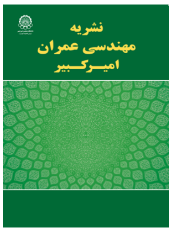

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Experimental investigation and statistical analysis on structural design and impact strengths of fiber geopolymer mortar

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ABSTRACT: Due to the high consumption of mortar and concrete, especially in structures and the increasing demand for cement production, considering the environmental degradation effects of this substance, it seems necessary. One of the solutions is to produce environmentally friendly materials and reduce the damaging effects of Portland cement production, Such as slag geopolymer mortar and concrete. The purpose of this paper is to experimentally investigate the statistical approach of the mechanical and resistive properties of cement mortar and geopolymer fibers mortar. Four mix designs, including three geopolymer mix designs with 0, 0.5, and 1% steel micro-fibers and a conventional mortar mix design, were considered. A total of 320 specimens were made, each consisting of 20 cubic specimens, 20 cylindrical specimens, 20 small beam specimens, and 20 small disc specimens. The results indicated that by increasing the percentage of steel microfibers up to 1% in geopolymer samples, the compressive strength, tensile strength and modulus of rupture increased by 6.39, 60.86, and 63.40%, respectively. The number of destruction resistance blows was also about 25 times higher. In all compressive, tensile, flexural, and impact strengths tests, the non-fiber geopolymer specimens had better behavior than conventional cement mortar specimens. In all geopolymer specimens with increasing fiber percentage, standard deviation and coefficient of variation increased as a result of data dispersion.

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1. INTRODUCTION

An alternative group of promising construction materials is geopolymer, first introduced and named by Davidovits in 1989, exhibiting excellent mechanical performance, durability, and fire and acid resistance. It can be cured and hardened at room temperature with 80%–90% fewer CO_2 emissions than Portland cement [1, 2]. Davidovits introduced the concept of geopolymer, which can be produced by the reaction of silica and alumina with the alkali activating solutions. The mechanism of geopolymers involves the reaction of silica and alumina, liberated by hydroxides and silicates of sodium or potassium as the alkali-activating solution, and results in the formation of strong alumina-silicate polymeric structures. Due to the slow reactivity of the source materials, the alkali activating solution often requires additional heat [3]. Due to the significant production of carbon dioxide and energy demand in cement factories, geopolymer mortars, including fly ash, slag, or metakaolin, are proper substitutes with cement-based concretes [4]. Hundreds of thousands of tons of waste blast furnace slag from steel factories accumulate unused every year. Granulated Blast furnace Slag (GBFS) is one type of calcium alumino-silicate solid waste material commonly used in geopolymer concrete and mortar. Geopolymers suffer brittle failure and sensitivity to cracking, as do other ceramics [5]. Such microcracks combine to create macrocracks where the composite fails to withstand the additional load. The brittle failure and inherent sensitivity to cracking of geopolymers impose constraints on structural design and undermine durability [6]. Reinforcement of cementitious composites with micro-fibers has been applied as a useful technique for overcoming material property drawbacks [7]. In this paper, an experimental study with a statistical approach was conducted on the mechanical and strength properties of fibrous geopolymer mortars and conventional mortar made with cement.

2. EXPERIMENTAL PROGRAMS

The fine aggregate (sand) used was clean, dry river sand that passes through a 2.36-mm sieve (No. 8). Granulated blast furnace slag and cement used in mortars were obtained from Isfahan Steel and Doroud Cement Companies. GBFS as a binder was activated by an alkaline solution phase consisted of a combination of liquid glass or sodium silicate (Na_2SiO_3) and 12 M sodium hydroxide (NaOH), pre-mixed with a ratio of Na_2SiO_3-to-NaOH of 2 (by mass). Micro steel fibers having a length of random 3 to 35 mm, a diameter of 0.3 mm, and ultimate tensile strength of more than 2400 MPa with an aspect ratio of between 10 and 116 were used for the present study. In the present experimental work, GM (geopolymer mortar) mix proportion was achieved by trial and error method to achieve the reliable compressive strength with

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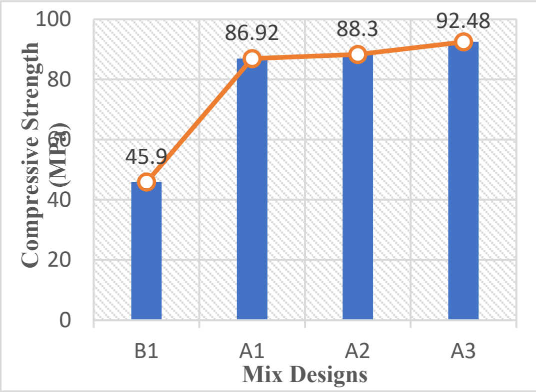

