Experimental study on mix proportion of green environmental protection type three-doped fair-faced concrete

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Abstract. Fair-faced concrete has been favored by the majority of architectural and structural designers. In response to the sustainable development strategy of our government, this paper studies the green environment-friendly fair-faced concrete mixed with agricultural and industrial wastes. Based on the statistical analysis of the existing literature on fair-faced concrete, the green environmental protection of fair-faced concrete was considered comprehensively. The mix proportion of “three-doped” fair-faced concrete mixed with ground rice husk ash, fly ash and mineral powder, which replaced the cement amount by 8%, 20% and 6% respectively, and its influence on compressive strength were studied through experiments. The experimental results show that the green environmental protection type fair-faced concrete mixed with rice husk ash, fly ash and mineral powder can achieve requirements of the compressive strength by the design. And the growth rate of compressive strength from the 28th day to the 56th day is higher than that of ordinary fair-faced concrete. At the same time, the curve equation of the relationship between the compressive strength and the age is put forward, and the fit is good, which can provide reference for the design of similar concrete mix proportion.

1. Introduction
Since the advent of concrete, it has been widely used in high-rise buildings and bridge buildings. However, the concrete structure has the shortcomings of single tone and gray expression. As a result, a new product came into being, which is decorative concrete, also known as fair-faced concrete [1]. With the rapid development of engineering construction in China, the construction technology of fair-faced concrete has been widely used in various types of concrete structure engineering [2]. Due to the limited unified standards and specifications related to fair-faced concrete at present, there are still many deficiencies in construction technology. Analogy to various new environment-friendly concrete derived from ordinary concrete, such as: green concrete mixed with rice husk ash. Rice husk ash replaces cement and mixed with concrete, which can significantly improve pore structure and increase the number of harmless pores. The obvious decrease of Ca(OH)₂ in concrete and the improvement of pore structure are the main reasons for the increase of compressive strength of rice husk ash concrete. In the first 7d, the strength of rice husk ash concrete increased slowly, but after 56d, the strength of rice husk ash concrete increased significantly. Therefore, for ordinary concrete, properly mixing agricultural waste not only follows the concept of sustainable development advocated by the state, but also can achieve the purpose of cement saving. Further more, it can reduce the expansion caused by the alkali aggregate reaction of concrete, which is conducive to improving the compressive strength of concrete [4]. As a kind of highly active pozzolanic ash, the performance of rice husk ash is greatly affected by the place of origin, calcination temperature, calcination time, grinding time, grinding aids and pretreatment methods,
which has the potential of concrete admixture \[5\]. Fly ash and slag are industrial wastes with potential activity. As good artificial pozzolanic material, the use of secondary raw materials will effectively reduce the emission of carbon dioxide and benefit the environment. For fair-faced concrete, agricultural and industrial wastes can also be mixed to replace the amount of cement by equal amount, so as to achieve a more environmental protection and green effect. However, according to the literature review on CNKI, there are few studies on this issue in the existing papers. Therefore, this paper focuses on the mix proportion design and mechanical properties of fair-faced concrete mixed with rice husk ash, fly ash \[6\] and mineral powder. Based on the statistical analysis of the existing literature on fair-faced concrete, this paper comprehensively considers the green environmental protection of fair-faced concrete, and studies the mix proportion design of green environmental protection three-mixed fair-faced concrete with ground rice husk ash, fly ash and mineral powder replacing cement by 8%, 20% and 6% respectively, and the influence on its compressive strength.

2. Test materials and scheme

2.1. Test materials

1) Cement: “Miaoling” brand ordinary silicate cement, strength grad 42.5Mpa, produced by Jilin Province North Cement Co;

2) Ground rice husk ash: 80 mesh, low-moisture drying and dust removal rice husk powder, produced by Chutian bran powder processing plant, Badong County, Enshi Prefecture, Hubei Province;

3) Natural fine aggregate: river sand from Yanji City, Jilin Province; it is medium sand with an apparent density of 2600 kg/m\(^3\) and a moisture content of 0%;

4) Natural coarse aggregate: crushed stone from Yanji City, Jilin Province is selected; the maximum particle size of the crushed stone was 30mm, the apparent density is 2680 kg/m\(^3\), and the moisture content was 0%;

5) Slag: selected S95 level powder, its specific surface area is 429 m\(^2\)/kg, and its density is 2.9g/cm\(^3\);

6) Fly ash: selected secondary fly ash produced by Tienan Heating Company in Yanji City, Jilin Province;

7) Water reducing agent: polycarboxylic acid water reducing agent of Fang Sheng Building Material Company of Yanji City, Jilin Province;

8) Water: Tap water.

The main raw materials of green and environment-friendly three-mixed fair-faced concrete used in this test are shown in Fig. 1.

![a) Fly ash b) Slag c) Rice husk ash](image)

Figure 1. Main test materials

2.2. Experimental scheme

1) Design index: the design strength grade of fair-faced concrete is C30, and the slump required for construction is T=150mm ~ 160mm.

2) Curing conditions: curing temperature of concrete test block is (20±2) °C, relative humidity is 80%.

