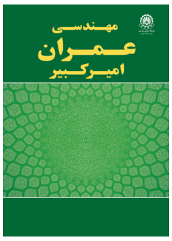

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Effect of alkaline solution to binder ratio on the fracture parameters of lightweight geopolymer concrete based on fly ash

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ABSTRACT: Geopolymer concrete is an innovative building material that is produced by the chemical action of mineral molecules. Removal of cement is one of the great advantages of the use of geopolymer concrete. For this reason, to know the types of geopolymer concrete, it is important to examine its different components and their effect on fracture parameters. In this paper, the fracture parameters of lightweight geopolymer concrete based on class C fly ash (LWFCGC) are presented. In this research, three mix designs with the activator to binder ratios of 0.4, 0.5 and 0.6 were considered. By changing the ratio of activator to glue from 0.6 to 0.4, compressive strength from 18.9 MPa to 28.4 MPa, toughness from 14.07 MPa mm to 19.04 MPa mm 0.5, fracture energy from N/ 17.31 m to 20.98 N/m and the length of the fracture process area changed from 54.12 mm to 29.07 mm.

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1- Introduction

A member in a structure may be susceptible to one or more types of fracture. The fracture can be defined as the process of separation (or fragmentation) of a solid into two or more parts under the influence of stress. Cracks exist in all concrete structures. Cracks act as tension concentrators in many cases. By increasing the amount of load, the concentration of stress is created and the cracks expand and eventually cause the destruction of the structure. Geopolymer cement is used as a semi-brittle material as an alternative to Portland cement [1-4].

Developing a fundamental model for a material requires its fracture parameters. The fracture parameters of a material are used to describe the formation and propagation of cracks in the material. The crack path in composite materials such as concrete depends on the mechanical interaction between the aggregates and the adhesive matrix. Energy The fracture of a composite material depends on the deviation of the crack path from the ideal crack surface [5, 6].

The results of recent studies have shown the potential of using heat-treated fly ash-based geopolymer concrete as building materials. Ongoing research on fly ash-based geopolymer concrete studied several short-term and long-term properties. It was shown that heat-cured geopolymer concrete has the properties of high compressive strength, shrinkage due to drying and low creep, and good resistance to sulfate and acid [7, 8]. Nazari et al [9] investigated the effect of processing temperature on the compressive strength of FA-RHBA geopolymer. FA was replaced with RHBA at three replacement levels of 20%, 30% and 40%. After the completion of the preparation period, the geopolymer samples were placed at 50-90 degrees Celsius for 36 hours. In this research, they concluded that the optimum processing temperature for all mixtures is 80°C.

This paper describes the results of laboratory research on the effect of activator to binder ratio on the fracture parameters of lightweight geopolymeric concrete based on class C fly ash. For this purpose, tests have been performed on the sample of split beams using the size effect method (SEM) and based on the RILEM recommendations [10]. In addition, mechanical parameters including modulus of elasticity, tensile strength and compressive strength have been determined.

2- Determining fracture parameters using the size effect method (SEM)

In this research, for each mixing design, 12 samples of notched beams with four different sizes were fabricated and tested by the universal servo electronic control device STM-150 at Razi Metallurgical Research Center (RMRC). According to RILEM recommendations, loading was done at a constant speed so that maximum loads were introduced into the sample within 5 minutes [10]. All samples were removed from the mold after 24 hours of storage in the mold.

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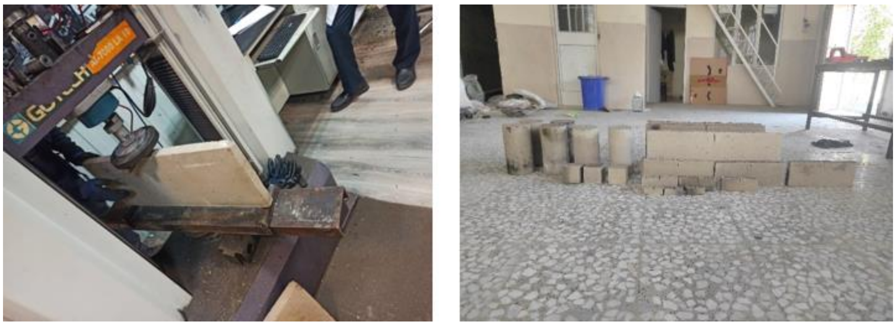

