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Influence of Mixing Process of High Performance Concrete

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Abstract. In this paper, three kinds of concrete mixing processes are studied, which are cement coating method, cement mortar method and cement paste method. Three mixing processes were compared with conventional method to explore the effect of the mixing process under vibration stirring on the working performance and mechanical properties of fresh concrete. Concrete slump, expansion, inverted slump cylinder emptying time, gas content and compressive strength were tested on a twin-shaft vibrating mixer to compare the differences in concrete workability and mechanical properties under different mixing processes. The results show that the cement coating method and the cement paste method have obvious effects on the improvement of concrete workability and compressive strength. The cement mortar method is superior to the common process in terms of mechanical properties, and the workability is not much different.

1. Introduction

The concrete concept of cement concrete has a history of 100 years, which is widely used in housing construction, roads, bridges and so on. With the acceleration of urbanization and the increasing demand for cement concrete, how to efficiently produce concrete and how to improve the performance of concrete is particularly important. The energy conservation and environmental protection are the themes of today's era. According to the existing literature[1], the influence of mixing process of high performance concrete has not been mentioned. Vibration mixing technology[2-3] can better disperse cement particles, reduce cement consumption, and reduce water consumption. At the same time, it will shorten mixing time, increase production efficiency and reduce total energy consumption.

Single feed method does not fully take into account the situation of the cement slurry coated with sand and gravel. The cement easily forms agglomerates when it meets the water, which affects the concrete mixing effect. It is necessary to prolong the mixing time for mixing the concrete well. In view of this, the effects of four stirring processes[4-5] on workability and mechanical properties were studied. In addition, it will explore which mixing process can better improve the workability, mechanical properties of concrete, and meet the pumping requirements[6]. It provides direction for future research on concrete performance and brings greater benefits for concrete production and the engineering application[1].

2. Experiment

2.1 Experimental material

The mixtures investigated in this study were prepared with ordinary Portland cement, which the main properties as shown in table 1. The mixing water used in the experiment was tap water. The water reducer used in the test is polycarboxylate superplasticizer, with a content of 1%, liquid content of 20% solid, and a density of 1100 kg/m^3. The coal ash used in the experiment is from the western suburb power plant. River sand, having maximum size 4.8 mm and a fineness modulus 2.7, was employed as the fine aggregate. Continuous graded limestone crushed stone used as coarse aggregate with a particle size of 5-31.5 mm.

Table 1. Principal physical performance of cement

specific surface area / ($m^2 \cdot kg^{-1}$)	stability	initial setting time / min	final setting time / min	requirement of normal consistency / %	Density / （kg/m^3）	residue on sieve （80μm） / %
382	qualified	156	271	28.25	3070	7.1

2.2 *Test block production and maintenance*

The mix proportion[8] of high performance concrete in the experiment is shown in table 2. When the mixing proportion is constant, a comparative test is carried out to prepare concrete in accordance with four different mixing processes. The test block was formed according to *the Standard Test Method for Performance of Common Concrete Mixtures* (GB/T 50080-2016). We maintain an ambient temperature of 20 ℃ ± 3 ℃, and relative humidity of about 65%. After a day, we try to demolish test blocks from the mould. Covering the surface of the test block with a geotextile and sprinkle it for maintenance. At 3d, 7d, and 28d, the test blocks were taken out and tested for compressive strength.

Table 2. The mix proportion of high performance concrete

Total amount of binding material / kg	Cement / kg	Coal ash / kg	Water / kg	Sand / kg	Gravel / kg	Sp (%)	Water reducer / kg	W / B
515	425	90	175	670	1113	39	5.15	0.34

2.3 *Experimental method*

- The slump, expansion, and gas content[9] tests are carried out in accordance with *the Standards for Testing Performance of Common Concrete Mixtures* (GB/T 50080-2016)[10].
- The mechanical properties are tested for compressive strength of 100 × 100 × 100 mm concrete test blocks in accordance with *the Standard Test Method for Mechanical Properties of Ordinary Concrete* (GB/T 50081-2002)[11]. Testing ages of concrete are 3d, 7d, and 28d. Three test blocks are taken from each group, and the test results are averaged.

2.4 *Mixing process*

Concrete is prepared by conventional methods, cement coating methods, cement mortar methods and cement paste methods. The specific process is shown in Figure 1. In the figure, t is used to indicate the total mixing time. In addition to this, t_1, t_2, and t_3 indicate the mixing time of the first time, the second time, and the third time, respectively.

