ASSESSMENT OF FLOW AND MECHANICAL PROPERTIES OF GEOPOLYMER COMPOSITE FOAM CERAMIC FILLERS

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Abstract- While creating cellular geopolymer mortar with geopolymers (GPL) has attracted a lot of attention, little study has been done to determine how particle fillers affect the final porosity. The goal of this research is to thoroughly examine the necessary elements for producing composite cellular geopolymer mortar. Analyzing the viscosity of the GPL slurry, which contains small particles derived from fireclay and ceramic dichroite, is one of the main goals. For GPL with fireclay and dichroite fillers, the viscosity values at 100 s^{-1} were 4.99 Pa. s and 4.23 Pa. s, respectively. Due to a significant distribution of linked porosity and big pores in the matrix, composite cellular geopolymer mortar reinforced with ceramic fillers has compressive strengths ranging from 1.51 to 10.1 MPa.

Keywords- Cellular geopolymer mortar; compressive strength; fireclay ceramics; flow properties.

1 Introduction

A novel family of inorganic polymers known as geopolymers (GPL) are produced when aluminosilicate materials are activated with an alkali-activated solution. Growing interest in GPL materials because of economic expansion and urbanization has centered attention on learning about the creation of GPL composites and their properties [1, 2]. The scientific community has emphasized the GPL system's potential to lower carbon emissions in addition to aluminosilicates' capacity to give desired features such durability, thermal stability, and resistance to acid attack [3, 4]. Numerous studies have investigated the parametrization of GPL to obtain the necessary porosity and microstructural stability [5, 6]. More uses for GPL cellular geopolymer mortar have surfaced recently, including concrete cellular geopolymer mortar [7], heavy metal adsorbents [9], fire-resistant panels [8], acoustic and thermal insulations [10], monolithic adsorbents for wastewater treatment [11], and ion exchangers [12]. The appropriate chemical cellular geopolymer mortar can be used to provide the necessary porosity, regardless of variations in development protocols and techniques [13]. Furthermore, a thorough analysis of variables is necessary for the synthesis of a porous composite to track changes in the test slurries' in-situ flow properties when different fillers or additives are added [5]. The goal of this research is to thoroughly examine the most essential factors to create composite cellular geopolymer mortar. Examining the viscosity of the GPL slurry with tiny particles sourced from fireclay and ceramic cordierite is one of the main goals. The research explores a novel blend of geopolymer and foam ceramic fillers, aiming to enhance sustainability through reduced carbon emissions and improved mechanical properties. This innovative approach holds promise for diverse engineering applications, offering lightweight, durable materials with enhanced thermal insulation capabilities.

2 Experimental Program

2.1 Materials

The GPL slurries were made using fireclay ceramics (FC), dichroite ceramics (DC), and metakaolin (MKL) powder as the main ingredients and ceramic fillers, respectively. The utilization of an alkaline potassium silicate solution resulted in a SiO_2/K_2O ratio of 1.65. A 30% concentration of H_2O_2 was utilized to provide the foaming properties. In addition, $Cl \leq 5$

ppm, retention ≤ 5 ppm, Pb ≤ 0.02 ppm, N ≤ 20 ppm, and Fe ≤ 0.5 ppm are specified by the manufacturer. The pore size distribution of the utilized components is shown in Table 1.

Table 1 Grain sizes of MKL, FC, and DC particles

Size distribution	**Mean size (µm)**	**Dv10 (µm)**	**Median size D50 (µm)**	**Dv90 (µm)**	**Density (g/cm^3)**
DC	288.28	32.76	253.95	591.47	2.77
FC	302.07	85.34	247.85	539.11	2.81
MKL	6.12	2.55	5.33	10.39	0.72

2.2 Preparation of Samples and Testing

The GPL slurry was made in accordance with a weight ratio of 1:1 for MKL and potassium silica solution at a room temperature of 23 °C. A 30% relative humidity was kept constant. Previous data reports served as the foundation for mix design [14]. The chemical formations of the porous GPL, GPL_DC, and GPL_FC solid specimens are shown in Table 2.

Table 2 Chemical formation of GPL, GPL_FC, and GPL_DC solid specimens

Mix	**SiO_2**	**Al_2O_3**	**CaO**	**Fe_2O_3**	**TiO_2**	**K_2O**	**MgO**	**Na_2O**
GPL	50.167	28.754	0.201	0.732	1.275	17.933	0.815	0.123
GPL_FC	51.506	32.82	0.151	2.939	2.333	10.048	0.158	0.045
GPL_DC	48.565	30.783	0.409	1.646	2.322	11.021	5.143	0.111

3 Results and Discussion

3.1 Mechanical Properties

To examine the specimen cylinders measuring 15 by 30 mm for compression strength, the average strength results were computed, and the discrepancies were depicted using error bars. The impact of ceramic fillers on measurements of compression strength and relative compression strength of samples is depicted in Figure 1. There is a paucity of important research contrasting the porosity microstructure at elevated temperatures. However, bulk GPL exhibits a comparable mechanism [15]. Higher temperatures, such as those between 70°C and 90°C, are known to improve the alkaline solution's interaction with the aluminosilicate source during GPL formation [16]. This generally increases the mechanical strength, although the GPL systems' chemical makeup has a big impact on it [17].

