

The relationship between compressive strength and flexural strength of pavement geopolymer grouting material

L Zhang^{1,2}, X X Han¹, J Ge³ and C H Wang^{1,4}

¹ School of Highway, Chang'an University, Xi'an, 710064, Shaanxi, China

² Henan Transport Investment Group Co., Ltd., 450052, Henan, China

³ Tianjin Municipal Engineering Design & Research Institute, Tianjin, 300051, China

⁴ E-mail: 2539526581@qq.com

Abstract. To determine the relationship between compressive strength and flexural strength of pavement geopolymer grouting material, 20 groups of geopolymer grouting materials were prepared, the compressive strength and flexural strength were determined by mechanical properties test. On the basis of excluding the abnormal values through boxplot, the results show that, the compressive strength test results were normal, but there were two mild outliers in 7days flexural strength test. The compressive strength and flexural strength were linearly fitted by SPSS, six regression models were obtained by linear fitting of compressive strength and flexural strength. The linear relationship between compressive strength and flexural strength can be better expressed by the cubic curve model, and the correlation coefficient was 0.842.

1. Introduction

With the rapid development of the road traffic industry, the total mileage of highways in China has increased rapidly, by the end of 2016, the total mileage of the highway has reached 4.6963 million kilometers [1]. But the road design, the construction of the shortcomings and traffic flow, the rapid increase in axle load made the use of the road after a period of time often subsidence, cracks, slurry pump and other diseases. It is very important to take effective measures to reinforce and strengthen the pavement structure. Grouting technology has some characteristics such as fast reinforcement, small impact for traffic and other advantages of the road reinforcement. As an important part of grouting technology, grouting material directly affects the effect of grouting reinforcement. There are three main types of grouting material. The existing cement grouting material is poor in stability and bleeding water easily [2]. Chemical grouting material is costly and most of them are poisonous [3]. Polymer grouting material can only fill the void of the structural layer, cannot bond loose material between layers, the effect of structural reinforcement is not good [4]. Therefore, the future direction of building materials is still green, excellent performance and low price [5]. Geopolymer grouting material is a kind of green material. It has the advantages of early strength, corrosion resistance, good durability, low energy consumption, low price and so on. Geopolymer grouting material is an ideal reinforcing material for pavement structure, it is widely used in the field of grouting technology. Researchers in the field of road engineering carried out a large number of experimental studies on geopolymer grouting materials. Zhang Haiyan et al studied found that either at ambient temperature or after exposure to high temperature the strength of geopolymer paste, mortar and concrete prepared in this study can almost reach or exceed that of cement paste, mortar and concrete [6]. Yuan Bo analyzed



the road performance of geopolymer grouting material through experiments. Found that after the grouting down the deflection on the surface enhance the obvious, can effectively extend the road life [7]. Wang Jian et al studied the influence rule of volume fraction of sodium silicate and powder proportion on initial/final setting time, uniaxial compressive strength, erosion resistance and dry shrinkage, the optimum mix amount of sodium silicate was determined to be 20% [8]. Yan C et al research on durability performance of novel double solution grouting material with metakaolin and the microstructure of this grouting material was analyzed [9]. Krivenko et al research a kind of shrinkage-compensating alkali activated slag cement mortars, this material can crack repair and joint grouting in concretes, the grouting material has good mechanical properties, durability and low-cost [10]. Cristelo N et al assessing using fly ash-based geopolymer material can significantly reduce CO₂ emissions [11]. Idrissi et al studied the effect of water content on microstructure and mechanical properties of geopolymer grouting material [12]. However, the existing research focuses on optimizing the preparation of geopolymer grouting material with multiple function and analyzing its microstructure, and the influence of different amount of materials on its performance was studied. But there is little research on the relationship between compressive strength and flexural strength.

Therefore, twenty groups of geopolymer grouting materials were prepared, the compressive strength and flexural strength were determined by mechanical properties test, on the basis of excluding the abnormal values through boxplot, the compressive strength and flexural strength were linearly fitted by SPSS. In order to determine the correlation between the compressive strength and the flexural strength of geopolymer grouting materials, this lays the foundation for the further study of the geopolymer grouting materials.

