

Synthesis and Characterization of Functional Composite Carbon-Geopolymers for Precast Panel Application

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Abstract. The purpose of this study is to examine the influence of carbon (C) particles as filler (aggregate) in the production of geopolymers functional composite for possible precast panel application. Geopolymers was synthesized through alkali activation of metakaolin added with carbon particles relative to the mass of metakaolin. The mixture was cured at 70°C for 2 hours and the resulting composites were stored in open air for 28 days. The bulk density and the apparent porosity of the composites were measured by using Archimedes method. The thermal properties of the samples was examined by using thermal conductivity measurement and differential scanning calorimetry (DSC). The microstructure characterization of the samples were performed by using x-ray diffraction (XRD) and Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS).

1 Introduction

Geopolymer is a new type of inorganic polymers synthesized through alkali activated Aluminosilicate materials at temperature below 100°C [1]. This new inorganic material consists of polymeric chains of –Si–O–Al– similar to zeolite but its network is amorphous [2,3]. Geopolymers is well known for its high early strength, low shrinkage, acid, corrosion, and fire resistance [3,4]. Nowadays, geopolymers can be synthesized from kaolin, clays, fly ash, red mud and other aluminosilicate materials [1].

This study utilized metakaolin as a raw material to produce geopolymers paste. Metakaolin is dehydroxilated product of kaolinite mineral at temperature around 750°C [2,5]. Geopolymers produced from metakaolin has already applied in many areas due to its excellent physical and mechanical properties [8]. Similarly, geopolymers synthesized from

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fly ash has also been applied as green concrete in many areas such as precast floor panels, airport runways, and pedestrians paths [4,5,9,12].

Functional composite is a material comprising two or more different starting materials, engineered to gain high performance material [1]. In this study, geopolymers were synthesized by adding carbon (C) particles as aggregate. The use of carbon fiber and particulates as filler (aggregate) of geopolymers have studied intensively in recent years. The addition of carbon fibers or particulates was found to improve the compressive, flexural, and tensile strength as well as heat resistance of geopolymers. The effectivity of carbon fibers and carbon nanoparticles with geopolymers matrices were studied at 750°C and revealed that the carbon fibers or nanoparticles did not react with geopolymers constituents [8,10,11].

2 Experimental method

Geopolymers paste were synthesized through alkali activation of metakaolin. The composition of the starting materials were adjusted to achieved the molar ratio of $\text{SiO}_2/\text{Al}_2\text{O}_3 = 3.0$, $\text{Na}_2\text{O}/\text{SiO}_2 = 0.25$, and $\text{H}_2\text{O}/\text{Na}_2\text{O} = 10$. Carbon particles were produced by burning coconut shell, grounded and shieved 200 mesh. The quality of carbon was examined by x-ray diffraction. The mass of carbon particles was varied from 1.0%, 1.5%, and 2.5% relative to the mass of metakaolin. The mixture between geopolymer paste and carbon particles was stirred manually and poured into plastic mold and cured at 70°C for 2 hours. The resulting composites were aged 14 days before conducting any measurements.

The bulk density and porosity of the resulting composites were measured by using Archimedes method. The flexural strength of the composites were measured by using three bending flexural measurement. The thermal properties of the materials were studied by using thermal conductivity measurement and Differential Scanning Calorimetry (DSC). The chemical composition and microstructure characters of the resulting materials were examined by using X-ray Diffraction (XRD) and Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS).

3 Results and discussion

Fig. 1 shows diffractogram of metakaolin and carbon particles used this study. Both metakaolin and carbon particles have amorphous structures. Metakaolin contain quartz which is originated form kaolinite mineral.