Fig. 1. Comparative diagram of compressive strengths

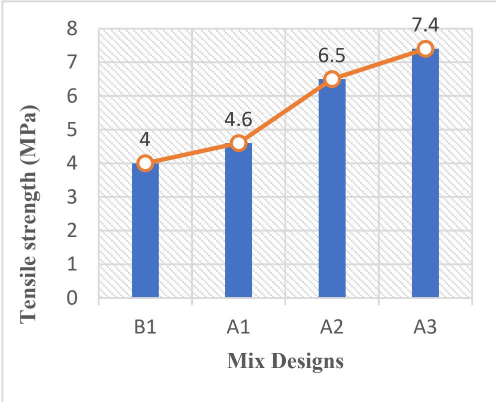

Fig. 2. Comparative diagram of tensile strengths

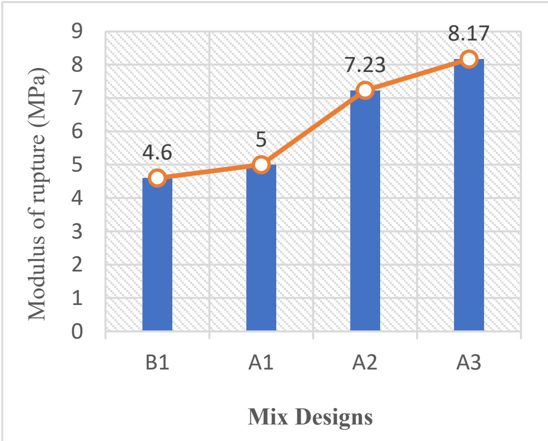

Fig. 3. Comparative diagram of modulus of ruptures

proper cohesive mix. Studying previous work by researchers in the field of geopolymer mortar gave us a good idea for designing the first mixing designs. To compare geopolymer mortar with conventional mortar, the weight of cement was equal to the weight of slag plus the amount of solids used in the sodium hydroxide solution and the sodium silicate liquid. The amount of sand and water used in mixing design of geopolymer and cement mortar was equal. In this study, to eliminate the effect of any extra heat in the geopolymer system, it was prepared 24 h prior to the casting. For all specimens the mixing procedure consisted of mixing all the dry constituents for three minutes, the water and activator solution were then added together and mixed for seven more minutes. The freshly mixed mortar was poured layer by layer, into cubes of size 50×50×50 mm^3 for compressive strength test, 50×100 mm^2 cylinders for splitting tensile test, 40×40×160 mm^3 small beam for modulus of rupture, 150×300 mm^2 cylinders for impact strength. All the specimens were then transferred to an oven set at a temperature of 60 °C and stored for 24 hours. After curing, the specimens were allowed to cool in air, demolded and kept in the open until the day of testing. In the case of samples made with cement mortar, the treatment was done using a wet sack for 7 days and after 28 days of manufacture, samples were tested.

3. RESULTS AND DISCUSSIONS

The addition of fibers had a relatively small effect on increasing the mean compressive strength of the specimens. The mean compressive strength of the group with 1% fibers was 92.48 MPa, which was 6.39 MPa and 4.73% higher than that of the group without fiber Conclusions. Also, the addition of fibers increased the average tensile strength of the specimens. The mean tensile strength of the 1% group was 4.6 MPa, which was 60.86 and 13.84% higher than the 0 and 0.5% groups, respectively. The maximum coefficient of variation for 1% group was 98.9% which is 18.24 and 14.84% higher than 0 and 0.5% groups. A3 series geopolymer samples with 1% microfiber had a higher mean modulus of rupture among the other groups. The mean modulus of rupture for A3 was 63.40 and 13.01% higher than 0 and 0.5% groups. In tensile splitting strength and modulus of rupture tests, the fiber specimens are prevented from spreading cracks and have better coherence. Figures 1 to 3 show a comparison diagram of strengths.

As the fiber percentage increased, the number of blows needed for the first crack to occur, as well as the failure strength, increased in the impact strength test. 1% group had higher impact strength than the other two groups. The average failure strength of 1% group was 25.33 times that of

0% group and 4.44 times that of 0.5% group. The maximum coefficient of variation for 1% group was 24.11%, which was 22.63 and 10.14% higher than 0 and 0.5% groups, respectively.

4. CONCLUSION

1. Proper performance of geopolymer mortars with blast furnace slag material, in terms of mechanical and resistance properties, demonstrates the high capacity and potential of the blast furnace slag for cement replacement.

2. The statistical data achieved for the compressive, tensile and flexural strengths were approximately normal distribution and hardly consistent with the normal distribution in impact strength.

3. In all compressive, tensile, flexural and impact tests, geopolymer specimens without fiber had better mechanical performance than conventional mortar specimens made with cement.

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