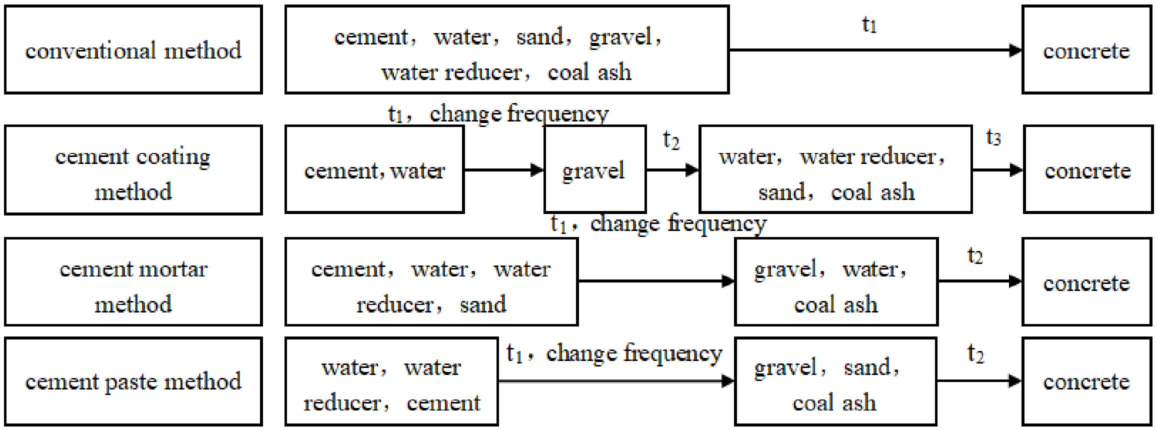

Figure 1. Processing sequence of mixing of concrete

3. Results and discussion

3.1 Effect of mixing process on concrete workability

The workability of high performance concrete is shown in table 3.

Table 3. Test results of high performance concrete workability

Mixing process	Slump / mm	Divergence / mm	Emptying time of inverted slump cylinder /s	Air content / %	Water retaining property	Cohesive-ness	Workability
convention-al method	234	470～541	8	1.71	bad	bad	bad
cement coating method	225	482～498	12	1.76	excellent	excellent	excellent
cement mortar method	224	474～498	10	1.73	excellent	excellent	excellent
cement paste method	227	491～589	7	1.75	good	bad	bad

The slump test is one of the classical methods for evaluating concrete workability[12]. The diagram of coarse and fine aggregate distribution under vibration mixing is shown in Figure 2. Under vibration mixing, the phenomenon of cement agglomeration is reduced and the aggregate distribution is more uniform. At the same time, the mixing time is shortened, and high performance concrete can easily meet the pumping requirements. However, different mixing processes have a big difference in the impact of concrete performance.

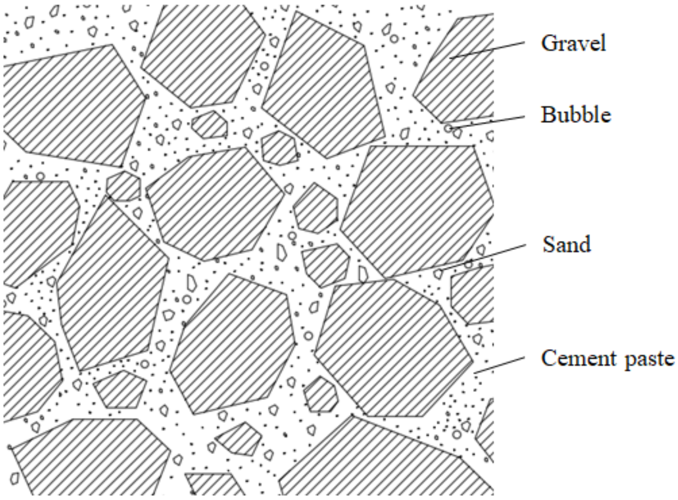

Figure 2. Diagram of coarse and fine aggregate distribution under vibration mixing

For conventional methods, fresh concrete has good fluidity. However, it is often accompanied by segregation. Water retention and cohesiveness are poor. The overall performance of concrete is poor. The reason is that the binding material is not fully combined with water. The cement agglomerates were scattered everywhere, which caused excess water to overflow, the concrete was bleeding, the aggregates were separated, and the workability of the concrete was deteriorated.

The cement paste method and the cement coating method improve the workability of the concrete. It not only maintains good fluidity of concrete, but also has good water retention and cohesiveness. Among them, the cement paste method is superior to the cement coating method. This is because the cement is mixed first and the water is fully combined with the cement particles. The agglomeration phenomenon can be effectively reduced, so that the cement slurry can be fully attached to the surface of sand and stone, and the adhesion can be improved.

The concrete prepared by the cement mortar method has maximum expansion and the best fluidity. However, there will still be bleeding and segregation, resulting in poor workability of concrete. It is the combination of water, cement and sand that results in poor particle size distribution when bound with gravel. The void ratio is large and the adhesion between the aggregates is lowered. It can be seen that the aggregate level and the degree of connection between the particles can reflect the performance of the concrete.

3.2 Effect of stirring process on mechanical properties of concrete

The compressive strength of concrete prepared under different ages and different mixing processes is shown in Figure 3. The concrete prepared by the conventional method has a low early compressive strength and a relatively fast compressive strength in the middle and late stages. The effect of cement coating method and cement paste method on the early compressive strength of concrete is obvious. The compressive strength of concrete prepared by these two processes is higher than the other two processes. The 28 d compressive strength of concrete prepared by cement paste method is the highest. The compressive strength of cement mortar method is lower for 7 d and 28 d.

