Experimental Study on the Influence of Red Clay Content on the Properties of Plastic Concrete in Bijie Area

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Abstract. In order to study the influence of red clay content on the performance of plastic concrete in Bijie area, Guizhou province, this paper designs the mixing proportion of plastic concrete with different red clay content, and measures the slump and diffusivity, elastic modulus, permeability coefficient and compressive and tensile strength parameters of plastic concrete with different mixing proportion. The experimental results show that the increase of red clay content has a negative effect on the working performance and mechanical parameters of plastic concrete. Red clay can effectively improve the permeability of plastic concrete. The research results of this paper have certain reference value for the application of plastic concrete in Guizhou water conservancy project.

1. Introduction
Plastic concrete is a kind of flexible engineering material between soil and ordinary rigid concrete formed by mixing, pouring and setting of raw materials such as clay, bentonite, cement, sand, gravel and water [1][2][3]. The low permeability coefficient of plastic concrete makes it have good anti-seepage performance, and the large deformation capacity leads to its excellent durability[4]. Since the advent of plastic concrete in the 1950s, it has been widely used in the reinforcement technology of cutoff wall in water conservancy projects[2][5][6]. Red clay is a common clay distributed in Guizhou, Guangxi, Yunnan, Hunan, Jiangxi and other southern regions of China[7]. In recent years, red clay has been widely used in plastic concrete[8][9][10]. In view of the impact of red clay on plastic concrete, scholars have done a lot of work[11][12][13]. Wu F., et al. [5], in order to explore the influence of low liquid limit red clay on workability and mechanical properties of concrete, used low liquid limit red clay, gravel and mechanical sand to prepare plastic concrete, and discussed the influence of clay content and water-cement ratio on workability, compressive strength, splitting strength and elastic modulus of concrete. Li X., et al. [11] used the finite element simulation software ABAQUS to conduct finite element analysis on a clay inclined wall earth-rock dam in Yunnan province, and to explore the changing rules of the impact of red clay plastic concrete cut offwall on the overburden in the dam foundation. Li X., et al. [13]made a comparative study on the influence of red clay and cement content on the properties of plastic concrete by using 3 series and 15 groups of mixing ratio, and by carrying out tests on compressive strength, splitting tensile strength, flexural strength, elastic modulus and permeability coefficient of plastic concrete. The composition and mechanical properties of red clay have significant regional differences. In this paper, the influence of red clay on the basic mechanical properties of plastic concrete...
in Bijie area of Guizhou province is studied through laboratory experiments, which is of great significance for the utilization and development of plastic concrete in Bijie area.

2. Test preparation and design

2.1. Material preparation

(1) Cement: The ordinary silicate 42.5 grade bagged cement produced by Bijie Saide cement factory is adopted, and its main mechanical indexes are in line with the relevant provisions of the standards of the People's Republic of China (GB175-2007).

(2) Clay: The slope clay beside the inverted Tianhe reservoir is used as raw material, which is silty clay. The selected red clay can be used only after drying, crushing, grinding and passing through 5 mm sieve hole.

(3) Aggregate: Fine aggregate adopts sand used in the project, with the mud content less than 3.0% and fineness modulus 2.8, which belongs to medium sand. 5 ~ 20 mm continuous gradation gravel was used for coarse aggregate.

(4) Bentonite: The sodium bentonite produced by Malin mineral products processing plant in Lingshou county, Hebei province.

