

Development of Coconut Trunk Fiber Geopolymer Hybrid Composite for Structural Engineering Materials

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Abstract. A research on the influence of coconut fiber trunk on mechanical properties based on fly ash has been conducted. The aims of this study was to examine the mechanical properties of geopolymer composites by varying the concentration of coconut trunk fiber. Geopolymer synthesized by alkali activated ($\text{NaOH} + \text{H}_2\text{O} + \text{Na}_2\text{O} \cdot 3\text{SiO}_2$) and cured at the temperature 700°C for one hour. Specimens were synthesized into 5 different mass of fiber 0 g, 0.25 g, 0.50 g, 0.75 g, and 1.00 g keeping fly ash constant. The highest compressive strength was 89.44 MPa for specimen added with 0.50 g of fiber. The highest flexural strength was 7.64 MPa for the same sample. The interfacial transition zone (ITZ) between the matrix of geopolymers and coconut fiber was conducted by using Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS). The chemical composition of the specimen was examined by using X-Ray Diffraction (XRD). The thermal properties of coconut fiber trunk was analyzed using Differential Scanning Calorimetry (DSC). It was found that coconut fiber was able to improve the mechanical and microstructure properties of geopolymers composites.

1. Introduction

The technology of geopolymers composites is promising due to their excellence in binder performance based on various alumino silicate material [1,2]. Geopolymers is an inorganic material synthesized through polymerization of alumino silicate minerals such as fly ash, metakaolin, furnace slag, and laterite soils [3]. Composite is a material consist of two or more starting materials which have different chemical properties. The resulting material show different properties from its constituents. Composite consist of matrix (binder) and aggregate (reinforcement) [4]. Research on geopolymers attracted a lot of attention because of its excellence properties such as mechanical strength, heat and fire resistance, as well as simple and low energy production [5, 6]. Fly ash is waste product of burning coal commonly found in power plants [7]. The amount of fly ash is increasing year by year and require careful handling. Intensive research is needed to convert this waste material into an environmentally and functional materials. Geopolymers is a promising material to meet these requirement by converting fly ash into composites such as green concrete for wide range applications. Fly ash is alumino silicate material rich with SiO_2 , Al_2O_3 , CaO and Fe_2O_3 [8]. Coconut fiber is a natural fiber produced from coconut trunk. This fiber showed high resistance for structural application and renewable [9,10]. Geopolymers is a good binder material and the addition of coconut fiber as an aggregate will produce a high quality of composite for many potential applications [11,12].



2. Method

Geopolymer paste was produced through alkali activation of fly ash mixed with coconut trunk fiber. The amount of fiber was varying from 0 g, 0.25 g, 0.5 g, 0.75 g, and 1 g relative to the mass of fly ash. The fiber was extracted manually from the coconut trunk, cut into 3 – 5 cm long, and immersed into NaOH solution for 1 hour. The mixture between geopolymers paste and fiber was poured into plastic mold and cured at 70°C for 1 hour. Samples were demolded after 2 days and then stored for 28 days before conducting any measurements. The mechanical properties of the samples were examined through compressive and flexural strength measurement. The microstructure of the samples was studied by using scanning electron microscope (SEM) and X-Ray Diffraction (XRD).

3. Results and Discussion

Fly ash used in this study was taken from Bosowa power plant in Jenepono, South Sulawesi. The morphology elemental composition of fly ash was examined by means of SEM coupled with energy dispersive spectroscopy (EDS). Figure 1 shows the SEM image and EDS spectrum of fly ash particle. The image shows the distribution of spherical fly ash particles with a size below 10 μm . The result of elemental analysis by means of EDS is shown in table 1 in which the molar ratio SiO_2 and Al_2O_3 is 2:1 indicating good quality of geopolymers starting material.

