Synthesis and characterization of polymer concrete with pumice aggregate and singkut leaf fiber as filler

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Abstract. Polymer concrete have been made based sand, pumice, epoxy resin, and singkut leaf fiber as fillers. The manufacture of polymer concrete uses block-shaped molds with a size of 100 mm x 20 mm x 10 mm with the press molding method using a hotpress. Variations in the composition polymer concrete of sand, pumice stone, singkut leaf fiber, and epoxy resin, namely 60:20:0:20 g, 60:18:2:20 g, 60:16:4:20 g, 60:14:6:20 g, 60:12:8:20 g, and 60:10:10:20 g. The variation in the composition was made into 2 groups of variations based on the concentration of NaOH used to singkut the leaves, namely the leaves with immersion of 5% NaOH and 13% NaOH. The polymer concrete then characterizes its physical properties (density and water absorption), mechanical properties (flexural strength, compressive strength, tensile strength), and SEM-EDX. The results of characterization carried out on concrete samples, show that the best composition is (60:18:2:20) g (5% NaOH content) with a density value of 1.74 g/cm\textsuperscript{3}, water absorption of 0.34%, flexural strength amounted to 37.07 MPa, compressive strength of 60.18 MPa, tensile strength of 8.33 MPa. The results of microstructure testing showed that the polymer concrete samples with a mixture of sand, pumice, epoxy resin, and singkut leaf fiber were mostly dominated by the element C (carbon).

1. Introduction

Concrete is the most widely used building material on earth. Nowadays, the growth and development of the construction industry in Indonesia is growing rapidly. The construction of concrete has the advantage that the material is easy to obtain, has high compressive strength, and is easy to maintain. However, the tensile strength of concrete is only about 10% of its compressive strength. To overcome these weaknesses, since the end of 1960 a solution has been found using fiber reinforced concrete (FRC) or better known as fiber concrete [1]. Another weakness of concrete as a construction material is its low flexural strength and brittle nature, so that concrete requires other solutions to increase tensile strength and flexural strength. Developed countries such as America and England have developed a concept to improve the weakness of concrete by adding fiber to the concrete mix. The fibers are scattered randomly in the concrete mix so as to prevent premature cracking [2]. The split tensile strength of concrete with the addition of areca bark fibers and sawdust in the variation of concrete has an increase in the tensile strength of normal concrete in variations of 0.25% and 0.5%, namely 3.002 MPa or 12.272% and 2.790 MPa or 4.369% [3]. Tadepalli (2015) uses steel fibers, the aim is to determine the dosing effect of steel fibers on the shear and bending capacity of concrete. The shear capacity of the concrete increased significantly by 90.4 MPa with the addition of 0.55 steel fibers [4]. The use of fiber concrete can increase the tensile strength of concrete, reduce cracks that
occur in the concrete, increase the compressive resistance of concrete and increase the ductility of concrete [5]. Awan Maghfirah (2020), making paving blocks using coffee husk waste, obtained a density value of 1.619 gr/cm$^3$, a porosity of 20%, water absorption of 12.334%, flexural strength of 8.68 MPa, compressive strength of 11.61 MPa and tensile strength amounting to 6.41 MPa [6]. The addition of bamboo fibers to the concrete mixture affects the compressive strength and tensile strength of the concrete. There was an increase in the compressive strength and tensile strength of concrete in the mixture with a percentage of the addition of bamboo fibers by 1% due to the role of bamboo fibers in resisting cracks due to excessive loads that occur in concrete [7]. In this research, sand-based polymer concrete, pumice stone, singkut leaf fiber and epoxy resin have been made. Singkut leaf fiber is one of the fibers that has the potential to be added to the concrete mix. Conventionally, the benefits of singkut leaves are as a binder (rope-changing material) because of the very strong fiber. Lemba (Curculigo latifolia) or singkut leaves are traditionally used as a source of doyo silk woven fabrics. Singkut leaf fiber is used for the traditional practice of weaving doyo cloth. [8]. Pumice can be used as an alternative filler because pumice contains chemical elements that can increase the bond strength that occurs in the volcanic component of rubber pumice [9]. The use of pumice stones in this study is as an aggregate. Aggregates are grains of hard and dense material in the form of sand, gravel, crushed stone which when mixed with binding agents and fibers containing cellulose will produce a material that has elastic properties [10-13]. So that the addition of singkut leaf fibers and the use of pumice as an aggregate are expected to increase the tensile strength, flexural strength, and compressive strength of polymer concrete.

