Study on Mix Proportion Optimization of C50 High Strength Concrete

Yunhua Wang\textsuperscript{1}, Fanji Cai\textsuperscript{2}, Qiong Wang\textsuperscript{2}, Dongfeng Li\textsuperscript{3} and Pan Guo\textsuperscript{4*}

\textsuperscript{1}Zhumadian Highway Engineering Development Co., Ltd., northeast corner of the intersection of Wenming road and Tianshun Road, Zhumadian City, Henan Province, 463005, China;
\textsuperscript{2}The Fourth Engineering Co., Ltd. of the Second Public Bureau of China Communications, No. 8, Yangwen Xiangyang Road, Zhanghe District, Luoyang, Henan Province, 471013, China;
\textsuperscript{3}Henan Anluo Expressway Co., Ltd., Zhengzhou Area of Henan Pilot Free Trade Zone (Zhengdong) No. 5, 10th Floor, West Unit, Block B, Henan Coal Construction Building, No. 6, Dehou Street West, 450000, China;
\textsuperscript{4}School of Civil Engineering, Zhengzhou University, 100 Science Avenue, Zhengzhou, 450001, China.
Email: guopan@zzu.edu.cn

Abstract. With the progress of engineering technology, C50 high-strength coagulation came into being for the needs of actual engineering. This research mainly focuses on the selection of cement varieties and admixtures of C 50 high-strength concrete, so as to realize the optimization research of the mix ratio of C 50 high-strength concrete. The results show that ordinary P.O 42.5 and fly ash admixture can increase the mechanical performance of concrete. However, the concrete compressive strength with the mixed admixture of fly ash and mineral powder is even lower than that without any admixture. On the premise of meeting actual engineering needs, the optimization of the mix ratio of high-strength concrete can not only achieve sustainable development, but also save investment in project economic costs.

Keywords. Coal fly ash, Ordinary portland cement, High-strength concrete, Mineral powder.

1. Introduction

High-strength concrete is widely used in highway engineering, construction engineering and other fields with the development of China's economy and the progress of science and technology [1, 2] because of its good durability and stability. In order to improve the construction quality of concrete, the research on mix proportion optimization of high strength concrete is of great significance.

The raw materials of high-strength concrete are mainly composed of aggregate, cement, mineral admixtures, water and admixtures [3]. High standard Portland cement is generally selected as the cement model in high-strength concrete, and the stability of cement quality shall be guaranteed [4]. Admixtures mainly include silica fume, mineral powder, fly ash and other admixtures. Fly ash is the product of coal burning in thermal power plant, which mainly plays a dispersing role in concrete. Mineral powder is a by-product of iron smelting, which mainly reduces the segregation resistance and corrosiveness of the mixture in concrete [4]. Mineral admixture is a component that has a great impact on its mechanical properties in the mix proportion study of high-strength concrete [5].
This paper mainly aims at the selection of cement varieties and the influence of fly ash and mineral powder as admixtures on the mechanical performance of C50, so as to realize the research purpose of optimal mix proportion, and provide some theoretical guidance and suggestions for the selection of raw materials of this type of concrete in practical engineering.

2. Test

2.1. Materials and Test Pieces

The cement varieties in the paper mainly include P.O 42.5 and P.O 52.5. The physical properties of P.O 42.5 and P.O 52.5 are shown in tables 1 and 2 [6]. The basic physical properties of mineral powder and the chemical composition of fly ash are shown in tables 3 and 4 separately.

| Table 1. P. O 42.5 physical property index of cement. |
|------------------------------------------------------|
| Loss on ignition/ % | Specific surface area / m²/kg | Setting time/ min | Flexural strength/ MPa | Compressive strength/ MPa |
|---------------------|-----------------------------|------------------|-----------------------|--------------------------|
|                     |                             | Initial setting   | Final set             | 3 d | 28 d | 3 d | 28 d |
| 3.9                 | 334                         | 173              | 236                   | 5.3 | 8.3  | 24.0| 48.8|

| Table 2. P. O 52.5 physical property index of cement. |
|------------------------------------------------------|
| Loss on ignition/ % | Specific surface area / m²/kg | Setting time/ min | Flexural strength/ MPa | Compressive strength/ MPa |
|---------------------|-----------------------------|------------------|-----------------------|--------------------------|
|                     |                             | Initial setting   | Final set             | 3 d | 28 d | 3 d | 28 d |
| 2.05               | 348                         | 151              | 212                   | 6.1 | 8.8  | 30.2| 56.0|