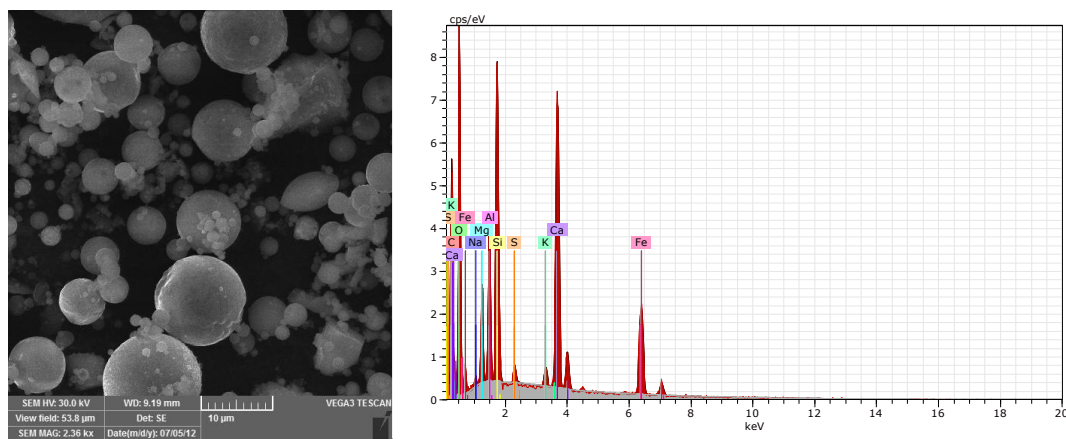


Figure 1. SEM Image and EDS Spectrum of fly ash

Table 1. EDS Analysis of fly ash

Element	Unn,C [wt.%]	Compound norm C	Comp C [wt.%]
Sodium	0.56	Na_2O	1.06
Magnesium	3.51	MgO	8.22
Aluminum	5.23	Al_2O_3	13.94
Silicon	8.05	SiO_2	24.30
Sulphur	0.51	SO_3	1.78
Potassium	0.73	K_2O	1.25
Calcium	14.14	CaO	27.91
Iron	11.86	FeO	21.53

Figure 2 shows the morphology and diffractogram of coconut trunk fiber. Fig 2.A examined the SEM image of surface which appear coarse. In addition, the diffractogram exhibited the amorphous structure

which contained 2-hydroxy-1,2-di(phenyl)ethanone phase around 86% and quartz 18%. Tensile strength of coconut trunk fiber was around 195,22 MPa. This value was so high and can use to as aggregate.

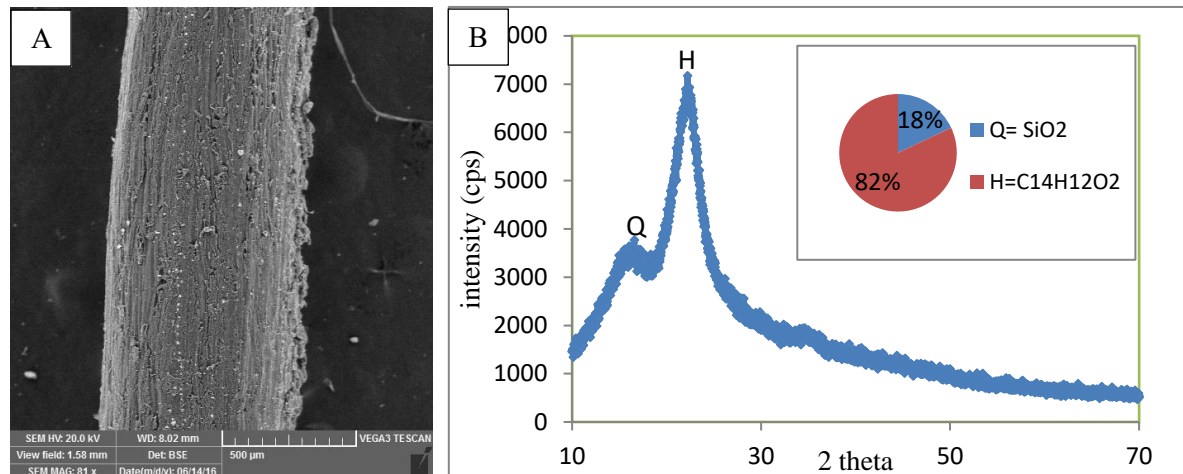


Figure 2. SEM image and Diffractogram of coconut trunk fiber

SEM image of geopolymer composite by using fly ash and coconut trunk fiber can be seen in figure 3(A). There was particle of fly ash which not reacted with alkaline solution. In addition, the surface of sample appeared a crack that caused by polishing process. Figure 3 (B) showed the interface between matrix and aggregate. As we can see on the figure 3 (B) that matrix have a good binding with aggregate. The brighter colour in the right side was matrix because matrix have the higher number of atom than aggregate.