2.2. Test method for various performance indexes of plastic concrete

The main indicators of this plastic concrete test are slump and diffusivity, elastic modulus, permeability coefficient, compressive strength (28d), tensile strength (28d). The measurement method and sample preparation refer to the relevant provisions of the latest "hydraulic plastic concrete test code" (DL/T 5303-2013). Slump and diffusivity can be measured according to relevant requirements after the mixing of plastic concrete. The main indicators of this plastic concrete test are slump and diffusivity, elastic modulus, permeability coefficient, compressive strength (28d), tensile strength (28d). The measurement method and sample preparation refer to the relevant provisions of the latest "hydraulic plastic concrete test code" (DL/T 5303-2013). Slump and diffusivity can be measured according to relevant requirements after the mixing of plastic concrete. Three elastic modulus samples were made in each group. The specimens were cylinders with a diameter of 150 mm and a height of 300 mm. Six effective specimens were made in each group for the permeability coefficient. The test block was a circular tabular block with the upper diameter of 175 mm, the lower diameter of 185 mm and the height of 150 mm. The compressive strength of the plastic concrete cube is a cube specimen with a side length of 100 mm. In this experiment, only 28 days' compressive strength is measured, with 3 pieces in each group. Tensile strength was measured by cube splitting experiment. Cube specimens with side length of 100 mm were also used for each group of 3 pieces.

2.3. Mix proportion design

Table 1. Mix proportion parameters of plastic concrete containing red clay

| Serial number | Cement (kg/m³) | Red clay (kg/m³) | Bentonite (kg/m³) | Water (kg/m³) | Sand (kg/m³) | Gravel (kg/m³) |
|---------------|----------------|------------------|-------------------|---------------|--------------|---------------|
| MP1400        | 140            | 0                | 50                | 190           | 785          | 785           |
| MP1404        | 140            | 40               | 50                | 230           | 745          | 745           |
| MP1408        | 140            | 80               | 50                | 270           | 705          | 705           |
| MP1412        | 140            | 120              | 50                | 310           | 665          | 665           |
| MP1416        | 140            | 160              | 50                | 350           | 625          | 625           |
| MP1420        | 140            | 200              | 50                | 390           | 585          | 585           |

The water-binder ratio of plastic concrete is usually controlled at 0.8-1.0, the wet density is generally 2000-2200kg/m³, and the sand ratio is about 50%[15][16]. The commonly used content of bentonite is
50-70 kg/m³[15][16]. In this experiment, the water-binder ratio was 1.0, the wet density was 2000 kg/m³, the sand rate was 50%, and the bentonite content was 50 kg/m³. The content of red clay is designed into six contents, which are 0 kg/m³, 40 kg/m³, 80 kg/m³, 120 kg/m³, 160 kg/m³ and 200 kg/m³ respectively. The specific scheme is shown in Table 1. In MP1408, S stands for sample Mix Proportion, 14 for 140 kg/m³ of cement and 08 for 80 kg/m³ of red clay.

3. Analysis of test results

Plastic concrete was prepared according to the mixing ratio in Table 1. The experimental data of slump and diffusivity, elastic modulus, permeability coefficient, compressive strength (28d) and tensile strength (28d) of plastic concrete measured in accordance with the relevant provisions of the latest "hydraulic plastic concrete test code" (DL/T 5303-2013) are shown in Table 2.

Table 2. Performance parameters of plastic concrete containing red clay

| Serial number | Slump (cm) | Diffusivity (cm) | Elastic modulus (MPa) | Compressive strength (MPa) | Tensile strength (MPa) | Permeability coefficient (10⁻⁷ cm/s) |
|---------------|------------|------------------|-----------------------|---------------------------|-----------------------|-------------------------------------|
| S1400         | 21.0       | 36.3             | 1227                  | 4.69                      | 0.49                  | 0.738                               |
| S1404         | 20.4       | 35.2             | 1162                  | 3.99                      | 0.41                  | 0.503                               |
| S1408         | 19.8       | 33.3             | 1117                  | 3.96                      | 0.35                  | 0.423                               |
| S1412         | 19.3       | 32.5             | 1023                  | 3.04                      | 0.31                  | 0.313                               |
| S1416         | 18.6       | 32.1             | 1056                  | 2.77                      | 0.3                   | 0.265                               |
| S1420         | 18.0       | 31.8             | 937                   | 2.74                      | 0.29                  | 0.255                               |

