength [2]. Red clay generally has a high liquid limit and is easy to shrink due to water loss, as shown in figure 1. Red clay is easy to cause some engineering accidents, such as pavement uplift, uneven deformation of foundation, slope instability, pavement cracking and building deformation [3], as shown in figure 2. It brings a lot of economic losses every year. However, there are very few regulations on red clay in current Chinese codes [4, 5]. Therefore, it is very necessary to research on the properties and treatment methods of red clay.

In China, red clay is mainly distributed in southwest and south China such as Yunnan, Guizhou, Guangxi, Hunan, Guangdong and other provinces. The properties of red clay vary greatly between different regions [6, 7]. Therefore, the red clay of each project needs to be tested to determine its engineering properties.

A highway under construction in Guangxi is about 145 kilometers long. There is a large amount of red clay along the highway. In order to save the project cost and the occupied area of waste muck, the construction company plans to use red clay as the roadbed filling material. For the safety of the project,
the engineering properties of red clay were tested before backfilling. And improvement test for red clay that does not meet the specifications has been done.

2. Basic properties test of red clay
Samples were taken along the highway in this study. Figure 3 and figure 4 are sampling photos.

2.1. Basic physical properties
Through laboratory tests, several physical properties of red clay were obtained, as shown in table 1. The liquid limit of red clay is 53.8%. So the red clay is high liquid limit soil.

| Water Content(%) | Specific gravity | Density(g/cm³) | Degree of saturation(%) | Void Ratio | Liquid limit(%) | Plastic Limit(%) |
|------------------|-----------------|---------------|------------------------|------------|----------------|-----------------|
| 30.2             | 2.76            | 1.88          | 1.45                   | 91.2       | 0.912          | 53.9            | 29.4            |

2.2. Filling performance of red clay
Filling performance is an important engineering performance of subgrade filler. The filling performance of red clay mainly includes optimum moisture content, maximum dry density and California Bearing Ratio (CBR) etc. In this study, compaction test and CBR test were carried out.

The relation curve between water content and dry density is shown in figure 5. The figure shows that the optimum moisture content of red clay is 13.7% and the maximum dry density is 1.81g/cm³.

CBR is the California Bearing Ratio. It is proposed by California Highway Administration to evaluate the strength of subgrade soil and pavement materials. CBR is widely used as the design parameter of pavement material and subgrade soil abroad. With the improvement of domestic test technology, CBR test has been paid more and more attention by design and construction staff. It has become one of the reference bases for design and construction.
Through experiments, the CBR of red clay in this study is 2.24%. The Code for Highway Geotechnical Test (JTG E40) gives the recommended value of CBR for highway red clay filler, as shown in table 3 and table 4. As can be seen from the two tables, the CBR of red clay in this study does not meet the specification requirement. Therefore, the red clay in this study cannot be directly used as filler for highway. If the red clay in this study is to be used as highway filler, it must be improved.

3. Red clay improvement test
In this study, improvement of red clay by the method of adding quicklime was carried out. The composition of quicklime is shown in table 4. The quicklime belongs to class III, which is in line with the relevant standards of highways. The test used three ash ratios: 3%, 5% and 7%. Ash ratio is the ratio of quicklime to dry soil. All samples were subjected to standard curing for 28 days. After the improvement, liquid limit test, compaction test and CBR test were carried out. Test results are shown in figure 7~ figure 10.

As can be seen from figure 6– figure 9, the liquid limit of red clay changed to 42% after adding 3% quicklime. The red clay changes from high liquid limit soil to non-high liquid limit soil. Then with the increase of quicklime content, the liquid limit of red clay decreased slowly. The optimal water content decreases and the maximum dry density increases after improvement. The law of change is not monotonous but wavy.

The CBR of red clay increases after improvement. And with the increase of the ash ratio, the CBR becomes larger and larger. The CBR of red clay sample increases greatly after ash mixing. When the ash ratio is 3%, the CBR is 51.67%, which meets the CBR value requirements of roadbed and embankment filler in the specification.
Table 4. The chemical composition of quicklime.

| composition | CaO | MgO |
|-------------|-----|-----|
| Percentage (%) | 1.11 | 1.09 |

4. Engineering applications

Research results in this paper are applied in the highway. In the highway, red clay was improved by adding quicklime. The ash ratio is 5%. Then the liquid limit and CBR of the modified red clay meet the specification requirements. And the red clay's water loss cracking has also been greatly improved.

5. Conclusions

This paper studied the red clay properties of a highway in southwest China and improved the red clay by the method of adding quicklime. The following conclusions were obtained.

1) The liquid limit of red clay is larger than 50%. It is high liquid limit soil. The CBR does not meet the specification requirement. It can’t be directly used as filler for highway.

2) After improved by adding quicklime, the red clay changes from high liquid limit soil to non-high liquid limit soil.

3) When the ash ratio is 3%, the CBR is 51.67%, which meets the CBR value requirements of roadbed and embankment filler in the specification.

4) In the supporting project, red clay was improved by adding 5% quicklime. Then the liquid limit and CBR of the modified red clay meet the specification requirements. And the red clay’s water loss cracking has also been greatly improved.
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