| Table 3. Basic physical properties of mineral powder. |
|------------------------------------------------------|
| Specific surface area / m²/kg | Moisture content/ % | Fluidity comparison/ % | Loss on ignition/ % | Density/ g/cm³ |
|--------------------------------|---------------------|------------------------|-------------------|--------------|
| 513                            | 0.4                 | 86                     | 1.2               | 2.832        |

| Table 4. Chemical composition of fly ash. |
|------------------------------------------|
| CaO/ % | SiO₂/ % | Al₂O₃/ % | MgO/ % | SO₃/ % |
| 1.84   | 57.84   | 29.01    | 2.73   | 0.37   |

| Table 5. Test conditions. |
|----------------------------|
| Test conditions | Cement variety | Admixture | Water binder ratio | Cement content/ kg | Dosage admixture/kg of |
|-----------------|----------------|-----------|-------------------|-------------------|------------------------|
| 1               | P.O 52.5       | /         | 0.33              | 485               | 0                      |
| 2               | P.O 42.5       | /         | 0.3               | 480               | 0                      |
| 3               | P.O 42.5       | Mineral powder | 0.3       | 430               | 50                     |
| 4               | P.O 42.5       | Fly ash   | 0.3               | 430               | 50                     |
| 5               | P.O 42.5       | Fly ash + mineral powder | 0.3       | 400               | 30+50                  |

The use of concrete test formwork meets the standard [7]. The compressive strength grade shall be determined. The side length of standard model is 150 mm × 150 mm × 150 mm, and the
manufacturing process is shown in figure 1. The test conditions of this study are shown in table 5. For each test condition, two groups of specimens are made, with three specimens in each group. The compressive strength value with 95% guarantee rate measured by standard test method at the age of 28d [8].

The specimen shall be placed in the curing room immediately after forming and plastering to maintain the surface humidity of the specimen. When the temperature is 20 ℃± 5 ℃ in the curing room and the relative humidity is greater than 50%, the test piece shall be left standing for 1 ~ 2 days. During the standing period, the test piece shall be protected from vibration and impact. After standing, it shall be numbered and marked and the formwork shall be removed. The test piece is placed in a standard curing room with a temperature of 20 ℃± 2 ℃ after the formwork is removed, and a relative humidity is more than 95% for curing. The test pieces are placed on the support at an interval of 10 mm ~ 20 mm, as shown in figure 2. The surface of the test pieces remains wet, and the curing process meets the relevant regulations [9].

2.2. Test Steps
The constant pressure testing machine is used to calculate the compressive strength of concrete standard cube specimens. The constant stress pressure testing machine is shown in figure 3 and meets the relevant provisions of national standards [10, 11]. The compressive strength was tested aged 7 days and 28 days respectively. The test process is continuously and evenly loaded, and the data are collected in real time, as shown in figure 4. The whole test process complies with relevant regulations [9].
3. Results and Discussion

The concrete compressive strength is shown in formula (1) [9]:

\[ f_{cc} = \frac{F}{A} \]  

(1)

where: \( f_{cc} \) is Compressive strength of concrete cube,
\( F \) is Specimen failure load,
\( A \) is Bearing area of test piece.

The arithmetic mean of the measured values of test pieces in each group is taken as the strength value of this group [9]. According to the results, the compressive strength of concrete specimens under working conditions is greater than 60 MPa, which meets the actual engineering needs [12].

3.1. Types of Cement

For the factors affecting the strength and workability of cement concrete, the type of cement and the quantity of cementitious substances are the two main factors. Whether the aggregate can play a role is closely related to the strength and bonding force of the cement material itself. Therefore, the determination of cement type is very important. When preparing high-strength concrete, the selection requirements of cement strength grade shall be higher than the corresponding concrete strength grade [13].