2. Materials and Methods

The raw materials for this study consisted of sand and pumice stone taken from Tuntungan River, Pancur Batu District, Deli Serdang Regency. Singkut leaf plants are taken from the Kabanjahe area, Karo district, North Sumatra. Epoxy Resin (Epoxy Resin and Epoxy Harder Technology and Licensed from Germany) which was purchased from PT. Justus Kimiaraya, and NaOH solutions with concentrations of 5% and 13% which were purchased from CV. Rudang Jaya Medan, North Sumatra. Sand and pumice stone are smoothed and sieved with a 100 mesh sieve. Singkut leaves that have been dried are cut into 1 cm size, soaked using 5% and 13% NaOH solution for 24 hours, rinsed using distilled water until the pH is neutral and dried in the sun to dry. Sand, pumice stone, singkut leaf fiber, and epoxy resin are mixed according to the variation in the composition as shown in Table 1. It is printed with a size of 100 mm x 20 mm x 10 mm then pressed using a hot press at 90°C for 20 minutes. The polymer concrete samples that have been printed are then characterized by physical properties (density, water absorption), mechanical properties (bending strength, compressive strength, tensile strength), and surface morphology using SEM-EDX.

| Composition | Sand (gr) | Concrete (gr) | Singkut leaf fiber (gr) | Epoxy Resin (gr) |
|-------------|-----------|---------------|-------------------------|------------------|
| 1           | 60        | 20            | 0                       | 20               |
| 2           | 60        | 18            | 2                       | 20               |
| 3           | 60        | 16            | 4                       | 20               |
| 4           | 60        | 14            | 6                       | 20               |
| 5           | 60        | 12            | 8                       | 20               |
| 6           | 60        | 10            | 10                      | 20               |

3. Result and Discussion

3.1. Density

The density value of polymer concrete is shown in Figure 1. The maximum density value is found in sample 2 (60:18:2:20) in which the result was 1.82 g/cm$^3$, in the fiber of singkut leaves soaked with
13% NaOH solution. Polymer concrete containing singkut leaf fibers has a higher density value when compared to polymer concrete without singkut leaf fibers. However, the density value decreases with the increase in the fiber composition of the singkut leaves. The more addition of singkut leaf fibers causes the epoxy resin adhesive not to bind the material well, so that the density is lower.

![Density Graph](image)

**Figure 1.** Graph of Relation between Density and Composition

### 3.2. Water Absorption
Figure 2 shows the water absorption test value of polymer concrete. The optimum water absorption value was found in sample 6 (60:10:10:20) in which the result was 5.7 g/cm³, in the fiber of singkut leaves soaked in 13% NaOH solution. Polymer concrete containing singkut leaf fibers has lower water absorption value when compared to polymer concrete without singkut leaf fibers. However, the value of water absorption increases with the increase in the composition of the fiber of the leaves. The more addition of singkut leaf fibers causes the epoxy resin adhesive not to bind the material well, so that its water absorption is higher.

![Water Absorption Graph](image)

**Figure 2.** Graph of Relation between Water Absorption and Composition

### 3.3. Flexural Strength
The Flexural Strength of the polymer concrete samples was tested using the Universal Testing Machine RTF-1350. The flexural strength value of polymer concrete is shown in Figure 3. The results of the flexural strength test show that the optimum flexural strength value is found in sample 2 (60:18:2:20) which is 60.18 MPa with 2 grams of singkut leaves content. Fiber is an additional material that can be used to improve the ductile properties of brittle concrete. Increasing the fiber
aspect ratio will have an effect on the tensile strength and flexural strength of the concrete, as well as the addition of fiber volume to the concrete mixture [14]. Singkut leaves have medium to long fiber quality fibers and good fiber bonds so that they can add to the flexural strength value of polymer concrete. Theoretically, the silica element found in pumice serves to increase the bending strength of a material. The decrease in the flexural strength of the concrete is caused by a decrease in the level of workability of the concrete along with the addition of the percentage of singkut leaf fibers in the concrete mixture. This results in the creation of cavities or voids in the concrete and disruption of the bonding between the resin and the aggregate in the concrete.

