

Experimental study on physical and mechanical properties of red mud under different compaction degree and water content

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Abstract

In order to study the physical and mechanical properties of red mud from Bayer process under conditions of different compaction degrees and water content, samples with 90 % and 95 % compaction degrees were prepared and natural consolidated red mud samples were sampled. The direct consolidation and fast shear test were carried out in the laboratory before and after saturation respectively. Test results show that as the change of dry density from 1.13 g/cm³ to 1.28 g/cm³, the shear strength index of red mud cohesive force of C increased by 13.4 %. Internal friction Angle of Φ increased 21.7 %, the deformation index of red mud compression modulus of E increased by 99.3 %, and the compressibility of a_v decreased by 55 %. After saturation, the cohesive force of C was decreased by 16.3 %, internal friction Angle of Φ by 22.1 %, the deformation modulus of E of red mud decreased by 41.1% and the compressibility of a_v increased by 77.1%. These results reveal the physical and mechanical properties of red mud from Bayer process under different compaction degree and water content, which has important reference value for the study of practical engineering problems.

Keywords: Red mud from Bayer process, Degree of compaction, Saturated red mud, Shear strength index, Deformation index.

1. General Remarks

Red mud is the tailings discharged from alumina factory. At present, the dry storage technology of red mud has been widely used in alumina production. The compaction degree and water condition of red mud are the main factors affecting the stability of red mud dam. In practical projects, the capacity of red mud storage yard is generally large, and the terrain, climate and other conditions are different. The compactness of red mud is mainly controlled by mechanical rolling and the water-bearing condition is mainly controlled by drying and rainfall drainage. Obviously, it is uneconomical and impractical to control the red mud storage with the same index, so the control index of red mud in the area that affects the stability of dam body should be higher, while the control index of red mud in the area that affects less can be reduced appropriately. The mechanical properties of red mud under different compactness and water conditions are inevitably different, and the study of its variation rule and quantitative analysis is beneficial to the long-term safe operation of red mud storage yard, and provides reference for similar projects.

In recent years, many achievements have been made in the research on the mechanical properties of red mud [1~5]. Tian Yue et al. [1] analyzed the mechanical properties of red mud accumulation starting from the generation of red mud. Liu Zhong-fa et al. [2] analyzed the drying degree and reasons of the red mud accumulation body and discussed its mechanical properties. Li Ming-yang [3] proposed that the moisture content of red mud and the outlying slope of sub-dam are the main factors affecting the slope stability of the red mud storage site in pingguo. Wu Yan-sen et al. [4] summarized the physical and mechanical properties of red mud and the factors affecting the test results through composition analysis and physical and mechanical test research of red mud. Chen

Xue-mei [5] obtained the relationship between the number of crushing times and the compactness and shear strength indexes through the crushing test of red mud filter cake. However, there are few researches on the change rules and quantitative analysis of physical and mechanical properties of red mud under different compactness and water conditions.

This paper aims at a dry red mud storage site in the guizhou province. Through the preparation of different degree of compaction of red mud samples and taking the natural consolidation of red mud samples, respectively for the consolidated quick shear tests study before and after saturated, test method and test data with reference to the related standard [6], and through the comparison of experimental results and analysis, expected to reveal red mud in different degree of compaction and water content under the condition of strength and deformation characteristics and the law along with the variation of parameters and scope.

2. Test Conditions and Plan

2.1. Sample Preparation and Adoption

(1) preparation of samples with a compaction degree of 90 % and 95 %

Step 1: the best moisture content and maximum dry density were 41.6 ± 2 % and 1.25 g/cm^3 , respectively, by using the disturbance sample of red mud filter cake taken in the field for compaction test. Then the 90 % compaction degree sample: water content $41.6 \pm 2\%$; rho dry density $= 1.25 \times 0.90 = 1.13 \text{ g/cm}^3$. The 95 % compaction degree sample: water content 41.6 ± 2 %; rho dry density $= 1.25 \times 0.95 = 1.19 \text{ g/cm}^3$.

Step 2: take red mud filter cake, air dry it and grind it [6]. Determine the corresponding air-dried moisture content. Then prepare samples close to the optimal moisture content of the two types of red mud filter cake and determine the actual moisture content after preparation.

Step 3: according to the volume of the sample made and the dry density required, weigh the wet soil quality required for a single sample, and use the method of compaction of sample to complete the preparation of the sample and keep it for test.

(2) Natural consolidation of red mud taken

The samples of natural consolidation of red mud are adopted by ring knife in front of dam at the initial stage of the red mud storage yard, and the natural consolidation time of red mud is more than 6 months.

(3) preparation of saturated samples

Prepared and adopted samples with a compaction degree of 90 % and 95% and natural consolidation, vacuum extraction saturation method [6] was adopted to conduct the saturation of the samples.

2.2. Test Plan

According to the above methods, 12 groups of red mud samples with compaction degree of 90 % and 95 % were prepared, and 12 groups of natural consolidation red mud samples were adopted. Among them, 6 groups of samples are used for direct consolidation and fast shear test, and the other 6 groups are used for consolidation and fast shear test after saturation. In this way, the physical and mechanical parameters of red mud with different compactness and natural

consolidation before and after saturation can be obtained. In Figure 1, the consolidation fast shear test process is on the left, and the sample saturation process is on the right.