In this study, the specimens under test conditions I and II in table 2 are used to compare the compressive strength values of concrete. As shown in figure 5, although the compressive strength with P.O 42.5 cement at the age of 7 days is lower than that with P.O 52.5 cement, the compressive strength with P.O 42.5 cement at the age of 28 days is 2.5% higher than that with P.O 52.5 cement, and the compressive strength of concrete specimens with P.O 42.5 cement from 7 days to 28 days has increased by 33.1%, while the compressive strength of concrete specimens with P.O 52.5 cement has only increased by 18.5%. The growth rate of compressive strength of C50 from 7 d to 28 d of P.O 42.5 cement is 78.9% higher than that with P.O 52.5 cement, and the strength growth trend of P.O 42.5 cement concrete is more obvious in the later stage [14].

In addition, the compressive strength for high-strength concrete decreases with the increase of water binder ratio [15, 16]. According to table 2, the water binder ratio with P.O 42.5 is less than that with P.O 52.5.

To sum up, P.O 42.5 is the best material for C50 high strength concrete in the actual project.
3.2. Admixture

It can be seen from Section 3.1 that the optimal cement selection for C50 concrete is P.O 42.5. Therefore, this section mainly studies the concrete specimens with cement type of P.O 42.5, and mainly studies the influence of different admixtures on the compressive strength of C50, so as to put forward the selection scheme of optimal admixtures.

3.2.1. Separately Mixed with Mineral Powder or Fly Ash. As shown in Figure 6, when the concrete age is 7 days, the compressive strength of concrete with mineral powder as admixture is higher than that without admixture and fly ash as admixture. However, when mineral powder is used as admixture, the growth rate of compressive strength of concrete aged from 7 days to 28 days is only 6.8%, which is far less than that of concrete without admixture and fly ash as admixture. Meanwhile, when mineral powder is used as admixture, the compressive strength of concrete at 28 d age is is 2.5% lower than that of concrete without admixture, and it is the lowest.

Therefore, when mineral powder is used as the admixture of C50 high strength concrete, it will have an adverse impact on the mechanical properties of concrete. The compressive strength of concrete with fly ash admixture is the highest, and the growth rate of concrete strength from 7 d to 28 d is the largest, which has good mechanical properties.

In conclusion, the best raw material for the admixture of C50 high strength concrete should be fly ash, and the actual engineering requirements should be considered as much as possible when selecting mineral powder.

Figure 6. Compressive strength of concrete with different ages and different admixtures.

Figure 7. Comparison of concrete strength growth rate.
3.2.2. Mixed Admixture. According to section 3.2.1, although mineral powder is a more unfavorable concrete admixture than fly ash, this study hopes to provide more concrete admixture selectivity for practical projects. Therefore, the compressive strength of concrete with mineral powder and fly ash is further studied. The dosage of admixture for concrete specimens is 50 kg of fly ash and 50 kg of mineral powder, 50 kg of fly ash and 30 kg of mineral powder respectively.

The results of concrete compressive strength test are shown in figures 8 and 9. Although the concrete strength growth rate of the mixed admixture of fly ash and mineral powder reaches 30.4%, the compressive strength of concrete with mixed admixtures decreases. The compressive strength of concrete with fly ash and mineral powder as mixed admixture is the lowest, which is 6.7%, 4.3% and 14.0% lower than that without admixture, single mineral powder and single fly ash respectively.

Therefore, fly ash and mineral powder as C50 high-strength concrete admixture are the most unfavorable.

![Figure 8. Compressive strength of concrete with different ages and different admixtures.](image1)

![Figure 9. Comparison of concrete strength growth rate.](image2)

4. Conclusions

(1) From 7 d to 28 d, the compressive strength growth rate of C50 high strength concrete with P.O 42.5 cement is 78.9% higher than that with P.O 52.5 cement, and the compressive strength of C50 high strength concrete with P.O 42.5 cement is 2.5% higher than that with P.O 52.5 cement.

(2) The compressive strength of C50 concrete with mineral powder as single admixture is 2.5% lower than that without admixture. Mineral powder is unfavorable to the mixing of C50 concrete.

(3) The compressive strength of fly ash single admixture concrete is 11.3% and 8.5% higher than that of mineral powder single admixture and non admixture concrete respectively. The best concrete admixture is fly ash.

(4) The compressive strength of concrete with fly ash and mineral powder as mixed admixture is the lowest, which is 6.7%, 4.3% and 14.0% lower than that without admixture, single mineral powder and single fly ash respectively. Therefore, fly ash and mineral powder as C50 high-strength concrete admixture are the most unfavorable.

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