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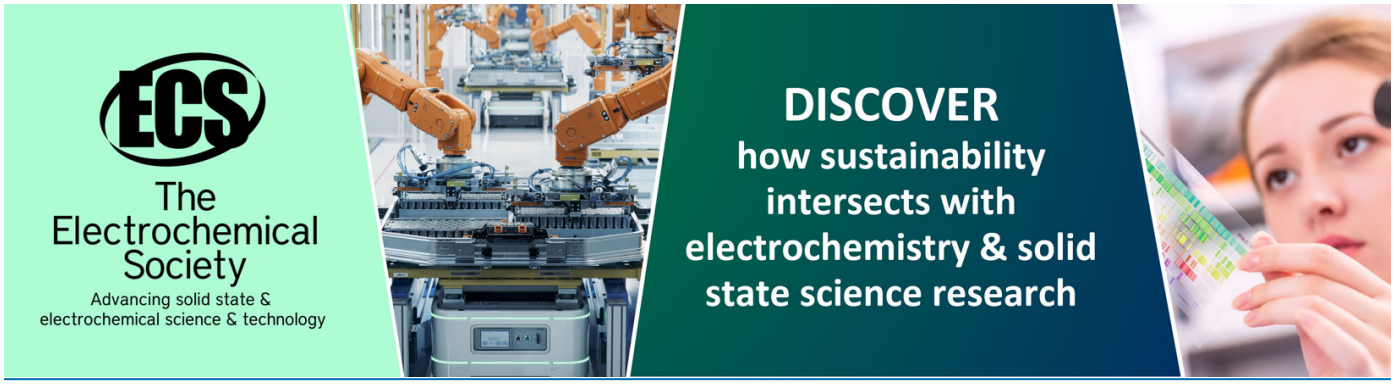

Research on influence of water-cement ratio on workability and mechanical properties of geopolymer grouting material

X Q Wang[1], P H Wen[2], Z W Gao[2, 3] and C H Wang[2, 4]

[1] Tianjin Municipal Engineering Design & Research Institute, Tianjin 300392, China
[2] School of Highway, Chang'an University, Xi'an 710064, Shaanxi Province, China
[3] Xizang Minzu University, Xianyang 712082, Shaanxi Province, China

[4] E-mail: 2539526581@qq.com

Abstract. To investigate the influence of water-cement ratio on the fluidity and mechanical strength of geopolymer grouting materials, the change of fluidity, compressive strength and flexural strength of road geopolymer grouting material with different water-cement ratio were tested. The results showed that the fluidity of geopolymer grouting material was enhanced while the compressive and flexural strength decreased with the increase of water - cement ratio. The optimum value of water-cement ratio was in range (0.39-0.42). The road geopolymer grouting material had the better fluidity and the strength requirement of reinforcement if the main constituent materials was not changed.

1. Introduction

As a kind of alkaline activated cementitious material, geopolymer grouting material is an inorganic polymer with amorphous three-dimensional network and mainly composed of ionic bond and covalent bond [1]. It has good corrosion resistance, high temperature performance, impermeability and volume stability [2-3]. At present, the production of geopolymer grouting material mainly is prepared using industrial wastes such as fly ash and blast furnace slag as main raw materials [4]. The resulting CO_2 is 80% less than Portland cement. In view of its environmental pleasant aspect, low prices, excellent performance and other advantages of geopolymer grouting material, it is more in line with the green concept, through research on its performance is necessary. Yu Q et al. found that the addition of $BaCl_2$ in alkali activated material can prolong the coagulation time and revealed the main mechanism [5]. Cristelo N et al. studied the relationship among the mechanical properties of fly ash-based geopolymer materials with alkali-activators, capital and environment, and found that using fly ash-based geopolymer material can reduce CO_2 emissions and construction costs significantly [6]. Khademi et al. used some data-driven models to predict the compressive strength of environment-friendly road materials [7]. Nie Qiong obtained the optimum proportion of slag-based grouting material in different ages through mean square design optimization process and compared the material with cement slurry [8]. Chen Lihua determined the optimum proportion of alkali-activated superfine slag powder grouting material, and the compressive strength was up to 13.82 MPa [9]. Ibrahim et al. ascertain compressive strength and water absorption of geopolymer bricks in different aging time [10]. Al Bakri Abdullah MM et al. investigated on the compressive strength of geopolymer material and the ratios of fly ash/alkaline activator and Na_2SiO_3 solution/NaOH solution [11]. But the effect of water-cement ratio on the workability and mechanical properties of the blast furnace slag-based geopolymer grouting material remains unclear.