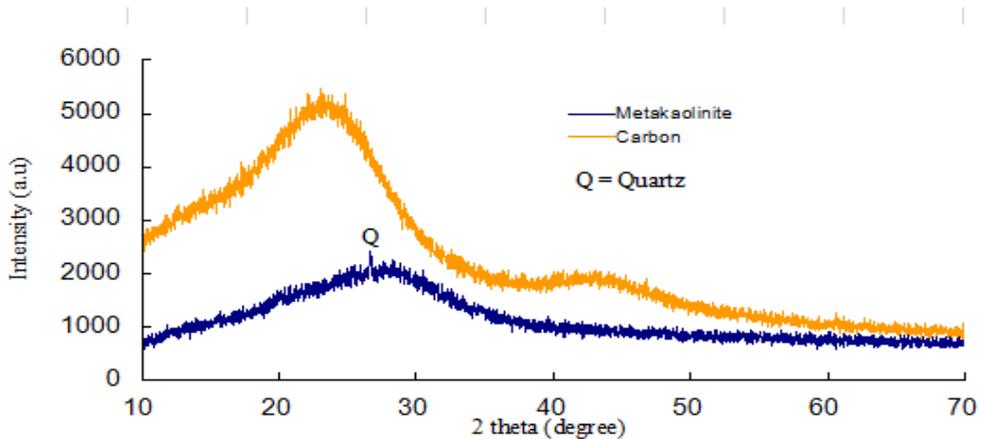


Fig. 1. Diffractogram of metakaolin and carbon particles.

Fig. 2 shows example of carbon-geopolymers composites produced in this study. Sample (a) contain 1.5% carbon, and sample (b) contain 2.5% carbon relative to the mass of metakaolin. Scratch on the surface of sample (B) was originated from defect on the surface of mold.



Fig. 2. Carbon-geopolymers composite (a) 1.5%, (b) 2.5% of carbon relative to the mass of metakaolin.

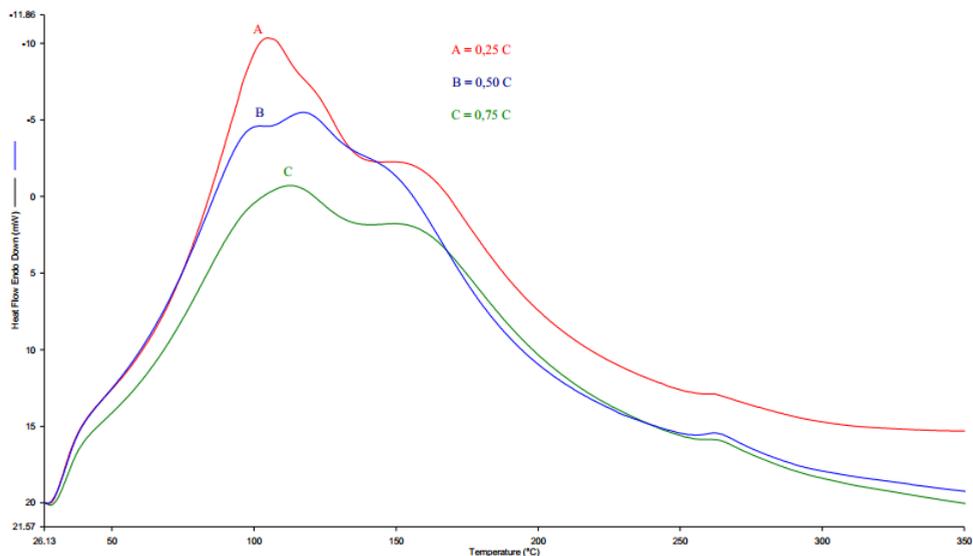
The maximum mass of of carbon particles added into geopolymers paste was 2.5% relative to the mass of metakolin. The addition of more carbon into the geopolymers paste keeping constant the concentration of alkali solution will be difficult to mix and results in low strength composite. The bulk density and apparent porosity of the resulting composites were determined by Archimedes method. Table 1 shows the density, the apparent porosity as well as electrical conductivity of the composites. The density and the apparent porosity of the samples revealed that the resulting composites were light and the incorporation of carbon did not increase the volume of pores in the bulk of geopolymers. The thermal and electrical conductivity was measured since carbon is a material with good thermal and electrical properties. The addition of carbon into geopolymers matrices was found to increase the thermal conductivity and it was higher than those made from standard metakaolin geopolymers [4].

