Study on Activation of Waste Clay Brick Powder

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Abstract. Recycling and recycling of construction waste is a hot research topic nowadays. In this paper, clay bricks in building waste are activated by physical method (grinding) and chemical method (alkali activation). The effects of fineness after grinding time, types and dosage of activator on the activity of waste brick powder are studied. The results show that with the increase of grinding time, the specific surface area of waste brick powder increases, and the activity coefficient of waste brick powder increases. When grinding time is 90 minutes, the activity index reaches 67%. When the specific surface area of waste brick powder is 467 m2/kg, the activity index of waste brick powder increases first and then decreases with the increase of calcium hydroxide content. When calcium sulfate dihydrate is added alone, the activity index of waste brick powder increases first and then decreases with the increase of calcium sulfate dihydrate content. When calcium hydroxide and calcium sulfate dihydrate are mixed together, the increase of activity index is better than that of calcium hydroxide and calcium sulfate dihydrate alone. The 4% calcium hydroxide + 3% calcium sulfate dihydrate composite system has the best activation effect on brick powder.

1. Introduction
Abandoned clay brick produces a huge amount, accounting for more than 50% of the total construction waste, but it has been in a low utilization rate situation [1-2]. The main components of waste clay brick are SiO2 and Al2O3, which have potential activity. In this paper, the possibility of using waste clay brick as admixture after grinding into fine powder is discussed. The waste clay brick is recycled [3-4]. After crushing, grinding for a certain time, grinding into powder. By means of physical grinding and chemical activation, the waste brick powder can be activated. By compounding with ordinary Portland cement with different dosage, the influence of dosage on the properties of composite cementitious materials is studied, and the optimum fineness and dosage of waste brick powder are finally determined. It has an important guiding effect for the application of waste brick powder as admixture in concrete, mortar and
other aspects.

2. Experimental scheme

2.1 Raw materials
Cement: in this experiment, 42.5 common portland cement was produced in the east of Hebei Province. Its chemical composition is shown in Table 1, and its physical properties are shown in Table 2.[5-6]

| Component         | SiO₂ | Al₂O₃ | Fe₂O₃ | CaO  | MgO  | SO₃ | R₂O | Loss |
|-------------------|------|-------|-------|------|------|-----|-----|------|
| Content           | 21.72| 5.81  | 4.33  | 62.41| 1.73 | 2.56| 0.54| 1.47 |

Table 2 Physical properties of cement

| Strength grade | Fineness / (m²/kg) | Stability | Setting time | Compressive strength / MPa | Flexural strength / MPa |
|----------------|--------------------|-----------|--------------|----------------------------|------------------------|
| 42.5           | 300                | Qualified | Initial      | Final                      | 3d  | 28d  | 3d  | 28d  |
|                |                    |           | 45min        | 600min                     | 17.0 | 42.5 | 3.6 | 6.5  |

Waste clay brick and brick powder: the abandoned sintered bricks used in experiments were taken from Wang Jia Tun, Shenyang. The buildings being demolished were served for 50 years, and the intensity was 5.05MPa. The waste clay brick is crushed and ground for a certain time to obtain brick powder. The specific surface area of waste clay brick powder was determined by nitrogen adsorption analyzer. The chemical composition of waste clay brick powder is shown in Table 3.

| Component         | SiO₂ | Al₂O₃ | Fe₂O₃ | K₂O  | MgO  | Na₂O | CaO  | TiO₂ | Other |
|-------------------|------|-------|-------|------|------|------|------|------|-------|
| Content           | 62.01| 21.11 | 7.00  | 3.37 | 2.00 | 1.60 | 1.45 | 0.99 | 0.43  |

Activator: in this experiment, calcium hydroxide and calcium sulfate two hydrate were used as activators in the production of industrial grade calcium hydroxide and Chemical Reagent Co., Ltd. produced by Liaoning Yi Dan calcium Co., Ltd.
Water reducing agent: Polycarboxylic acid superplasticizer, solid content (>20%), water reducing rate (>30%).
Water: tap water

2.2 Design of Experimental Scheme
In order to obtain better properties of composite cementitious materials, physical grinding, chemical activation were used and we ran a comparison with different amounts of waste clay brick powder [7], among these three kinds of waste clay brick powder with grinding time of 70 min, 80 min and 90 min,
brick powder with large specific surface area and high activity index after grinding is selected as cementitious material; calcium hydroxide stimulation, calcium sulfate dihydrate reagent stimulation and their combination are used. Alkali excitation, select the two groups with the highest activity index; in the composite cementitious materials with different brick powder content, choose the one with the highest strength; synthesize above three conditions, configure the samples to verify whether the performance indicators meet the national standards of cement.

3. Activation of waste clay brick powder

3.1 Activation of Physical Grinding Activity

After crushing the waste clay brick, the same size of the debris is used for ball milling. During the grinding process, the debris of the waste clay brick gradually decreases until it becomes powder, the specific surface area increases, the surface energy increases, and the active points on the surface of the waste clay brick powder increase \(^{[8-9]}\), so that the activity of the waste clay brick powder increases. The specific surface area and activity index of brick powder change with the increase of grinding time during physical grinding as shown in Table 4.

| Specific surface area / m\(^2\)/kg | Compressive strength /MPa | Activity coefficient /% |
|-----------------------------------|---------------------------|-------------------------|
|                                   | 3d | 28d | 3d | 28d |
| Cement                           | 352 | 18.9 | 40.8 | 100 | 100 |
| 70min                             | 408 | 6.9 | 23.4 | 36.5 | 57.4 |
| 80min                             | 432 | 7.2 | 25.3 | 38.1 | 62.0 |
| 90min                             | 467 | 7.7 | 27.4 | 40.7 | 67.2 |

![Fig. 1 Effect of grinding time on activity of brick powder](image-url)
As it can be seen from Fig. 1, the activation coefficient of brick powder increases with the increase of grinding time. Because the grinding time is prolonged, the fineness and specific surface area of waste clay brick powder increases gradually, which improves the activity of waste clay brick powder\cite{10}. However, with the prolongation of grinding time, the increasing rate of activity coefficient decreases gradually. Considering the economic cost and other aspects, 90 minutes of grinding brick powder is selected for the test.