This paper used blast furnace slag as the basic raw material to prepare geopolymer grouting material with alkali-activators, revealed the influence of water-cement ratio on the workability and mechanical properties of the geopolymer based on fluidity, compressive and flexural test.

2. Materials

It is an effective method to prepare the geopolymer grouting material by alkali-activated blast furnace slag at normal temperature. In this study, the main materials include blast furnace slag (SL), sodium silicate (SS), sodium hydroxide (SH), water-reducing agent and so on. Blast furnace slag (superfine powder, produced by a plant in Hebei province, average grain diameter is equal 0.05mm, activity index≥95%, 35% of silicon dioxide, 14% of aluminum oxide, 41% of calcium oxide, and 8% of magnesium oxide), alkali-activators including sodium silicate solution (9% of Na_2O, 30% of SiO_2, density is equal 1.39 g/ml, industrial grade, modulus is equal 3.3) and sodium hydroxide solution (purity≥99%, white, flaky solid, industrial grade), water-reducing agent (the main component is sulfonated melamine（SM）, white powder, no chloride, bulk density is equal 450-750 kg/m^3, less than 4% of weight loss on drying, PH about 9-11), water.

3. Test method

The geopolymer grouting material can be prepared by using alkaline activator to stimulate the aluminum source materials including the potential active silicon or industrial wastes such as fly ash, blast furnace slag, steel slag. The geopolymer grouting material was prepared with a certain proportion of blast furnace slag, sodium silicate, sodium hydroxide, water-reducing agent and water. Table 1 shows the mixture proportion of geopolymer grouting material.

Table 1. The mixture proportion.

Series number	m_W/m_{SL}	m_{SS}/m_{SL}	m_{SH}/m_{SL}	m_{SM}/m_{SL}
1	0.36	0.09	0.07	0.006
2	0.39	0.09	0.07	0.006
3	0.42	0.09	0.07	0.006
4	0.45	0.09	0.07	0.006
5	0.47	0.09	0.07	0.006

A certain amount of blast furnace slag, sodium silicate solution and NaOH were weighed out according to the mix ratio described in table 1. Sodium silicate and water was put into the beaker to mix, and NaOH was added in the mixing process, and the beaker was sealed with a plastic wrap to avoid the evaporation of water after the mixing was finished, until NaOH was dissolved and stirred evenly, stoped stir and cooled it down to ambient temperature. After the solution was completely cooled, the geopolymer slurry was prepared according to “Test methods for water requirement of normal consistency setting time and soundness of the Portland cement” (GBT1346-2011 of China).

The fluidity of the geopolymer grouting material is an important index to study its practical applicability in road engineering, and determined its effective diffusion radius.

The fluidity test mold was selected according to “cementitious grout” (JC/T 986-2005 of China). The truncated cone is required as follows: The inner wall is smooth, the height is 60mm ± 0.5mm, the inner diameter is 70mm ± 0.5mm, the inner diameter of the lower mouth is 100mm ± 0.5mm, the outer diameter is 120mm, and the wall thickness is more than 5mm. Test method reference to “Cade for concrete admixture application” (GB 50119-2013 of China), i.e., the 500mm×500mm glass plate was placed horizontally, glass plate, truncated cone mold and mixer internal surface were wetted, and the mold was covered with a damp cloth, the geopolymer slurry was poured into the expansion cylinder for mortar fluidity test, the maximum diameter of the two perpendicular directions were measured after 10 seconds, and the results were represented by averages.

When the mechanical strength of geopolymer grouting material was tested, prepared geopolymer grouting material according to the design ratio and formed 40mm×40mm×160mm specimens using the

way of removing the bubble by artificial patted. Six samples were prepared for each mixture ratio. They were sealed with plastic wrap to prevent rapid evaporation and precipitation of water, the specimen were removed from mold after curing for 24 hours at ambient temperature of 20℃±5℃ and room humidity about 50%, then specimens were cured in water until reached the test age. The flexural strength and compressive strength were measured according to "Method of testing cements-Determination of strength"(GB/T 17671-1991 of China), and the loading speed should be strictly controlled within 2200 N/s-2600 N/s during the process of determination.

