Experimental Study on the Mechanical Properties of C40 Self-Compacting Solid Ferrous Tailings Concrete

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Abstract. Through the experiments on the mechanical properties of the self-compacting solid ferrous tailings concrete, it studied the effect of tailings powders under various substitution rates upon the mechanical properties of C40 self-compacting solid ferrous tailings concrete. By experiments on the slump expansibility and expansion time T500 of the self-compacting solid tailings concrete, it also studied the effect on the workability of the ferrous tailings powder under various substitution rates. In the light of the experimental results, it provided that, the slump expansibility of the self-compacting solid ferrous tailings concrete enlarged by degrees with the increase of substitution rate of the ferrous tailings powder; the expansion time T500 shortened as the substitution rate of the ferrous tailings powder increased. The cubic compressive strength, the axis compressive strength, the splitting tensile strength as well as the plastic modulus of the self-compacting solid ferrous tailings concrete all inclined to decrease with the swell of substitution rate of the ferrous tailings powder.

1. Introduction

The ferrous tailings powder with certain fineness can be used as a kind of mineral admixture. By blending it into the concrete, it can give full play to the “micro-aggregate” and “morphological” effects and thus relieving the concrete mineral admixture short supply situations in most regions of China. More than that, the admixture endows the concrete with favorable workability and durability [1]. Through using the ferrous tailings as aggregates in concrete production, it can provide effective solution to the issue of sandstone resource shortage as well as to the issue of ferrous tailings resource waste in China [2]. At present, most researches by scholars from home and abroad are about blending the sandstone and ferrous tailings powder into the ordinary concrete. Among them, Mohan Yellishetty [3], Kiran K. Shetty [4], Sahil Goyal [5] and Shettima [6] all achieved encouraging research findings. However, limited researches are developed in the direction of mixing the ferrous tailings as raw materials into the self-compacting solid ferrous tailings concrete. On basis of fixed fly ash contents, this thesis explored that, the ferrous tailings were admixed as per certain proportion to obtain the coarse aggregate with various particle sizes. Then, by mixing a certain amount of fly ash, ferrous tailings powder and else admixtures, it prepared to obtain the self-compacting solid tailings concrete. Regarding the substitution rate of the ferrous tailings powder versus the fly ash as a variable, it carried out the self-compacting solid ferrous tailings concrete experiments.
2. General Descriptions of Experiment

2.1. Characteristics of Ferrous Tailings
The ferrous tailings possess uniform and compact specialties. As of now, they have been compiled as rubbles in the category of GB/T 14685-2011 “pebbles and rubbles for construction purpose”. The key factor of eligible self-compacting solid ferrous tailings concrete depends on the quality of ferrous tailings. Therefore, in accordance with the standard specifications, the particle grading and crushing value along with the apparent density and the stacking density were determined and then the experimental results were analyzed accordingly. The specific values were shown in Table 1 and Table 2.

| Square hole size/mm | 2.36 | 4.75 | 9.5 | 16 | 19 |
|---------------------|------|------|------|----|----|
| Cumulative sieve residue percentage | Iron tailed ore | 100 | 100 | 60 | 10 | 0 |
| Specification requirements | 95-100 | 90-100 | 40-80 | - | 0-10 |

| category | Apparent density/kg/m³ | Bulk density/kg/m³ | Crushing index/% | Calculate voidage/% |
|----------|------------------------|--------------------|------------------|--------------------|
| Iron tailed ore | 2700 | 1600 | 7 | 43.1 |
| Specification requirements | ≥2600 | ≥1350 | ≤20 | ≤47 |

2.2. Proportional Design of the Self-Compacting Solid Ferrous Tailings Concrete
After comprehensive consideration on both the compressive strength of the self-compacting solid concrete and the workability of admixtures, the fly ash which accounted for 30% amount of the cementing material was selected as the appropriate admixture. Thereupon this thesis finally acquired an optimized proportional ratio that met the performance requirements of the self-compacting solid concrete on basis of the fixed 30% content of fly ash. The actual proportional ratio of C40 self-compacting solid ferrous tailings concrete was shown in Table 3.

| Substitution rate/% | Iron tailed ore | cement | water | sand | Water cement ratio | Fly ash | Iron tailing powder | Water reducing agent |
|---------------------|----------------|--------|-------|------|-------------------|--------|---------------------|---------------------|
| 0                   | 888            | 328    | 199   | 758  | 0.40              | 142    | 0                   | 2.579               |
| 50                  | 888            | 328    | 199   | 758  | 0.40              | 71     | 71                  | 2.579               |
| 100                 | 888            | 328    | 199   | 758  | 0.40              | 0      | 142                 | 2.579               |

3. Analysis on the Experimental Results

3.1 Analysis on the Operational Properties
In the midst of T500 experiments on the slump expansibility and the expansion time, it evaluated the operational properties of the self-compacting solid ferrous tailings concrete. The experimental details were shown in Figure 1.
Fig1 Fall scale test

