Mix Design and Strength Properties of Full Iron Tailings Concrete

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Abstract. In this paper, the iron tailings powder, iron tailings sand and iron tailings gravel in Qian’an city are used to replace fly ash, river sand and gravel respectively as admixture, fine and coarse aggregates of concrete. Through mix design, the high-fluidity concrete with strength grade C25, C30 and slump of 180~200mm is prepared. The compressive strength of all kinds of concrete with iron tailings powder as admixture can meet the requirements of the corresponding strength grade. The basic strength properties of full iron tailings concrete are more prominent in all kinds of concrete with iron tailings powder as admixture, and are the closest to that of fly ash concrete.

1. Introduction
With the shortage of resources and the enhancement of environmental awareness, Using iron tailings to develop green construction materials have become a hot research topic. Ismail Z. Z et al. have carried out systematic research on iron tailings gravel and iron tailings sand as coarse and fine aggregates of concrete [1-2]. Liu Jia used fly ash and iron tailings as main raw materials to study the preparation of all tailings aggregate concrete [3-5]. Wang Anling et al. investigated the activity of iron tailings powder as admixture of concrete[6].

Qian’an city is a large city of iron and steel production base in China, with a large stock of iron tailings. However, there are relatively few studies on the use of iron tailings of Qian’an city in concrete, and almost no researches on the use of iron tailings powder as concrete admixture. In this paper, the iron tailings powder, iron tailings ore and iron tailings sand from Qian’an city are used as admixture, coarse and fine aggregates of concrete respectively. Through mix design, the high-fluidity concrete with strength grade C25, C30 and slump of 180~200mm is prepared. By comparison with fly ash ordinary concrete, this paper analyzes the similarities and differences of strength properties for concrete by using iron tailings powder, iron tailings sand and iron tailings ore instead of fly ash, river sand and gravel as admixture, fine and coarse aggregates of concrete respectively.

2. Test Methods

2.1. Test Material
P.O 42.5 ordinary Portland cement is used as the main cementitious material. The comparison admixture, fine and coarse aggregates are the fly ash, river sand and ordinary gravel respectively. The test admixture, coarse and fine aggregates are iron tailings powder, crushed iron tailings ore and iron tailings sand originated from Qian’an city respectively. The polycarboxylateis used to improve the workability of concrete.
2.2. Mix Design
In this test, the mix ratio design was carried out according to the code of China for the mix design of ordinary concrete (JGJ 55-2011). The water-binder ratio is calculated according to the 28d cementitious sand strength of cementitious material. The basic strength properties of concrete were measured according to the Chinese standard for test methods for strength properties of ordinary concrete (GB/T 50081-2002). The concrete design strength of this test is C25 and C30, the admixture content is 30%, and the coarse and fine aggregates are completely replaced. The water consumption is fixed at 170kg/m³. By adjusting the water reducer content and sand rate, the slump reaches 180~200mm while ensuring the cohesion and water retention as far as possible. Since the unscreened iron tailings sand have particles size of more than 5mm up to 22.2%, which are far more than the secondary sand grading, the portion of unscreened iron tailings sand that exceeds secondary sand grading is converted into coarse aggregate. The converted mix ratio is shown in table 1. In the table, A and B represent that the strength grades of concrete is C30 and C25 respectively, and 1, 2, 3 and 4 represent four types of concrete with different admixtures and aggregates respectively.

| Number | Water-binder ratio | Sand rate | Cement | Fly ash | Iron tailings powder | River sand | Iron tailings sand gravel | Iron tailings ore | Water reducer |
|--------|------------------|-----------|--------|---------|----------------------|------------|--------------------------|----------------|--------------|
| A1     | 0.510            | 0.42      | 233.3  | 100.0   | -                    | 786.7      | -                        | 1086.5         | -            | 2.033        |
| A2     | 0.450            | 0.42      | 264.4  | -       | 113.3                | 780.7      | -                        | 1078.1         | -            | 2.002        |
| A3     | 0.450            | 0.40      | 264.4  | -       | 113.3                | 762.5      | 1144.5                   | -              | 2.342        |
| A4     | 0.450            | 0.42      | 264.4  | -       | 113.3                | 794.3      | -                        | 1141.1         | 2.115        |
| B1     | 0.575            | 0.45      | 207.0  | 88.7    | -                    | 858.9      | -                        | 1049.8         | -            | 1.892        |
| B2     | 0.510            | 0.42      | 233.3  | -       | 100.0                | 853.9      | -                        | 1043.6         | -            | 1.833        |
| B3     | 0.510            | 0.42      | 233.3  | -       | 100.0                | 812.1      | 1137.2                   | -              | 2.166        |
| B4     | 0.510            | 0.43      | 233.3  | -       | 100.0                | 843.7      | -                        | 1106.9         | 1.933        |