Table 1. Bulk density, apparent porosity, thermal and electrical conductivity of produced composites.

No.	Sample	Density (g/cm ³)	Apparent Porosity (%)	Thermal Conductivity (W/mK)	Electrical Conductivity (S/cm)
1	Geo-C 1.0%	1.62	8.72	0.77	9.47E-07
2	Geo-C 1.5%	1.63	6.67	0.78	1.21E-06
3	Geo-C 2.5%	1.65	8.20	0.83	1.37E-06

The addition of carbon was found to increase the electrical conductivity of the composites but their magnitudes were still in the range of insulator materials [7].

Fig. 3 shows the DSC results of the composites. The measurement was conducted at temperature range 30–400°C with a heating rate of 20°C/minutes. The addition of carbon particles reduced the heat flow and the enthalpy of the composites. The enthalpy of composite contain 1.0% carbon was 315.5406J/g, 278.2725J/g for 2%, and 259.851 J/g for 2.5% carbon. This results are in good agreement with thermal conductivity measurements which showed that the addition of carbon increased the thermal conductivity of the composites.

**Fig. 3.** DSC results of carbon-geopolymer composites with different concentration of carbon.

Diffraction patterns of the resulting composites is shown in Fig. 4 which showed typical amorphous structure of geopolymers made from metakaolin. The reaction between alkali solution with aluminosilicate species in geopolymers formed a phase of sodium dialuminum phyllo-decaoxodihydroxoalumotrisilicate, $\text{NaAl}_2(\text{AlSi}_3)\text{O}_{11}$. The addition of

carbon was found did not affect the amorphous structure of geopolymers and a small hump observed between 40 – 45° 2θ was due to the amorphous structure of carbon.

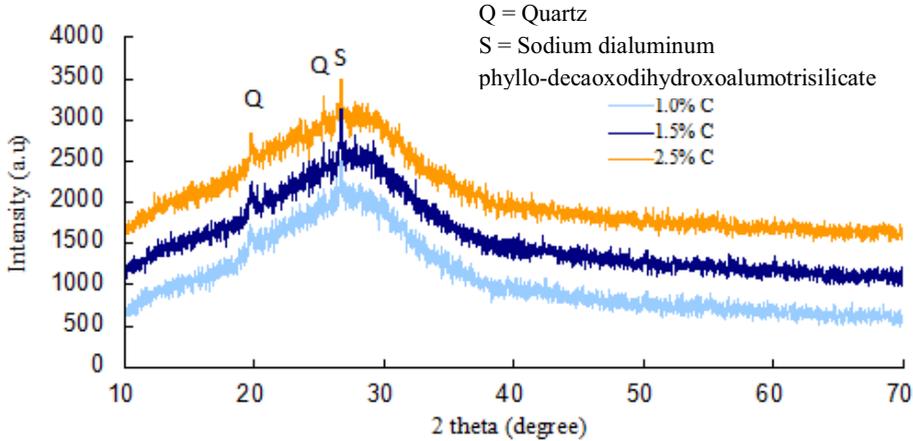


Fig. 4. Diffractogram patterns of carbon-geopolymer composites.

The resulting composites were calcined at 750°C to examine the formation of new phases due to high temperature and reaction between carbon particles with other constituent of geopolymers. Fig. 5 shows diffractogram of calcined composites in which the peaks of amorphous structure of geopolymers shifted to lower 2θ indicating restructure of geopolymers network [4]. Besides that, calcination at 750°C caused the loss of $\text{NaAl}_2(\text{AlSi}_3)\text{O}_{11}$ phase from the network of geopolymers.