(a) **(b)**

Fig. 1. (a) Sample with d=304.8 mm under bending test (b) Samples of mixing design A1

The samples were tested after one day of processing in an oven with a temperature of 80 °C. Also, for each mixing design, three cubic samples with dimensions of 100 mm × 100 mm × 100 mm and six standard cylindrical samples with dimensions of 150 mm x 300 mm were made. These samples were tested according to ASTM C469 [11], ASTM C496 [12] and BS EN 12390 [13] standards to determine the modulus of elasticity, tensile strength and compressive strength, respectively. In Figure 1a, one of the samples related to the design code LWFCGC1 with d=304.8 mm is shown in the three-point bending test. Figure 1b shows examples of LWFCGC1 design code built with the A1 mixing scheme. In this picture, 12 samples related to the three-point bending test, three cubic samples for the compressive strength test and 6 cylindrical samples for tensile strength and modulus of elasticity test are shown.

3- Analysis of the results

The obtained results showed that reducing the ratio of activator to adhesive (Al/Bi) leads to an increase in the fracture load. In the case of conventional concrete, the fracture load increases as the water-cement ratio decreases. This shows the similarity of the role of the activator in geopolymer concrete with water in conventional concrete and the binder in geopolymer concrete with cement in conventional concrete. By increasing the ratio of activator to adhesive (Al/Bi): First, the porosity of the geopolymer paste increases and its compressibility decreases [14-16]. Secondly, the total amount of water, the number of hydroxide ions and their cations (such as Na^+ and Si^{4+}) in the system increases. These disrupt the geopolymerization process and cause a lower content of N-A-S-H gel with poor microstructure to form [14, 15]. And thirdly, the drying shrinkage of the geopolymer paste increases, leading to more microcracks in the hardened paste [16]. Accordingly, intergranular fracture occurs at a higher Al/Bi ratio due to the creation of more porosity and microcracks in the paste as well as the low quality of the geopolymer paste. In this case, the cracks pass partly through the matrix and partly along the interfaces. Therefore, the fracture energy is reduced and the ductility is increased.

4- Conclusion

In this paper, the effects of activator to binder ratio (Al/Bi) on fracture parameters of lightweight geopolymer concrete based on class C fly ash (LWFCGC) were investigated using the size effect method (SEM). The main results are summarized as follows:

By increasing the ratio of activator to adhesive (Al/Bi) from 0.4 to 0.6, the fracture energy Gf changed from 20.98 N/m to 17.31 N/m and decreased by 17.5%. The fracture toughness of KIC decreased from 0.5 MPa mm 19.04 to 0.5 MPa mm 14.07, which showed a reduction of 26%. While the length of Cf fracture development area increased from 29.07 mm to 54.12 mm and showed an increase of 86.1%. This means that by increasing the ratio of activator to binder (Al/Bi), similar to what was observed in increasing the ratio of water to cement in ordinary concrete, the fracture energy decreases and the ductility increases.

By increasing the ratio of activator to adhesive (Al/Bi) from 0.4 to 0.6, the compressive strength fc decreased from 28.4 MPa to 18.9 MPa. 33.4% decrease changes. The modulus of elasticity E also decreased from 17.28 GPa to 11.43 GPa, which is equivalent to a 34% decrease.

In all samples, with the increase of compressive strength fc from 18.9 MPa to 28.4 MPa, Gf increased from 17.31 N/m to 20.98 N/m. And the fracture toughness of KIC increased from 14.07 MPa $mm^{0.5}$ to 19.04 MPa $mm^{0.5}$. And the length of the fracture area Cf decreases from 54.12 mm to 29.07 mm. As a result, the higher the compressive strength, the higher the fracture energy and brittleness.

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