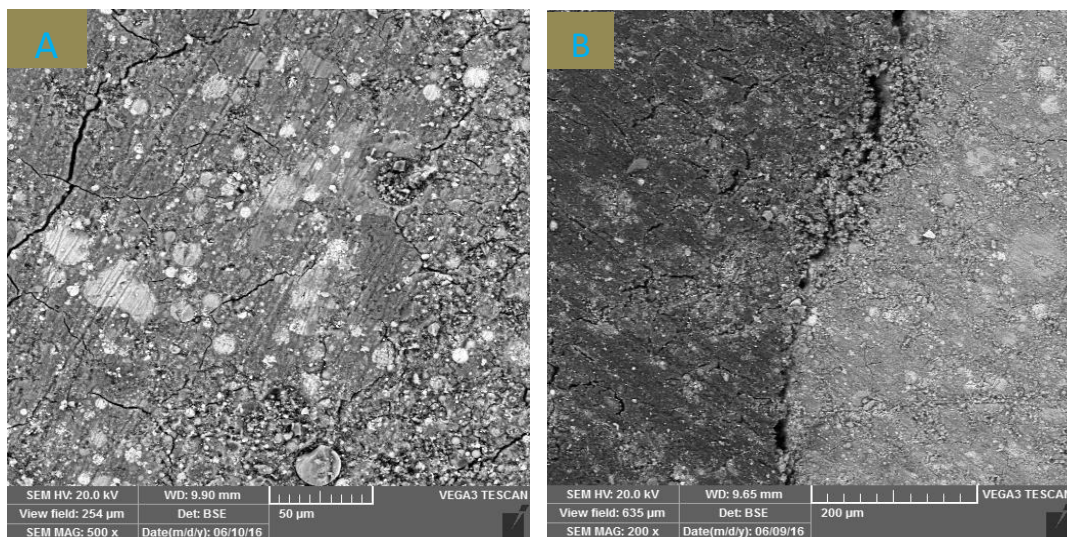


Figure 3. SEM image of fly ash geopolymer composite (a) without fiber, (b) with coconut trunk fiber

XRD characterisation of geopolymer composite based on fly ash with coconut trunk fiber can be seen in figure 4. Based on diffractogram, variation of coconut trunk fiber mass relative toward geopolymer paste have not the influence in structure of geopolymer. But, the intensity of quartz phase become increased at the addition of coconut trunk fiber around 1.00 gram.

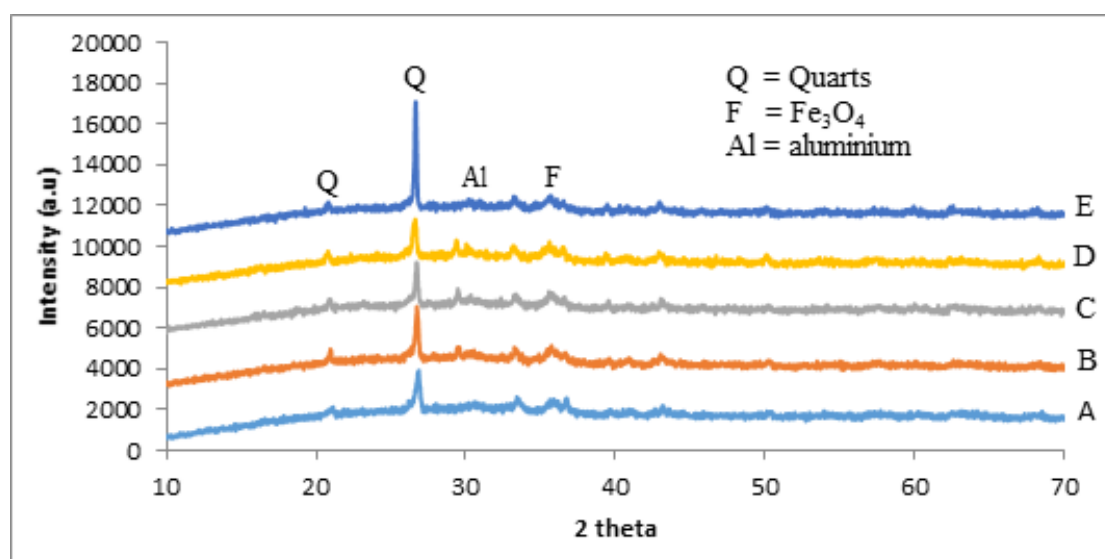


Figure 4. diffractogram of geopolymer comosite fly ash with coconut trunk fiber

Thermal properties measurement of coconut trunk fiber exhibited eksotermic characteristic at 30°C until 190°C, and endothermic characteristic at 310°C - 350°C as in figure 5. This result indicated that coconut trunk fiber influenced the thermal and mechanical properties of composite. But, at temperature 350°C coconut trunk fiber was decomposed.

