

Effects of Construction Waste Composite Powder Materials on the Strength and Shrinkage Performance of C20 Concrete

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Abstract. To explore the feasibility of using construction waste composite powder materials in the small concrete member, this paper studied the strength and shrinkage performance of C20 concrete under different construction waste composite powder materials dosages. The results show: C20 concrete had the highest strength and the best shrinkage performance when the dosage of construction waste composite powder material was 30%; the construction waste composite powder materials improved the strength and shrinkage performance of the C20 concrete for the reason that it has good morpha effect, microscopic aggregate effect and volcanic ash effect. Therefore, rational selection of construction waste composite powder dosage can ensure both high strength and good shrinkage performance of C20 concrete.

1 Introduction

According to industry statistics, the annual output of construction wastes were more than 15 tons in 2014, accounting for 30%~40% of total urban wastes. The construction wastes have become another major problem in cities after industrial and household wastes [1]. A large amount of construction wastes are transported to the suburbs, air storage or deposited in the landfill, which not only occupies a lot of lands, polluting the environment, but also wastes a great amount of resources.

The construction waste brick accounts for about 40% of the total construction wastes, therefore, finding an effective way to reuse the construction waste brick has become a major research topic in recent years. Recycling of the construction waste brick is also a direction for development of low-carbon economy era [2~4]. However, construction waste brick has low activity which limits its utilization. In order to improve the activity of construction waste brick, our research group developed a new technical approach which composited fly ash, slag, mineral powder and alkali-activator with construction waste brick powder, which called construction waste composite powder materials. This paper studied the influences of the composite powder materials on strength and shrinkage performance of small concrete member (i.e. C20) used in transportation engineering.

2 Raw materials

Cement: 42.5 ordinary Portland cement with apparent density 3.112g/cm³; coarse aggregate: Xingping stone factory crushed stone; fine aggregate: river sand with fineness modulus 2.48; water: ordinary drinking water. Construction waste composite powder materials consist of 25% brick powder, 50% slag, 25% fly ash and alkali-activator. The chemical compositions of the brick powder are shown in Table 1, and the required properties of the brick powder are: the specific surface area should be greater than 300m²/kg, the density should be in the range of 2~3g/cm³, the ignition loss should be less than 5%, the grain size should be in the range of 5~16μm, the activity index should be greater than 60% and the water content

should be less than 1.0%. The specific surface area of the brick powder used in this paper was 450m²/kg.

Tables 2 and 3 show the physical properties and chemical compositions of the construction waste composite powder materials, and the SEM images of the brick powder and the construction waste composite powder materials are showed in Figures 1 and 2 respectively. Figure 3 shows the XRD map of the brick powder.

Table 1. Physical properties of brick powder

Major components	Content/%
CaO	1.13
SiO ₂	49.3
Al ₂ O ₃	17.9
Fe ₂ O ₃	2.92
MgO	1.66
K ₂ O	2.09

Table 2. Physical properties of construction waste composite powder materials

Physical indicators	Index
Standard consistency water (%)	0.285
Loss on Ignition (%)	4.22
Density (kg/m ³)	2.82
Specific surface area (m ² /kg)	415
Particle size (μm)	8~16

Table 3. Chemical compositions of construction waste composite powder materials

Major components	Content/%
CaO	21.7~25.5
Al ₂ O ₃	15.8~18.5
Fe ₂ O ₃	2.6~4
SiO ₂	42.5~37.5