3) Test block production: a total of 12 test blocks were produced. The size of the test block for the
compressive strength of the exposed concrete cube is 150mm×150mm×150mm. The grinded rice husk ash, fly ash and mineral powder replaced the cement by the same amount (according to the mass) respectively, 8%, 20% and 6%.

4) Mix proportion design: according to the "Specification for mix proportion design of ordinary concrete" (JGJ 55-2011), carry out the mix proportion design of green environmental protection three-doped fair-faced concrete, the calculation steps are shown in Table 1.

| Table 1. mix proportion design steps of mixed fair-faced concrete |
|-----------------------------------------------|
| \( f_{cu,0} \geq f_{cu,k} + 1.645\sigma \) | \( f_{cu,0} \) is the configuration strength of concrete (MPa); \( f_{cu,k} \) is the standard value of the compressive strength of concrete cubes; \( \sigma \) is the standard deviation of concrete strength (MPa); |
| \( \sigma = \left[ \frac{\Sigma f_{cu,i} - m_{fcu}}{(n-1)} \right]^{1/2} \) | \( F_{cu,i} \) is the specimen strength of group i (MPa); \( m_{fcu} \) is the average strength of the specimen of group n (MPa); \( n \) is the number of specimens, and the value of n should be greater than or equal to 30; |
| \( W/B = \alpha_a \times f_b / (f_{cu,0} + \alpha_a \times \alpha_b \times f_b) \) | \( W/B \) is the water-binder ratio of concrete; \( \alpha_a, \alpha_b \) are regression coefficients; \( f_b \) is cementitious material 28d mortar strength (MPa); |
| \( m_{w0} = m_{w0}'(1-\beta) \) | \( m_{w0} \) is the water consumption per cubic meter of concrete to meet the actual slump requirements (kg/m³); \( \beta \) is the water reduction rate of admixture (%); |
| \( m_{b0} = m_{w0} / (W/B) \) | \( M_{b0} \) is used to calculate the amount of cementitious material per cubic meter of concrete (kg/m³); |

With reference to the existing references and “Specification for mix proportion design of ordinary concrete” (JGJ169-2009), after repeated adaptation and adjustment, the laboratory fit of 1m³ fair-faced concrete is obtained, as shown in Table 2.

| Table 2. laboratory mix proportion of three mixed fair faced concrete (kg/m³) |
|-----------------------------------------------|
| Water | Cement | Ground rice husk ash | Slag | Sand | Crushed stone | Fly ash | Water reducing agent |
|------|--------|----------------------|-----|-----|--------------|--------|---------------------|
| 223  | 220    | 70                   | 30  | 785 | 1060         | 20     | 1.66                |

3. Test results and analysis

3.1. Test detection

1) Slump test: calculate the amount of each material needed to test the slump according to the mix proportion of three-doped fair-faced concrete proposed in this paper. After mixing evenly, the slump is tested by slump bucket, and the measured value of slump is 155mm. The slump test is shown in Fig. 2.
Because the number of test blocks is not required much, this test uses the method of manual vibration to mix concrete. In this experiment, ground rice husk, fly ash and mineral powder were mixed, so there is a systematic error between the test value of concrete block test and the configuration strength value.

2) Compressive strength test: The compressive strength of the test blocks was measured at a rate of 5kN/s on the pressure machine in the laboratory on 7d, 14d, 28d and 56d after the completion of the test blocks. As shown in Fig. 3.

Each group consists of 3 test blocks, and the average value of the test values of the 3 test blocks is taken as the compressive strength value. The test results of the compressive strength of concrete test blocks are shown in Table 3.

| Block | 7d  | 14d | 28d | 56d |
|-------|-----|-----|-----|-----|
| 01    | 12.28 | 14.51 | 18.58 | 35.89 |
| 02    | 13.16 | 14.82 | 19.09 | 36.90 |
| 03    | 12.36 | 14.44 | 18.94 | 35.85 |
| Average | 12.60 | 14.59 | 18.87 | 36.21 |

3.2. Relationship between compressive strength and age
1) Fit the equation of the curve
The test results of the data are shown in the table. The data in the above table are fitted by using the software Origin. The relationship between compressive strength and age is shown in Fig. 4.
Figure 4. Relationship between compressive strength and age of concrete

Shows that the relationship between the compressive strength and the age of the concrete satisfies the fitting equation: $y=1.795x^3-9.625x^2+18.3x+2.13$. ($R^2=1$)

2) Experimental analysis

From the curve analysis in the figure, it can be concluded that the compressive strength increases with the age, and the growth rate from the 28d to the 56d is significantly higher than that of ordinary fair faced concrete.

4. Conclusion

1) The mixture of C30 green environmental protection smooth concrete with rice husk ash, fly ash and mineral powder not only meets the standard of ordinary fair-faced concrete in appearance, but also reaches the compressive strength of ordinary C30 concrete, and the strength growth rate from 28d to 56d is higher than that of ordinary fair-faced concrete.

2) In this paper, the mix proportion of green and environment-friendly three-doped fair-faced concrete is water: cement: fly ash: rice husk ash: sand: crushed stone: mineral powder = 223:220:70:30:785:1060:20. The fitting curve equation of the relationship between the test value of compressive strength and the age is: $y=1.795x^3-9.625x^2+18.3x+2.13$.

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