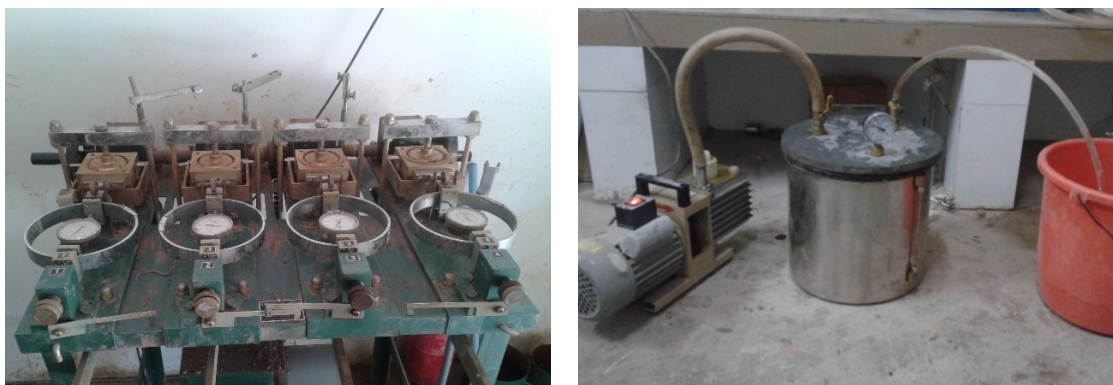


Figure 1. The test process.

3. Test Results and Analysis

3.1. Compaction Characteristics

According to section 2.1, dry density of samples with compaction degree of 90 % and 95 % is 1.13 g/cm³ and 1.19 g/cm³, respectively. The average dry density of naturally consolidated red mud is 1.25 g/cm³, which is basically consistent with the maximum dry density of red mud. Each of the above six groups of samples underwent consolidation and fast shear tests before saturation, and the test results are shown in table 1 (the data in the table are the mean values of the six groups of samples).

Table 1. Consolidation fast shear test results.

Samples	Dry density ρ_d /(g/cm ³)	Cohesive force C/KPa	Internal friction Angle Φ /°	Compressibility a_v /MPa ⁻¹	Deformation modulus of E/MPa
compaction degree 90 %	1.13	29.2	24.9	0.4	6.36
compaction degree 95 %	1.19	30.8	25.5	0.29	8.41
Natural consolidation	1.25	33.1	30.3	0.18	12.68

3.1.1 Impact of Compaction Degree on Strength

In order to analyze the effect of different compaction degree on the strength parameters, the curve of strength index cohesive force of C, internal friction Angle of Φ and dry density ρ_d is shown in figure 2.

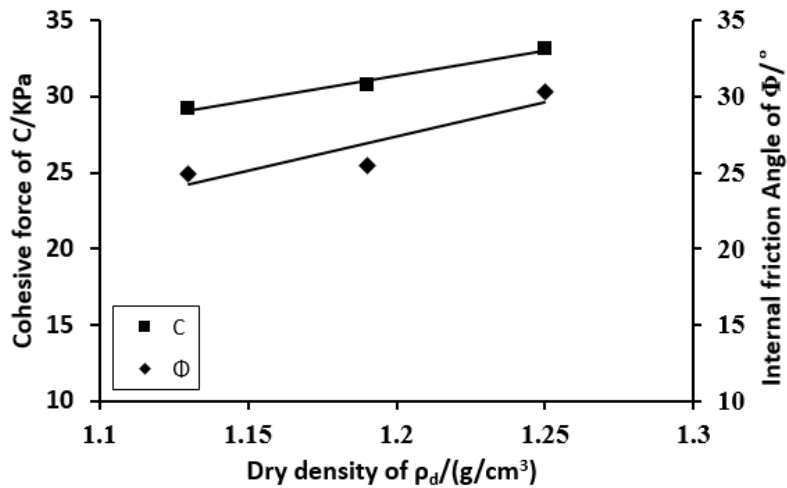


Figure 2. Relationship between Cohesive force of C, internal friction Angle of Φ and dry density ρ_d .

From table 1 and figure 2, the higher the degree of compaction, the higher the strength index cohesive force of C and internal friction Angle of Φ , and the natural consolidation red mud is the largest. The strength index cohesive force of C and internal friction Angle of Φ are increased with the increase of dry density, dry density of 1.13 g/cm³ - 1.28 g/cm³ change process, the cohesive force of C increased by 13.4 %, the internal friction Angle of Φ increased by 21.7 %.

3.1.2 Impact of Compaction Degree on Deformation Parameters

In order to analyze the effect of different compaction degree on deformation parameters, the curve of deformation indicators compression modulus of E, compressibility coefficient of a_v and dry density ρ_d is shown in figure 3.