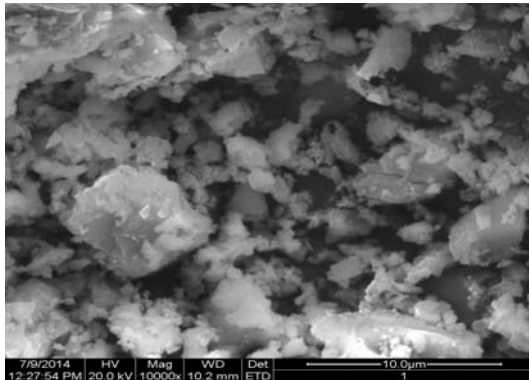


Figure 1. SEM image of brick powder

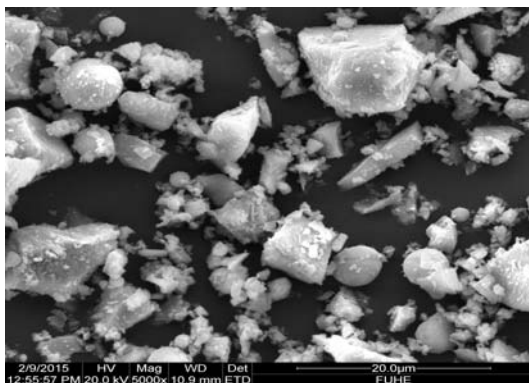


Figure 2. SEM image of construction waste composite powder materials

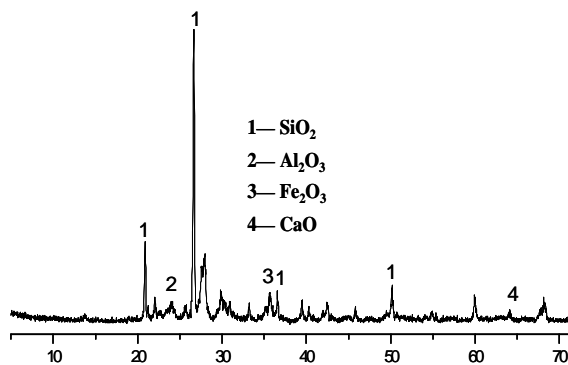


Figure 3. The XRD map of brick powder

Tables 2 and 3 show that the construction waste composite powder materials have larger specific surface area than cement (360m²/kg), indicating that the construction waste composite powder materials have more small size particles, these small size particles can fill the voids between cement particles, therefore, resulting in good morpha effect and microscopic

aggregate effect. The CaO content of construction waste composite powder materials is 21.7% ~ 25.5%, much higher than that of brick powder (1.13%), which may be one of the reasons that the activity of construction waste composite powder materials is higher than that of brick powder. From Figures 1 and 2, it can be seen that construction waste composite powder materials have appropriate grain size distribution which may also contribute to its high activity.

3 The mechanical properties of C20 concrete with construction waste composite powder materials

Low strength concrete is generally used as small precast concrete in transportation engineering. The C20 concrete was selected in this paper to study the influence of construction waste composite powder materials on concrete strength. The mix ratio of the C20 concrete is shown in Table 4, which was obtained through orthogonal test by previous research.

Table 4. Mix ratio of C20 concrete

C20 concrete		
Water-cement ratio		0.52
Dosage/%		30
Sand ratio/%		34
Materials consumption of unit voulme concrete (kg/m ³)	Cement	228
	Construction waste composite powder materials	98
	Aggregate	1256
	Sand	647
	Water	170

Four different construction waste composite powder materials dosages, i.e. 0%, 20%, 30% and 40%, were selected in this paper. The mechanical properties of concrete mixed with construction waste composite powder materials are shown in Figures 4 and 5.

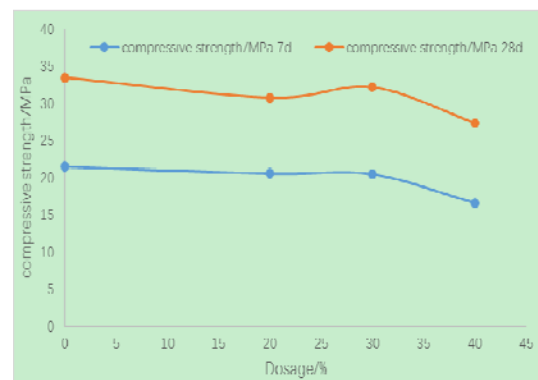


Figure 4. The results of compressive strength (Curing age: 7d and 28d)

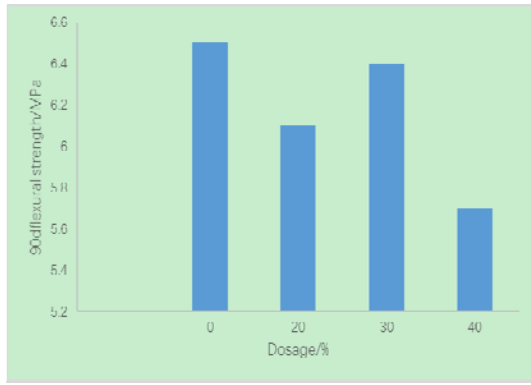


Figure 5. The results of flexural strength (Curing age: 90d)

Figures 4 and 5 show that the construction waste composite powder materials reduced 7d and 28d compressive strengths, and 90d flexural strength of the C20 concrete. The 7d compressive strength decreased with the increase of construction waste composite powder materials dosage, but the 28d compressive strength and the 90d flexural tensile strength increased initially and then decreased. The results illustrate that construction waste composite powder materials replacing some portion of cement decreased the mechanical properties of C20 concrete, the reason is that hydration products were reduced when cement was replaced by construction waste composite powder materials, therefore, the concrete structure became relatively loose, resulting in lower mechanical performance.