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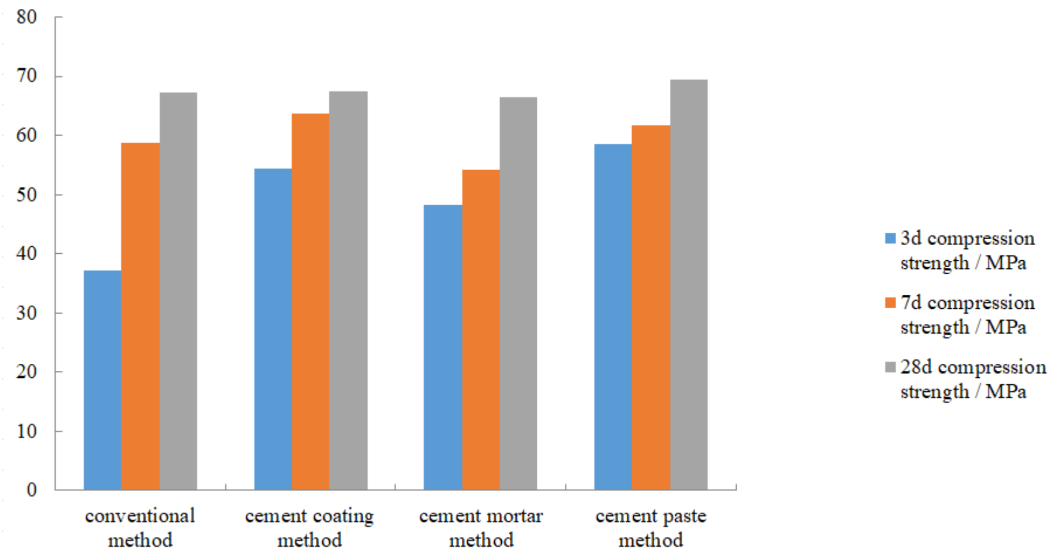

Figure 3. Compressive strength of concrete at different ages and different mixing processes

The macro section of the concrete test block is shown in Figure 4. The Interfacial Transition Zone (ITZ) is the weakest link inside the concrete. ITZ is the interface between concrete aggregate and cement slurry. In the figure, (a), (b), (c), and (d) respectively show concrete test blocks prepared by the conventional method, the cement coating method, the cement mortar method, and the cement paste method. It is apparent that the coarse and fine aggregates of concrete under the conventional method are distributed. Cracks are mainly produced at the interface between the binding material and the coarse aggregate. The gravel is hardly sheared, resulting in a low compressive strength at the early stage of the test block. The concrete prepared by the cement mortar method has a lower compressive strength than the other two secondary agitation processes due to the poor effect of the fine aggregates on the coarse aggregates. The concrete prepared by the cement coating method and the cement paste method have little difference in compressive strength.

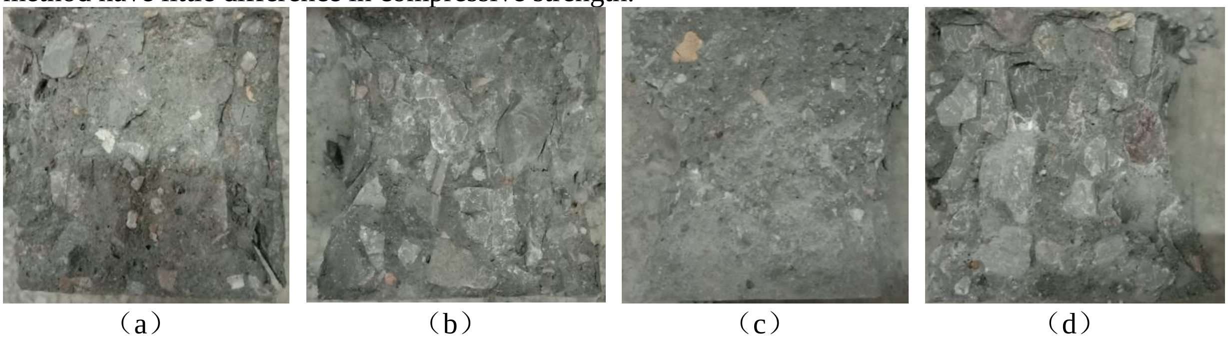

Figure 4. Macro section of concrete test block

4. Conclusion

- The cement paste method and the cement coating method greatly improve the water retention and cohesiveness of the concrete compared to the conventional method and the cement mortar method. At the same time, the overall workability of the concrete is improved. Not new mixing processes have a positive impact on concrete workability.
- In comparison, the concrete prepared by the cement paste method and the cement coating method have better mechanical properties. They are superior to other mixing processes in both the early and middle stages.

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