2. Test raw materials

The main raw materials used in this paper are 300 mesh blast furnace slag, water glass solution, industrial grade sodium hydroxide (sodium hydroxide content $\geq 99\%$) water reducing agent and water. The main components and basic index of blast furnace slag, water glass and water reducing agent are shown in table 1, table 2, table 3.

Table 1. Chemical composition of blast furnace slag.

Technical index	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	MnO	S
Blast furnace slag	35.06	14.38	41.12	7.93	0.58	0.17	0.76

Table 2. Basic index of water glass.

Water glass	Na ₂ O (wt%)	SiO ₂ (wt%)	Density (g/cm ³)	Water insoluble (wt%)	Modulus
Requirements	≥ 8.2	≥ 26.0	1.368~1.394	≤ 40	3.1~3.4
measured	9	30	1.39	≤ 40	3.3

Table 3. Technical index of water reducing agent.

Technical index	Colour	Bulk density (kg/m ³)	Loss on drying (%)	PH value
Water reducing agent	white	430~740	< 4.0	9~11.4

3. Test method

The sodium hydroxide solution was prepared by mixing sodium hydroxide with 80% water in proportions. After cooling the solution to room temperature and blended it with water glass solution to prepare alkaline activator, mixed the water reducing agent with the remaining 20% of the water. According to the "Test methods for water requirement of normal consistency, setting time and

soundness of the portland cement"(GBT 1346-2011 of China)cleaned the mixing pan and mixing blade with a damp cloth, mixed the blast furnace slag powder and alkaline activator in the slurry mixer. After 120s low speed stirring, stopped stir and added residual water reducing agent solution, and stirred the mixture at high speed for 120s in the stirrer.

The polymer grouting material was prepared by refering to the method above, 40mm × 40 mm × 160mm specimens were molded by artificial pound and eliminate the air. To avoid the molded specimen water evaporation and water precipitation covered with fresh-keeping film, put specimens at temperature $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$, relative humidity greater than 50% of the environment for 20 to 24 hours. Then start mould stripped. Scraped off the surface of specimen, then put the specimen up in $20 \pm 1^{\circ}\text{C}$ water for curing. The curing specimen was removed from the water 15 minutes before the test age (7days). The compressive strength and flexural strength were tested referring to the "method of testing cements-determination of strength" (GB17671-1999 of China).

In order to facilitate the actual application process to calculate the composition of the geopolymer grouting material, based on blast furnace slag powder. The mass ratio of water glass solution to blast furnace slag powder was SS / SL, the mass ratio of sodium hydroxide to blast furnace slag was SH / SL. The mass ratio of water to blast furnace slag was W/SL. The mix design of pavement geopolymer grouting material is shown in the table 4.

Table 4. Proportioning design of road geopolymers grouting material.

Number ing	SL:SS:SH: W	Number ing	SL:SS:SH: W	Number ing	SL:SS:SH: W	Number ing	SL:SS:SH: W
1	1:0.09:0.07: 0.37	2	1:0.09:0.09: 0.47	3	1:0.09:0.11: 0.42	4	1:0.11:0.07: 0.47
5	1:0.11:0.09: 0.42	6	1:0.09:0.07: 0.42	7	1:0.09:0.07: 0.45	8	1:0.09:0.08: 0.42
9	1:0.09:0.08: 0.45	10	1:0.09:0.08: 0.47	11	1:0.10:0.07: 0.42	12	1:0.10:0.07: 0.45
13	1:0.10:0.07: 0.47	14	1:0.10:0.11: 0.45	15	1:0.11:0.08: 0.45	16	1:0.11:0.08: 0.42
17	1:0.07:0.07: 0.42	18	1:0.07:0.09: 0.37	19	1:0.07:0.11: 0.47	20	1:0.11:0.11: 0.37

4. The relationship between the flexural strength and the compressive strength

Using the boxplot in SPSS (Statistical Product and Service Solutions), the abnormal values of compressive strength and flexural strength of 20 groups of geopolymer grouting materials were determined and eliminated. Draw the boxplot shown in figure 1, the internal and external limits are not shown in figure 1.