When the dosage was 40%, the 7d, 28d compressive strengths and the 90d flexural strength of the C20 concrete were decreased by 22.8%, 18.2% and 12.3%, respectively, which showed that the decreasing degree of mechanical properties decreased with the increase of hydration age. The reason is that construction waste composite powder materials had volcanic ash effect in alkaline environment, which can reduce the content of $\text{Ca}(\text{OH})_2$ that has poor performance, and generate low alkalinity C-S-H gel with high strength, therefore, the strength was improved with the growth of curing age.

4 The shrinkage performance of C20 concrete with construction waste composite powder materials

4.1 Dry shrinkage performance

The shrinkage performance of C20 concrete with 0%, 20%, 30% and 40% construction waste composite powder materials were studied. The specimens were prism with dimensions of 10cm*10cm*40cm. The testing procedures were: logged the initial lengths of the specimens (curing age: 3d, from the date when mixing the water into concrete) and then moved the specimens into dry shrinkage chamber (temperature: $20 \pm 2^\circ\text{C}$; relative humidity: $60 \pm 5\%$); logged the 1d, 3d, 7d, 14d, 28d and 60d lengths of the specimens from the date when moving into the dry shrinkage chamber. The shrinkage rate of the concrete was calculated as:

$$\varepsilon_{st} = (L_0 - L_t) / L_0 \quad (1)$$

where ε_{st} is the shrinkage rate of the concrete at curing age t days, which starts from the day for logging initial length; L_0 is the measurement range of the specimen, which equals to the length of specimen minus two times of gauging head burial depth (mm); L_t is the specimen length at curing age t days (mm).

The results of the shrinkage performance are presented in Figure 6.

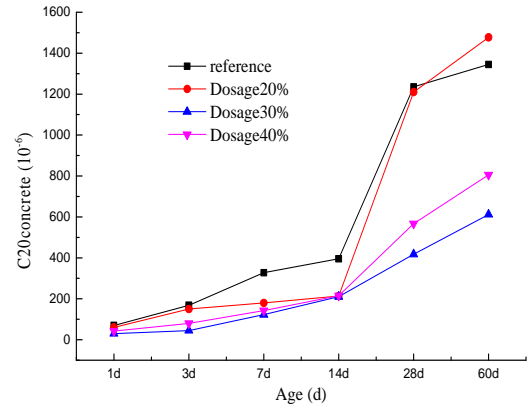


Figure 6. Dry shrinkage test results of C20 concrete

It can be seen from Figure 6 that the dry shrinkage ratio reduced initially and then decreased with the increase of construction waste composite powder materials dosage, the C20 concrete obtained the best dry shrinking property at dosage 30%. The dry shrinkage ratios of concrete with construction waste composite powder materials were all lower than that of the reference concrete before curing age of 28d. At the curing age of 60d, the dry shrinkage ratio of C20 concrete with 20% construction waste composite powder materials was higher, whereas that of concrete with the other two dosages were lower than that of the reference concrete, which meant that appropriate construction waste composite powder materials dosage can improve the shrinkage performance of concrete [5]. The construction waste composite powder materials reduced the early age dry shrinkage ratio for the reason that the effective cement ratio was improved by replacing some portion of cement with construction waste composite powder materials, thus accelerated the hydration of the cement and, improved the ability to resist shrinkage deformation. In addition, the construction waste composite powder materials could absorb water and reduce the content of free water, therefore decreasing the shrinkage stress inside the concrete [6].

4.2 Temperature shrinkage performance

This paper tested the temperature shrinkage performance of the C20 concrete and the results are shown in Figure 7.

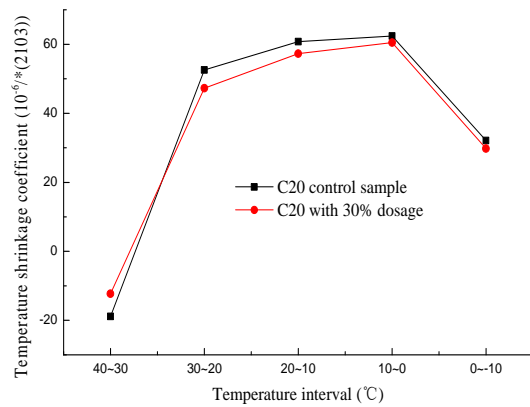


Figure 7. Temperature shrinkage test results of C20 concrete

The results show that the construction waste composite powder materials reduced the temperature shrinkage rate of C20 concrete. From the test results above, it can be concluded that the construction waste composite powder materials have positive effects on the shrinkage performance of the C20 concrete.

5 Conclusions

- (1) The construction waste composite powder materials have higher activity than that of the brick powder;
- (2) The construction waste composite powder materials reduced the mechanical strength of C20 concrete, and the reduction increased with the increase of its dosage;
- (3) The construction waste composite powder materials improved the shrinkage performance of C20 concrete;
- (4) The construction waste composite powder materials are economic, environmentally-friendly and technically feasible.

References

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