3.2 Activation of Brick Powder by Calcium Hydroxide

Calcium hydroxide was used to stimulate the activity of waste clay brick powder. The activity coefficients of waste clay brick powder were tested with different dosages of calcium hydroxide (0\%, 2.5\%, 3\%, 3.5\%, 4\%). Fig. 2 shows the effect of calcium hydroxide dosage on the activity coefficients.

![Fig. 2 Effect of calcium hydroxide content on activity](image)

As it can be seen from Figure 2, with the increase of calcium hydroxide content, the activity coefficient of alkali-activated waste clay brick powder first increases and then decreases. When the content of calcium hydroxide is 3\%, the activity coefficient is the highest, the activity coefficient is 97.5\%.

3.3 Activation of Brick Powder by Calcium Sulfate Dihydrate

Calcium sulfate dihydrate was used to stimulate the activity of waste clay brick powder. Calcium sulfate dihydrate with different dosages (0\%, 2.5\%, 3\%, 3.5\%, 4\%) were used to stimulate the activity coefficient. The influences of different calcium hydroxide dosages on the activity coefficient were tested. Figure 3 shows the effect of calcium hydroxide dosage on the activity coefficient.
As it can be seen from Fig. 3, with the increase of calcium sulfate dihydrate content, the activity coefficient of alkali-activated waste clay brick powder first increases and then decreases. When the content of calcium sulfate dihydrate is 3.5%, the activity coefficient is the highest, and the activity coefficient is 92.5%.

3.4 Complex Activation of Brick Powder by Calcium Hydroxide-Calcium Sulfate Dihydrate

The mixed system of calcium hydroxide and calcium sulfate dihydrate was used to activate the activity of waste clay brick powder. The activity coefficient was tested. Fig. 4 shows the effect of calcium hydroxide-calcium sulfate dihydrate complex system on the activity coefficient.

Among them, group 1: 3% calcium hydroxide + 3.5% calcium sulfate dihydrate; group 2: 4% calcium hydroxide + 3% calcium sulfate dihydrate; group 3: 2% calcium hydroxide + 4% calcium sulfate dihydrate.

As it can be seen from Fig. 4, the activity index of compound doping 2 is the highest among the three groups. Although the compound group 1 is the best content of single doping, the compound effect is not the best.

3.5 Dosage Test of Waste Clay Brick Powder
In order to determine the maximum proportion of brick powder, the ratio of 0 to 60\% substitution was selected to explore the influence of substitution amount on the strength of mortar. Fig. 5 and 6 respectively show the effect of brick powder substitution on the flexural strength and compressive strength of cement mortar specimens.

![Fig. 5 Effect of brick powder substitution on flexural strength](image1)

![Fig. 6 The influence of brick powder substitution on compressive strength](image2)

From Fig. 5 and Fig. 6, it can be seen that the flexural strength and compressive strength of mortar specimens increase first and then decrease with the increase of the replacement amount of waste clay brick powder. When the replacement amount of brick powder is 20\%, the 3-day flexural strength is 5.9 MPa; the 3-day compressive strength is 23.5 MPa; the 28-day flexural strength is 12.9 MPa; and the 28-day compressive strength is 48.1 MPa. When the replacement amount of brick powder is more than 20\%, the flexural strength and compressive strength of mortar specimens have been declining, and the mechanical properties have declined significantly.

**4 Conclusion**

(1) Activated by physical grinding, the specific surface area and activity coefficient of waste clay brick powder increase with the increase of grinding time. When grinding time is 90 minutes, the activity coefficient reaches 67\%. 
(2) When the waste clay brick powder activated by chemical activation is activated by calcium hydroxide alone, the activity coefficient of the waste clay brick powder first increases and then decreases with the increase of calcium hydroxide content. When the content of calcium hydroxide is 3%, the activity coefficient is the largest, and the activity coefficient is 97.5%. When calcium sulfate dihydrate is taken as the only activator, the activity coefficient increases with the increase of calcium sulfate dihydrate content. The activity coefficient of waste clay brick powder increases first and then decreases. When the dosage of calcium hydroxide is 3.5%, the activity coefficient is the highest, 92.5%. When the dosage of calcium hydroxide-calcium sulfate dihydrate is 4% calcium hydroxide + 3% calcium sulfate dihydrate, the activity coefficient is the highest, and the activity coefficient is 102%.

(3) In the experiment of brick powder content, the flexural strength and compressive strength of mortar specimens increased first and then decreased with the increase of replacement amount of waste clay brick powder. When the replacement amount of brick powder is 20%, the flexural strength and compressive strength are the highest, the 28-day flexural strength is 12.9 MPa, and the 28-day compressive strength is 48.1MPa.

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