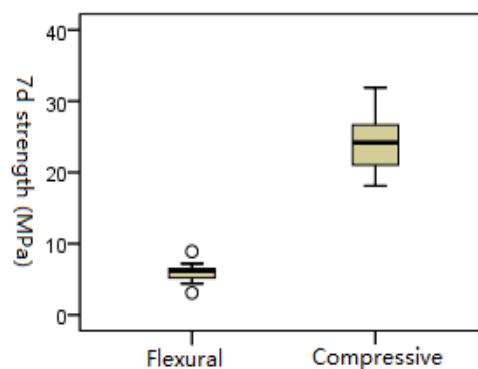


Figure 1. Compressive strength and flexural strength of 7days with different geopolymer grouting material.

Through the SPSS boxplot to verify, different geopolymer grouting materials have two mild outliers in the flexural strength test data in 7days, Flexural strength of 8.9MPa at SL:SS:SH:W=1:0.09:0.07:0.37, Flexural strength of 3.1MPa at SL:SS:SH:W=1:0.10:0.11:0.45, taking into account the composition of the two kinds of geopolymer grouting materials, there is a possibility that the flexural strength is higher or lower. Therefore, these two moderate anomalies are included in the analysis of the relationship between compressive strength and flexural strength of the geopolymer grouting material 7days.

The compressive strength and flexural strength of 7days grouting material are analyzed by linearity, logarithm, quadratic curve, cubic curve, power and six indexes. The result is shown in figure 2.

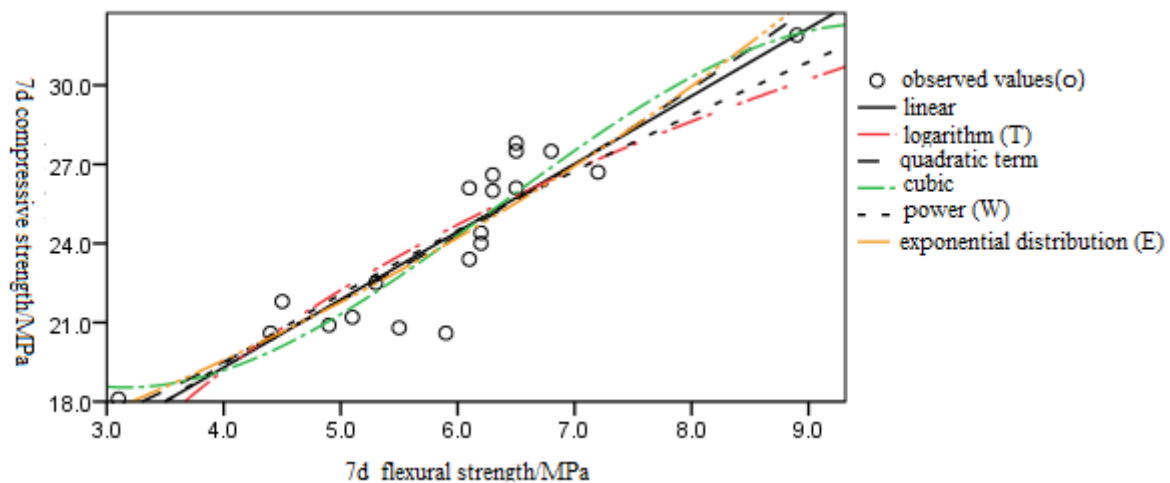


Figure 2. Regression analysis of flexural strength and compressive strength of geopolymer grouting material in 7days.

As you can see from figure 2, the cubic curve has the best fitting effect and the R^2 value is the largest, the relationship between the flexural strength and the compressive strength of the 7days geopolymer material can be expressed by $y = 32.076 - 9.627x + 2.027x^2 - 0.106x^3$, $R^2 = 0.842$, the fitted equation can better reflect the relationship between them.

5. Conclusions

In this paper, 20 groups of geopolymer grouting material were prepared, the compressive strength and flexural strength were determined by mechanical properties test, on the basis of excluding the abnormal values through boxplot, the compressive strength and flexural strength were linearly fitted by SPSS, the results show that, the compressive strength test results were normal, but there were two mild outliers in 7days flexural strength test, the conversion relationship between compressive strength and flexural strength of six ground geopolymer grouting material in 7days is established, the cubic curve can better reflect the relationship between them. The correlation coefficient is 0.842. In the follow-up study, the actual effect of 20 groups of different geopolymer grouting materials will be tested. This will provide a theoretical basis for further study and engineering application of geopolymer grouting material.

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