The experimental results of the slump expansibility and the expansion time T500 for the self-compacting solid ferrous tailings concrete were shown in Table 4. In accordance with the results, the slump expansibility level of three various proportional self-compacting solid ferrous tailings concrete all reached SF2; and their expansion time T500 levels all achieved VS1. Therefore, all three experimental objectives had met the design requirements.

| Number | Expansibility/mm | T500/s |
|--------|------------------|--------|
| R1     | 650              | 5.0    |
| R2     | 690              | 4.5    |
| R3     | 700              | 4.1    |

Shown in Table 4, with the increase of substitution rate on ferrous tailings powder, the slump expansibility of the self-compacting solid ferrous tailings concrete tended to increase as well. To be specific, as the substitution rate of ferrous tailings powder increased from 0% to 100%, the slump expansibility of self-compacting solid ferrous tailings concrete rose up to 6.1%~7.8%. Simultaneously, the growth on the substitution rate of ferrous tailings powder caused a decreasing tendency on the expansion time of the self-compacting solid ferrous tailings concrete. In the experiment, when the substitution rate rose up from 0% to 100%, the expansion time T500 of the self-compacting ferrous tailings concrete went through a decrease of 10%~18%. In that the ferrous tailings powder is a kind of inert material, throughout the hydration reaction of the self-compacting solid ferrous tailings concrete, the water consumption decreased and thus the slump expansibility enlarged. Compared with the ferrous tailings powder which contained mostly irregular articles, the fly ash possessed more favorable spherical degree; consequently, the fly ash worked well as the lubricant in the self-compacting ferrous tailings concrete; and thus, improving its viscosity and shortened the expansion time T500.

3.2 Analysis on the Mechanical Properties

The trial blocks of the self-compacting solid ferrous tailings concrete were used to test the cubic compressive strength, the axial compressive strength the splitting tensile strength and the plastic modulus. Shown from the experiment, the substitution rate of the ferrous tailings powder possesses certain effect on the mechanical properties of the self-compacting solid ferrous tailings concrete. The detailed data was shown in Table 5.

| Number | Cube compression (MPA) | Modulus of elasticity (MPA) | Splitting tension (MPA) | Axial compression (MPA) |
|--------|------------------------|-----------------------------|------------------------|------------------------|
| R1     | 54.8                   | 36374                       | 5.16                   | 44.7                   |
| R2     | 51.3                   | 34327                       | 4.83                   | 42.9                   |
| R3     | 46.9                   | 32118                       | 4.59                   | 41.4                   |

From the Table 5, it can be seen that, the mechanical properties of the self-compacting solid ferrous tailings concrete decreased with the growth of the ferrous tailings substitution rate. Specifically, when
the substitution rate increased by 50% and 100% from 0%, the compressive strength of the self-compacting solid ferrous tailings concrete decreased by 6.39% and 14.42% respectively. As a kind of inert material in the mineral admixture, the ferrous tailings powder possesses less activity than that of the fly ash. Therefore, by adding ferrous tailings powder, the cubic compressive strength of the self-compacting solid ferrous tailings concrete inclined to decrease. In the experiment, when the substitution rate of ferrous tailings powder increased by 50% and 100% from 0%, the axis compressive strength of the self-compacting solid ferrous tailings concrete occurred a decrease of 4.03% and 7.387% respectively. Once the substitution rate of the ferrous tailings powder increased by 50% and 100% respectively, the splitting tensile strength of the self-compacting solid ferrous tailings concrete decreased by 6.4% and 11% accordingly. Despite that the ferrous tailings powder with certain fineness possessed some reactivity and occurred secondary hydration, its complete activity is relatively lower. The influence of the mineral admixture acted on the tensile strength of the concrete was mainly decided by its activity. Because the fly ash possesses relatively higher activity, it improved the structural density and the tensile strength of the concrete. In this experiment, when the substitution rate of the ferrous tailings powder rose by 50% and 100% from 0%, the splitting tensile strength of the self-compacting solid ferrous tailings undertook a decrease of 5.63% and 11.7% respectively. The filling properties of the fly ash articles are more favorable than that of the ferrous tailings power; as a result, the fly ash plays a more significant role in affecting the plastic modulus of the self-compacting solid ferrous tailings concrete.

4. Conclusions

(1). The slump expansibility of the self-compacting solid ferrous tailings concrete grew step by step with the increase of the substitution rate of the ferrous tailings powder. When the substitution rate reached 100%, a maximum growth of 7.8% was found in the experiment; on the other hand, the expansion time T500 shortened accordingly. When the substitution rate achieved 100%, a maximum decrease of 18% in expansion time was identified. Moreover, its cohesiveness reduced as the substitution rate of ferrous tailings powder rose.

(2). As the substitution rate of the ferrous tailings powder increased, the cubic compressive strength, the axis compressive strength, the splitting tensile strength and the plastic modulus of the concrete which contained self-compacting solid ferrous tailings powder all inclined to decrease. When the substitution rate of the ferrous tailings powder became 100%, a maximum decrease of 14.42%, 7.38%, 11% and 11.7% for the four above parameters was found respectively. It indicated that the activity of the mineral admixtures played an essential role in the mechanical properties of concrete which was mixed by self-compacting solid ferrous tailings powder.

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