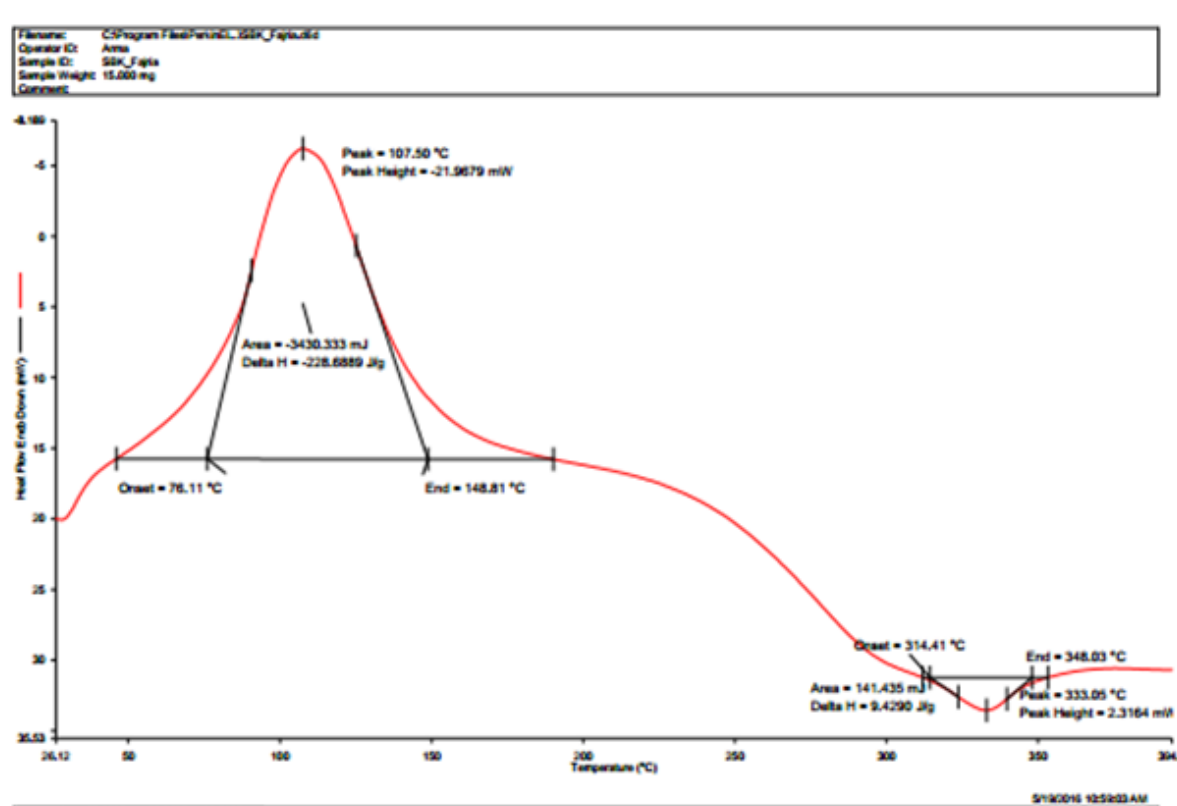


Figure 5. DSC curve of coconut trunk fiber

Table 2. Compressive and flexural strength by varying coconut trunk fiber concentration

No.	Sample Code	<i>Compressive Strength (Mpa)</i>	<i>Flexural Strength (Mpa)</i>
1	FASBK_T Serat	80.72	74.43
2	FASBK_0.25 g	56.89	43.31
3	FASBK_0.50 g	89.44	76.44
4	FASBK_0.75 g	38.44	47.74
5	FASBK_1.00 g	39.33	47.70

Table 2 shows the compressive and flexural strength of geopolymers samples by varying concentration of coconut trunk fiber. As we can see on the table, the highest compressive and flexural strength was sample added with 0.50 g of coconut trunk fiber (FASBK_0.50). Its mean that the best composition of added coconut thrunk fiber was 0.50 g relative from fly ash mass. If the fiber composition was more than 0.50 g, matrix not be capable to bind the aggregate.

4. Conclusion

Coconut trunk fiber is one of the natural fiber that can be used as reinforcement. Mechanical testing result showed that coconut trunk fiber has high of commpressive strength, flexural strength and tensile strength and its can be used as geopolymer composite. Microstructural characterisation show the high phase all of the sample is quartz.

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