3. Analysis of Test Results
3.1. Strength Properties
Table 2 shows the basic strength properties of each group of concrete. It can be seen from the table that the 28-day compressive strength of each group of concrete can meet the corresponding strength grade. For the same strength grade, the 28-day compressive strength of different types of concrete has little difference. By comparing the 28-day compressive strength of C30 concrete type 2 and 3, it can be seen that the compressive strength of iron tailings sand as fine aggregate of concrete is slightly higher than that of river sand as fine aggregate of concrete. This is because the unscreened iron tailings sand contain more particle size of 5~10mm than river sand, which makes the accumulation of concrete more compact. Comparing and analyzing the 28d compressive strength of C30 concrete type 3 with C30 concrete type 4 found that the compressive strength of concrete with iron tail coarse aggregate is higher than that with ordinary gravel coarse aggregate concrete, which is because the crushing index of iron tailings ore is lower than that of gravel.
Table 2. Basic strength properties of concrete

| Number | Cube compressive strength(MPa) 7d | Cube compressive strength(MPa) 28d | Axial compressive strength(MPa) | Splitting tensile strength(MPa) | Elastic modulus(MPa) |
|--------|---------------------------------|-----------------------------------|--------------------------------|-------------------------------|---------------------|
| A1     | 21.7                            | 32.0                              | 29.0                           | 2.60                          | 3.06×10⁴            |
| A2     | 25.4                            | 34.3                              | 24.4                           | 2.03                          | 3.23×10⁴            |
| A3     | 25.5                            | 35.0                              | 28.2                           | 2.41                          | 3.29×10⁴            |
| A4     | 26.8                            | 35.6                              | 24.7                           | 2.04                          | 3.07×10⁴            |
| B1     | 15.7                            | 26.7                              | 20.3                           | 2.20                          | 2.93×10⁴            |
| B2     | 20.1                            | 29.1                              | 17.2                           | 1.71                          | 3.20×10⁴            |
| B3     | 22.1                            | 31.2                              | 22.8                           | 1.92                          | 2.92×10⁴            |
| B4     | 22.9                            | 27.8                              | 20.8                           | 2.03                          | 2.74×10⁴            |

Figure 1 shows the curve of age change for concrete compressive strength. It can be seen from the figure that the slope of the curve of fly ash concrete is slightly higher than that of other kinds concrete, which indicates the early strength of all kinds concrete with iron tailings powder as admixture is higher than that with fly ash as admixture. This is because the fly ash slows down the hydration process of the cement and reduces the early strength of the cement slurry, while the iron tailings powder mainly plays the role of micro-aggregate filling in concrete and will not inhibit the hydration process of cement, so the early strength of concrete with iron tailings powder as admixture is higher than that with fly ash as admixture.

![Figure 1. Curve of compressive strength-age of concrete](image-url)
Elastic modulus is an index for concrete to resist elastic deformation. The elastic modulus of concrete is a necessary parameter to calculate the concrete structural stress, deformation and crack of concrete structures, and is an important index of engineering material performance. It can be seen from table 6 that the elastic modulus of all kinds of concrete with iron tailings powder as admixture is basically similar to that of fly ash concrete. This indicates that the stiffness of all kinds of concrete with iron tailings powder as admixture is very close to that of the fly ash concrete.

4. Conclusions
This paper studies the influence of iron tailings powder, iron tailings sand and iron tailings gravel on the strength property of concrete through the mix ratio test and basic strength property test of iron tailings concrete. By comparison with the common concrete with fly ash, river sand and ordinary gravel as admixture, coarse and fine aggregates respectively, the conclusions are as follows:

(1) The compressive strength of all kinds of concrete with iron tailings powder as admixture meets the requirement of corresponding strength grade. The basic strength properties of full iron tailings concrete are more prominent. The elastic modulus of all kinds of concrete with iron tailings powder as admixture is very similar to that of fly ash concrete. The full iron tailing concrete can be used in engineering.

(2) For the full tailing concrete with strength grade of C30 and C25, iron tailing powder, iron tailing sand and iron tailing gravel occupy 88.4% and 90.0% of the total solid raw materials of concrete respectively. This shows that the full tailings concrete can make the best use of iron tailings resources

5. References
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