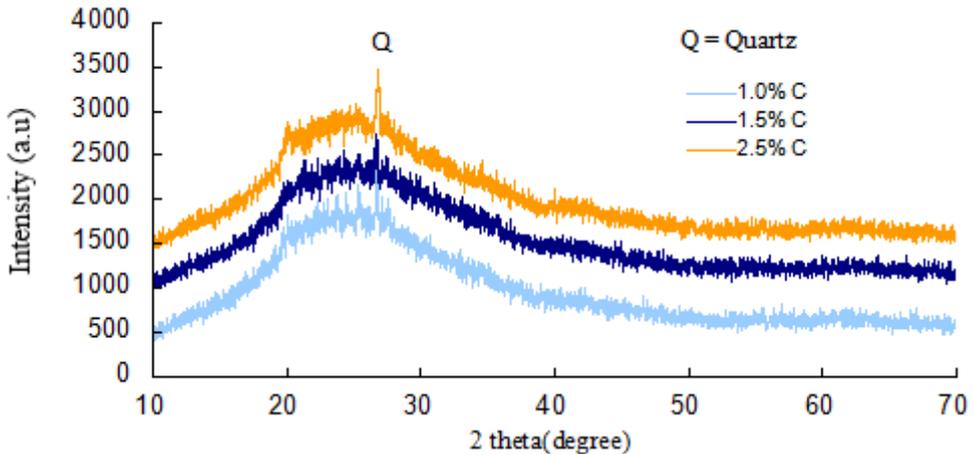


Fig. 5. Diffractogram of calcined carbon-geopolymer composites

Fig. 6 shows SEM images of the surface of the samples. The images showing the interface between carbon particles and geopolymers matrices. The bond between carbon and geopolymers matrix become weaker as the concentration of carbon increase as can be seen in Fig. 6C which shows the propagation of cracks around the interfacial zone between carbon particle and the matrix. Figure 6A and 6B showed that the bond between carbon particle and the matrix is strong and there is no sign of cracks development. This suggest that the addition

of excess carbon into the geopolymers matrix will affect the strength of the resulting composites.

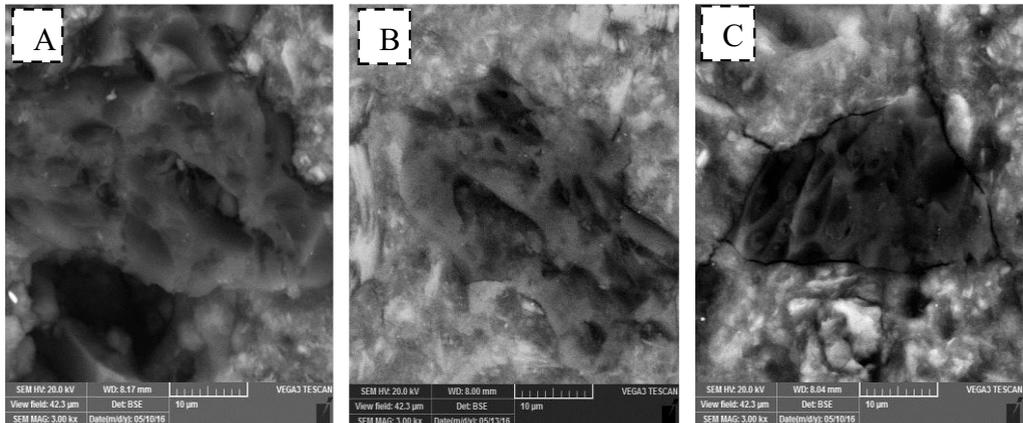


Fig. 6. SEM images of carbon-geopolymer composites contain (a) 1.0% (b) 1.5% (c) 2.5% of carbon particles.

4 Conclusion

The synthesis and characterizations of functional composite carbon-geopolymers have been conducted. The geopolymers matrix was synthesized through alkali activation of metakaolin and carbon was derived from burning coconut shell. The resulting composites reveal good surface quality, amorphous structure and good thermal and electrical conductivity for precast panel application. The maximum content of carbon which result in good quality of composite was 1.5%. SEM investigation showed that the bond between carbon and the matrix for samples containing 1% and 1.5% of carbon was strong and did not show any cracks opening.

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