4. Test results and discussion

4.1. Workability

The fluidity of geopolymer grouting material with different water-cement ratio was analyzed, the results of the analyses are shown in figure 1.

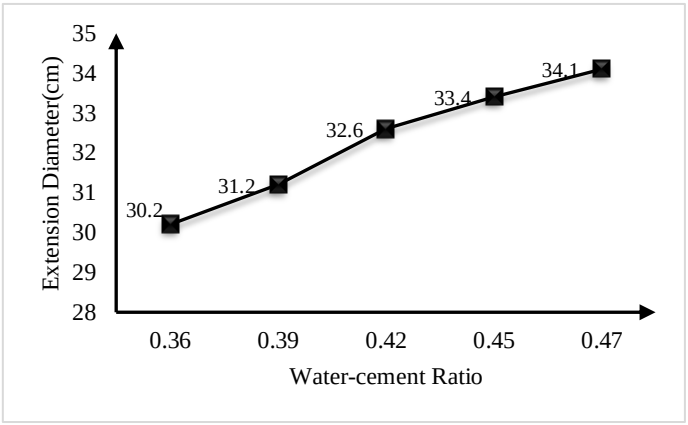

Figure 1. The fluidity.

From figure 1, it is noted that the fluidity increases as the water-cement ratio increases, when the water-cement ratio is between 0.39-0.42, the extension diameter of the mortar increase larger, but the increasing of the extension diameter is reduced when the water-cement ratio exceeds 0.42. In view of the results, it is indicating that the water-cement ratio is more influential to the fluidity when the water-cement ratio is between 0.39-0.42.

4.2. Mechanical properties

According to the test results, the compressive strength and the flexural strength of geopolymer grouting material of 7 days curing ages related with different water-cement ratio is shown in figure 2.

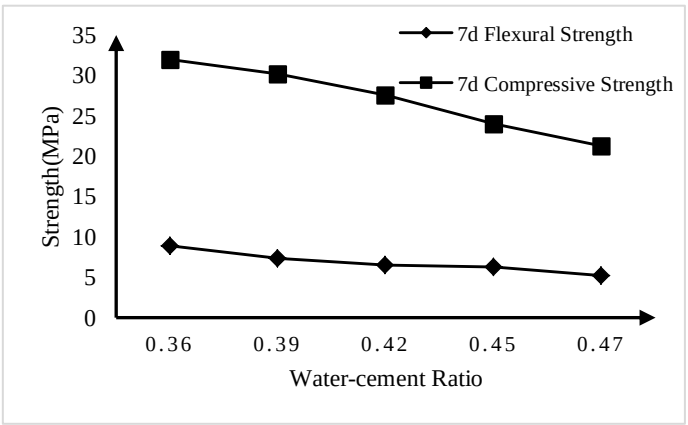

Figure 2. Mechanical properties.

The following conclusions can be drawn according to the results shown in figure 2.

(1) The flexural strength and compressive strength of the specimen decrease gradually with the increasing water-cement ratio, the decrease of compressive strength is larger than that of flexural strength.

(2) Water-cement ratio is an important factor that affects the strength of the geopolymer grouting material, the remaining water of the material is higher with the increase of the water-cement ratio after the polymerization reaction, the excess water remain in the interior of the geopolymer grouting material that become blisters or produce bubbles will affect the strength properties.

Considering the influence of water-cement ratio on the workability and mechanical properties of the geopolymer grouting material, it is suggested that the water-cement ratio can be controlled between 0.39 and 0.42 in the preparation process. The optimum water-cement ratio can make the geopolymer grouting material have better working performance and mechanical properties in the process of road reinforcement.

5. Conclusions

In this study the geopolymer grouting material was prepared with alkaline activators and investigated the effects of water-cement ratio on the workability and mechanical properties based on the fluidity test, compressive and flexural test. The main conclusions include the following aspects:

(1) The fluidity of the geopolymer slurry increases with the increase of the water-cement ratio, and the water-cement ratio which is between 0.39-0.42 has a greater effect on the fluidity of the polymer grouting material.

(2) The compressive strength and flexural strength of the mortar material decreases with the increasing of the water-cement ratio, compressive strength decreases significantly with the increasing of the water-cement ratio.

(3) The water-cement ratio can be controlled between 0.39 and 0.42 in the preparation process to ensure the geopolymer grouting material have better workability and mechanical properties in the process of road reinforcement.

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