3.1. The influence of red clay content on the workability of plastic concrete

Fluidity and cohesion are the two most important aspects of plastic concrete workability. As can be seen from Table 2, with the change of red clay content from 0 kg/m³ to 200 kg/m³ at each time of 40 kg/m³, the slump decreased from 21.0 cm to 18.0 cm, with a change of 3 cm. It can be seen from Figure 1 that slump decreases linearly with the increase of red clay content. However, the diffusivity decreased from 36.3 cm to 31.8 cm with the same change of red clay content, with a change of 4.5 cm. Diffusivity also decreases linearly with the increase of red clay content, but the dispersion of diffusivity data is larger than that of collapse data. The variation range of diffusivity is greater than that of slump.
3.2. The influence of red clay content on the strength of plastic concrete

![Compressive strength diagram](image1)

![Tensile strength diagram](image2)

Figure 3. The diagram of the 28d compressive strength with red clay content

Figure 4. The diagram of the 28d splitting tensile strength with red clay content

It can be seen from Table 2 that the compressive strength (28d) and splitting tensile strength (28d) of plastic concrete show a linear relationship that decreases with the increase of red clay content. The compressive strength (28d) decreased from 4.69 MPa to 2.74 MPa, while the splitting tensile strength (28d) decreased from 0.49MPa to 0.29MPa. The declines were about the same. By comparing Figure 3 and Figure 4, it can be seen that the discretization of the two data shows the same trend and the same direction. By comparing the values of compressive strength and tensile strength, it can be seen that the value of tensile strength is 0.09~0.11 times of compressive strength, and the data is relatively stable.

3.3. Effect of red clay content on elastic modulus of plastic concrete

![Elastic modulus diagram](image3)

![Permeability coefficient diagram](image4)

Figure 5. The diagram of elastic modulus with red clay content

Figure 6. The diagram of permeability with red clay content

Plastic concrete has the characteristics of low elastic modulus and large Poisson’s ratio. As can be seen from Table 2 and Figure 5, the red clay content is 0 kg/m$^3$, and the elastic modulus is the largest, which is 1227 MPa. The content of red clay is 200kg/m$^3$, and the elastic modulus is 937MPa. The variation is 290 MPa, with a variation range of 23.63%. The elastic modulus of plastic concrete decreases linearly with the increase of red clay content. At low red clay content, the data dispersion of elastic modulus is small. When the content of red clay is high, the dispersion of elastic modulus is large. Thus it can be seen that red clay can effectively increase the plasticity of concrete.
3.4. Effect of red clay content on permeability coefficient of plastic concrete

As can be seen from Table 2 and Figure 6, the red clay content increases from 0 kg/m$^3$ to 200 kg/m$^3$, and the permeability coefficient of plastic concrete decreases from 0.738 (10$^{-7}$cm/s) to 0.255 (10$^{-7}$cm/s). The permeability coefficient decreased by 65.45%. The permeability coefficient of plastic concrete decreases linearly with the increase of red clay content. Thus it can be seen that mixing red clay into plastic concrete can effectively reduce its permeability and improve the anti-penetrability of plastic concrete.

4. Conclusion

Under different red clay content in this paper, by comparing the plastic concrete slump, diffusion degree, elastic modulus, compressive strength, tensile strength and the permeability coefficient of the experimental data shows that with the increase of red clay content, plastic concrete slump, diffusion, elastic modulus, compressive strength, tensile strength and permeability coefficient linear decrease. It can be seen that the content of red clay has a negative effect on the performance of plastic concrete in terms of working performance and mechanical parameters. The permeability of plastic concrete can be improved with the increase of red clay content. In practical engineering, the optimal mix proportion should be designed based on the influence of red clay on the physical and mechanical properties of plastic concrete, and the requirements of different engineering on strength, stiffness, permeability and construction performance.

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