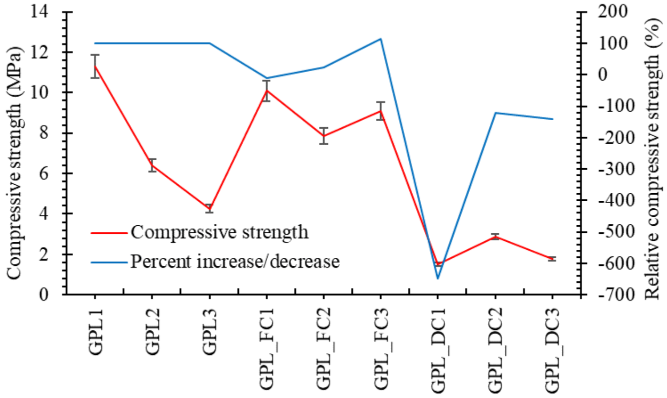

Figure 1: Results for compression strength and relative compressive strength of samples.

3.2 Viscosity and Flow Properties

The dynamic viscosity of the fresh GPL mixtures was tested around two minutes after mixing. After measuring the viscosity, H_2O_2 was added as the blowing material. In the rising regime of shear rate, testing of the unreinforced GPL slurry revealed that the material behaved as a non-Newtonian fluid, with viscosity fluctuating with induced stress [18]. For the GPL mix at 100 s^{-1}, the green circle plot in Figure 2 validates a shear thinning response of 0.58 Pa.s. Furthermore, in the quasi-plateau plot zone, the viscosity of the GPL decreased beyond 50 s^{-1}. The curve displayed a linear increase up to 50.1 Pa. s at 100 s^{-1}, as shown in Figure 2.

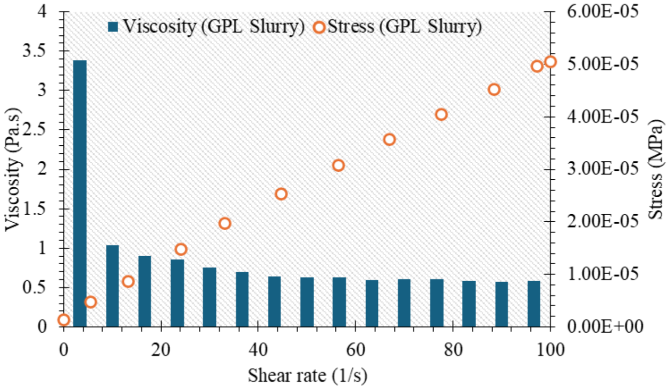

Figure 2: Flow and viscosity plots as a function of the shear rate of GPL slurry.

At a shear rate of 100 s^{-1}, the GPL_DC mixture's viscosity was determined to be 4.99 Pa. s, while the GPL_FC mixtures was 4.23 Pa. s (Figure 3). The viscosity of the GPL_DC particles increased during shear deformation. Similar trends in pycnometer results, which displayed equivalent bulk density values, can be linked to this tendency. The flow properties of GPL slurries were greatly impacted by the presence of ceramic fillers, which resulted in decreased workability during the initial mixing stage. System densification is the main cause of this decline [19]. The apparent viscosity of the slurry increased by more than eight times when ceramic fillers were added. It went from 10 s^{-1} to 100 s^{-1}. The system continued to behave in a pseudoplastic manner, as seen by the viscosity decreasing as the shear rate increased [20]. To find the dynamic yield stress and plastic viscosity of the matrices under study, curve fitting with the Bingham model was utilized.

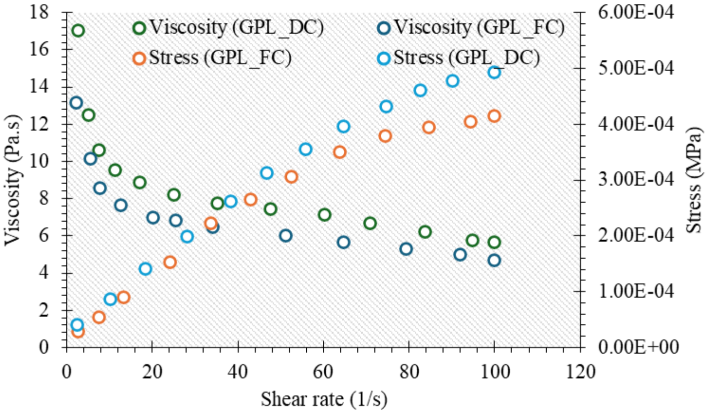

Figure 3: Flow and viscosity plots versus shear rate of GPL_FC and GPL_DC mixes.

4 Conclusion

The geopolymer slurry's apparent viscosity was enhanced by adding ceramic filler while preserving a pseudoplastic reaction. For instance, the plastic viscosity increased to over 5.89 Pa. s with a yielding stress surpassing 24.98 Pa. with the addition of dichroite fillers. The FC particles preserved the mechanical integrity of the composite cellular geopolymer mortar, exhibiting a compression strength of approximately 11.29 MPa. The slurry's apparent viscosity grew dramatically from 10 s^{-1} to 100 s^{-1}, frequently by more than eight times, with the addition of ceramic fillers, while the system's pseudoplastic behavior stayed the same. This innovative approach holds promise for diverse engineering applications, offering lightweight, durable materials with enhanced thermal insulation capabilities

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