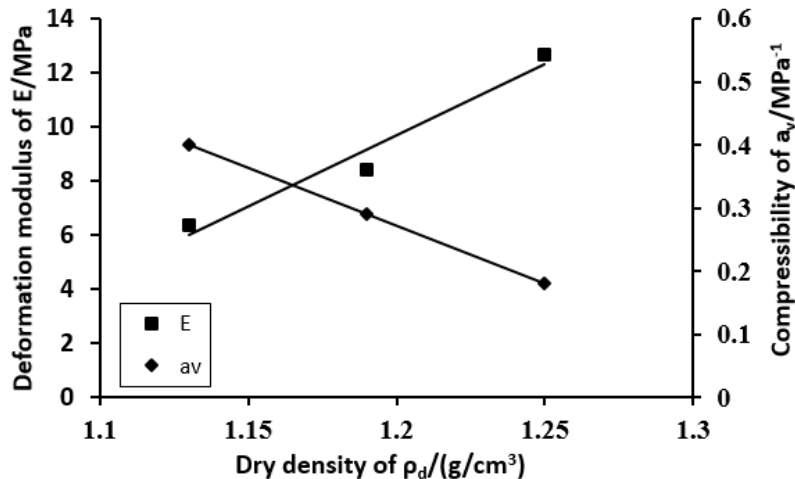


Figure 3. Relationship between compression modulus of E, compressibility coefficient of a_v and dry density ρ_d .

From table 1 and figure 3, deformation indicators compression modulus of E is increased with the increase of dry density, compressibility coefficient of a_v is decreased with the increase of dry density, dry density of 1.13 g/cm³ - 1.28 g/cm³ change process, the compression modulus of E increased by 99.3 %, the compressibility coefficient of a_v decreased by 55 %.

3.2. Saturation Characteristics

According to section 2.1, six groups of samples with 90 % compacted degree, 95 % compacted degree and natural consolidated red mud samples were saturated first, and then the consolidation fast shear test was conducted. The test results are shown in table 2 (the data in the table are the mean values of the six groups of samples).

Table 2. The test results of consolidation fast shear after saturation.

Samples	Dry density $\rho_d/(g/cm^3)$	Cohesive force C/KPa	Internal friction Angle $\Phi/^\circ$	Compressibility a_v/MPa^{-1}	Deformation modulus of E/MPa
compaction degree 90 %	1.13	24.6	19.6	0.58	4.38
compaction degree 95 %	1.19	25.6	21.4	0.46	5.26
Natural consolidation	1.25	27.7	21.5	0.41	5.73

According to the consolidation fast shear test results of the table 1 and table 2, the comparative analysis shows: after saturation, the shear strength indexes of cohesive force of C and internal friction Angle of Φ of red mud are less than before the saturation, the cohesive force of C reduced by an average of 16.3 %, internal friction Angle of Φ reduced by an average of 22.1 %. After saturation, the deformation modulus E of red mud decreases somewhat compared with that before saturation, with an average decrease of 41.1 %. After saturation, the compression coefficient a_v of red mud increases somewhat compared with that before saturation, with an average increase of 77.1 %.

4. Conclusion

By preparing 90 % and 95 % compaction degree of samples and adopting natural consolidation samples of red mud from a red mud storage site in the guizhou province, respectively for the consolidated quick shear tests study before and after saturated, the following main conclusions can be obtained:

- (1) The compaction degree and saturation of red mud in the storage process have a significant impact on the mechanical properties of red mud, including the strength characteristics and deformation characteristics, which should be very useful in terms of practical engineering.
- (2) The higher the degree of compaction, the higher the strength index cohesive force of C and internal friction Angle of Φ , and the natural consolidation red mud is the largest. The strength index cohesive force of C and internal friction Angle of Φ are increased with the increase of dry density, dry density of 1.13 g/cm³ - 1.28 g/cm³ change process, the cohesive force of C increased by 13.4 %, the internal friction Angle of Φ increased by 21.7 %.
- (3) The deformation indicators compression modulus of E is increased with the increase of dry density, compressibility coefficient of a_v is decreased with the increase of dry density, dry density of 1.13 g/cm³ - 1.28 g/cm³ change process, the compression modulus of E increased by 99.3 %, the compressibility coefficient of a_v decreased by 55 %.
- (4) After saturation, the shear strength indexes of cohesive force of C and internal friction Angle of Φ of red mud are less than before the saturation, the cohesive force of C reduced by an average of 16.3 %, internal friction Angle of Φ reduced by an average of 22.1 %. After saturation, the

deformation modulus E of red mud decreases somewhat compared with that before saturation, with an average decrease of 41.1 %. After saturation, the compression coefficient a_v of red mud increases somewhat compared with that before saturation, with an average increase of 77.1 %.

(5) This test reveals the physical and mechanical properties of red mud from the Bayer Process under different conditions of compacted degree and water content, and its quantitative results can be used as reference for analogy and parameter prediction of similar projects. For example, in the case that the maximum compactness and water cut conditions cannot be guaranteed in the storage yard under special topography and climate conditions, when the stability of the dam body of the storage yard is reviewed, the variation trend and range of the corresponding mechanical indexes can refer to the results of this paper.

5. References

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