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

F Amalia*, N Akifah, Nurfadilla, Subaer
Laboratorium Fisika Material, Jurusan Fisika, Universitas Negeri Makassar, Indonesia
Jl. Daeng Tata Raya, Makassar, Indonesia

*fajriaamalia494@gmail.com

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 (NaOH+H2O+Na2O.3SiO2) 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 SiO2, Al2O3, CaO and Fe2O3 [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 Jeneponto, 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 SiO₂ and Al₂O₃ is 2:1 indicating good quality of geopolymers starting material.

![Figure 1. SEM Image and EDS Spectrum of fly ash](image)

| Element | Unn,C [wt.%] | Compound norm C | Comp C [wt.%] |
|---------|--------------|-----------------|---------------|
| Sodium  | 0.56         | Na₂O            | 1.06          |
| Magnesium | 3.51        | MgO             | 8.22          |
| Aluminum| 5.23         | Al₂O₃           | 13.94         |
| Silicon | 8.05         | SiO₂            | 24.30         |
| Sulphur | 0.51         | SO₃             | 1.78          |
| Potassium| 0.73         | K₂O             | 1.25          |
| Calcium | 14.14        | CaO             | 27.91         |
| Iron    | 11.86        | FeO             | 21.53         |

Table 1. EDS Analysis of fly ash

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](image)

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](image)

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.
Thermal properties measurement of coconut trunk fiber exhibited exothermic 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.
Table 2. Compressive and flexural strength by varying coconut trunk fiber concentration

| No. | Sample Code  | Compressive Strength (Mpa) | Flexural Strength (Mpa) |
|-----|--------------|----------------------------|-------------------------|
| 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 trunk 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 compressive 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.

References
[1] T. Balarami Reddy 2013 Mechanical Performance Of Green Coconut Fiber/Hdpe Composites. Journal Of Engineering Research And Applications Vol.3, Issue 6, pp. 1262-1270.
[2] Kuncoro Diharjo 2013 Pengaruh Kandungan Dan Ukuran Serbuk Genteng Sokka Terhadap Ketahanan Bakar Komposit Geopolimer, Jurnal Rekayasa Mesin Vol.4, No.1.
[3] Riger Manuahe 2014 Kuat Tekan Beton Geopolymer Berbahan Asap ABU (Fly Ash), Jurnal Statik Vol.2 No.6.
[4] Anupama Sai Priya N. P. Veera Raju, P. N. E. Naveen 2014 Experimental Testing of Polymer Reinforced with Coconut Coir Fiber Composites. International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 12.
[5] Zhao Q, B. Nair, T. Rahimian, P. Balaguru 2007 Novel geopolymer based composites with enhanced ductility, J Mater Sci, pp 3131–3137.
[6] Li Lin, Shaobin Wang, Zhonghua Zhu 2006 Geopolymeric adsorbents from fly ash for dye removal from aqueous solution. Journal of Colloid and Interface PP. 52–59.
[7] Subaer 2016 The Influence of Si:Al and Na:Al On The Physical and Microstructure Characters of Geopolymers Based on Metakaolin, Materials Science Forum Vol. 841, PP 170-177.
[8] Olawale Margaret Damilola 2013 Syntheses, Characterization And Binding Strength Of Geopolymers: A Review, International Journal Of Materials Science And Applications, Vol. 2, No. 6, pp 185-193.
[9] Bongarde U.S, V.D.Shinde 2014 Review On Natural Fiber Reinforcement Polymer Composites, International Journal Of Engineering Science And Innovative Technology (IJESIT),Volume 3, Issue 2.
[10] S B V J Chand Badshah 2015 Fabrication and mechanical properties of natural (coconut) & synthetic fibers (glass fibers) reinforced polymer composites material. International Journal of Emerging Trends in Engineering Research (IJETER), Vol. 3 No. 6, pp 483 – 488.
[11] Jahagirdar Muneerabibi S 2014 Biodegradable Composites: Vinyl Ester Reinforced With Coconut Fibers and Vinyl Ester Reinforced With Coconut Fibers and Rubber Particles, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 8.

[12] Kinga Korniejenko 2015 Fly Ash Based Fiber-Reinforced Geopolymer Composites as the Environmental Friendly Alternative to Cementitious Materials, Proceedings of International Conference on Bio-Medical Engineering and Environmental Technology, London, pp. 164-171.