![Graph of Relation between Flexural Strength and Composition](image)

**Figure 3.** Graph of Relation between Flexural Strength and Composition

### 3.4. Compressive Strength

The Compressive Strength of polymer concrete samples was tested using the Universal Testing Machine RTF-1350. The flexural strength value of polymer concrete is shown in Figure 4. The optimum compressive strength value is found in sample 2 (60:18:2:20) which is 60.18 MPa with 2 g of singkut leaves.

![Graph of Relation between Compressive Strength and Composition](image)

**Figure 4.** Graph of Relation between Compressive Strength and Composition

The polymer concrete sample contains 18 g of pumice stone affects the hardness properties of a material so that the compressive strength value reaches the optimum value. However, the addition of higher quantity of fiber to the sample will actually decrease its compressive strength value. The decrease in compressive strength occurs because the fiber will reduce the level of concrete density so that it can affect the ability of concrete to distribute compressive forces to aggregate grains [14].
3.5. Tensile Strength
The tensile strength of the polymer concrete samples was tested using the Universal Testing Machine RTF-1350. The tensil strength value of polymer concrete is shown in Figure 5. The optimum tensile strength value is found in sample 2 (60:18:2:20), which is 6.42 MPa with 2 grams of singkut leaves content. Figure 5 shows that the addition of singkut leaf fibers to the polymer concrete sample will decrease the tensile strength value. This is because the fiber content is expansive or absorbs water. Eichorn (2001) states that natural fibers have hydrophilic characteristics, which are easy to absorbs water. So that the water which initially functions as an activator of the hydration properties of the bonds between cement is reduced and causes the tensile strength of the concrete to become weak [15]. Research conducted by Nurul (2017) in the journal of the effect of palm fiber as an added material on the split tensile strength of concrete shows that the addition of fibers causes the tensile strength to increase if it is in a small percentage but causes a decrease in tensile strength along with the addition of a significant percentage of palm fiber [16].

![Figure 5. Graph of Relation between Tensile Strength and Composition](image)

3.6. Morphological Analysis
The morphology of polymer concrete without and with singkut leaf fibers was tested using a SEM (Scanning Electron Microscope) -EDX (Energy Dispersive X-Ray Spectrometer) tool and the results can be seen in Figure 6 and Figure 7. Figure 6 shows the morphology of polymer concrete composition 1 (60:20:0:20). Figure 7 shows the morphology of polymer concrete composition 2 (60:18:2:20). The morphology of polymer concrete sample 1 is smoother than polymer concrete sample 2. This is because in sample 1 there is no fiber so that the epoxy resin can bind the material well. SEM-EDX polymer concrete analysis was carried out to determine the elemental composition of polymer concrete. EDX analysis shows a graph of the relationship between two parameters, namely the element energy in keV and the intensity of the calculation (cps/count per second). Figure 6 shows the elements in polymer concrete with a composition of 1 (60:20:0:20). The dominant percentage (% weight) was C (Carbon) 46.12%, O (Oxygen) 23.71%. These two elements are the main elements of sand.
Figure 6. Morphology and EDX Results of polymer concrete samples composition 1 (60:20:0:20) with a magnification of 2500X

Figure 7. Morphology and EDX Results of polymer concrete samples composition 2 (60:18:2:20) with a magnification of 2500X
Meanwhile, Figure 7 shows the elements in polymer concrete with a composition of 2 (60: 18: 2: 20). The dominant percentage is still dominated by C (Carbon) 68.31%, O (Oxygen) 16.08%. The reduced oxygen content shows that the sample added with 2 g of singkut leaf fiber becomes denser, has less voids or cavities, when compared to samples without the addition of fiber.

4. Conclusion
The use of singkut leaf fiber as a filler can improve the mechanical properties of polymer concrete. The density value of each sample indicates that the distribution of the pumice stone and the fiber of the leaves increases the density value. Samples reinforced with singkut leaf fibers increased the flexural strength, compressive strength and tensile strength of polymer concrete based on the results of the flexural strength, compressive strength and tensile strength tests. SEM-EDX analysis also showed a reduction in oxygen content due to the addition of singkut leaf fibers. The best composition of polymer concrete is the sample with the lowest addition of singkut leaf fiber.

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