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PRELIMINARY STUDY ON USING IPOMOEA CARNEA (IC) POWDER AS A REINFORCEMENT MATERIAL FOR POLYMER ROOF TILES

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Graphical abstract

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Abstract

Roof tiles play a crucial role in the construction industry by providing protection against sunlight and rain. The quality of roof tiles depends significantly on the materials used and the manufacturing process involved. This study investigates the potential of using Kangkung pagar (Ipomoea carnea) powder as a reinforcement for polymer roof tiles. The composition of the powder and sand varies according to specific volume fractions. In this study, the mix consists of 10% asphalt, 30% polyester, and varying ratios of Ipomoea carnea powder to sand: 10:50%, 20:40%, and 30:30%. The initial process of making roof tiles involves mixing these components. The resulting mixture is then molded and compacted under a pressure of 200 kg/cm². To characterize the mechanical properties of the roof tiles, several tests are performed, including proximate analysis, porosity and density calculations, flexural strength testing, and hardness testing. The results indicate that the composition of the powder and sand significantly influences the properties of the polymer roof tiles. Among the compositions tested, the 30:30 blend of Ipomoea powder and sand yielded optimal values for density, hardness, and flexural strength, measuring 0.994 g/cm³, 19.1 BHN, and 1.71 MPa, respectively.

Keywords: polymer roof tiles; Ipomoea Carnea; mechanical properties

Abstrak

Genteng berperan penting dalam industri konstruksi dengan memberikan perlindungan terhadap sinar matahari dan hujan. Kualitas genteng sangat dipengaruhi oleh material yang digunakan dan proses pembuatannya. Penelitian ini menyelidiki potensi penggunaan serbuk kangkung (Ipomoea carnea) sebagai penguat genteng polimer. Komposisi serbuk dan pasir bervariasi menurut fraksi volume spesifik. Dalam penelitian ini, campuran terdiri dari 10% aspal, 30% poliester, dan berbagai rasio serbuk Ipomoea carnea terhadap pasir: 10:50%, 20:40%, dan 30:30%. Proses awal pembuatan genteng melibatkan pencampuran komponen-komponen ini. Campuran yang dihasilkan kemudian dicetak dan dipadatkan di bawah tekanan 200 kg/cm². Untuk mengkarakterisasi sifat mekanis genteng, beberapa pengujian dilakukan, termasuk analisis proksimat, perhitungan porositas dan kepadatan, pengujian kekuatan lentur, dan pengujian kekerasan. Hasil penelitian menunjukkan bahwa komposisi serbuk dan pasir secara signifikan memengaruhi sifat genteng polimer. Di antara komposisi yang diuji, campuran bubuk Ipomoea dan pasir dengan perbandingan 30:30 menghasilkan nilai optimal untuk kepadatan, kekerasan, dan kekuatan lentur, masing-masing sebesar 0.994 g/cm³, 19.1 BHN, dan 1.71 MPa.

Kata kunci: genteng polimer; ipomoea carnea; sifat mekanis

1.0 INTRODUCTION

Using of composite materials has evolved alongside the increasing global population. Composite polymers serve as a viable alternative to metals, offering several advantages, including excellent mechanical properties, lower density, corrosion resistance, readily available raw materials, relatively low cost, and effective heat and sound insulation [1], Additionally, they can function well as electrical insulators.

Traditional roof tiles are typically made from clay, which requires a costly firing process to convert it into ceramic material. Indriani et al. [2] propose an innovative solution by using waste from Hindu ceremonies to create roof tiles. Their composition consists of 85% clay and 15% ceremonial waste from Bali, resulting in a reduction of 30.6 tons of clay and a similar decrease in waste each year. The quality of the tiles produced still meets the standards outlined in SNI 03-6861.1-2002. However, one drawback of traditional roof tiles is their heavier weight [3].

The use of nutsedge as a roofing tile material combined with an HDPE matrix has an impact on both the radiation heat transfer value and the thermal stability of the composite. The findings of this study indicate that incorporating 20 wt% of nutsedge results in a very low thermal stability value associated with radiation heat transfer [4]. Buasri and Surin [5] demonstrated that higher concentrations of Urea Formaldehyde (UF), Phenolic Formaldehyde (PF), and Polymeric Methyl Diphenyl Diisocyanate (PMDI) lead to an increase in the density of the roof tiles. Among these binders, those using UF are relatively lighter. Additionally, thermal resistance improves when both the density and resin content are lower.

To address these challenges, it is essential to investigate natural materials from Indonesia that can enhance material properties. One such plant that is abundant and easy to cultivate in Indonesia is Ipomoea carnea. This plant grows rapidly, is simple to cultivate, and can even thrive in poor soil conditions [6]. Currently, Ipomoea carnea is used for various purposes, including as a hepatoprotector [7], for isolating active biomolecules [8], in contemporary medicine due to its phytoconstituent content [9], for wastewater treatment [10], and as a reinforcement in polymer composites [11].

The inclusion of Ipomoea carnea fiber can enhance the tensile strength, flexural strength, and impact resistance of the composite [12]. Composites reinforced with Ipomoea carnea (IC) not only increase strength and modulus but also improve wear resistance while remaining lightweight. The optimal performance is achieved with an IC content of 30 wt%. However, if the IC content exceeds 40 wt%, it can lead to pull-out due to a decrease in interfacial adhesion [13].

IC cultivation not only strengthens roof tiles but can also function as a green belt on land contaminated by waste [14]. Additionally, the presence of IC can help regulate mosquito populations, indicating its potential as a synthetic pesticide [15]. This study will investigate the effect of the ratio between IC particles and sand on the performance of the resulting composite roof tiles.

2.0 METHODOLOGY

2.1 Materials

In the manufacture of roof tile composites, four types of materials are used, namely: IC powder, sand, polyester resin, and asphalt.

IC powder. IC stems are obtained from BKT-Jakarta. IC stems are dried in the sun for 20 days. After that, the stems are sawn to get the powder. The sawn powder is then blended to achieve a finer size and filtered through a 60-mesh sieve. Kangkong hedge trees are visible in Figure 1.

Figure 1. Ipomoea carnea plant

Sand. The sand is washed with clean water to reduce mud content, then dried in the sun. Afterward, it is filtered through a 60-mesh sieve. The sand was obtained from Rangkas, as shown in Figure 2.

Figure 2. Sand particle

Polyester resin. Polyester resin is an unsaturated resin of the Yukalac brand, type 157 BQTN-EX, combined with the MEKPO hardener. The ratio of resin to hardener is 1:10. Both components are depicted in Figure 3.

Figure 3. Polyester resin

Asphalt. The asphalt used is solid, specifically the Sealant Bulk brand shown in Figure 4. It is cut to the desired weight and then heated until melted before mixing.

Figure 4. Bulk sealant asphalt

2.2 Sample Coding

Sample preparation was conducted with variations in the composition of powder and sand, as detailed in Table 1, under a compaction pressure of 200 kg/cm².

Table 1. Material Composition

Sample code	IC powder (%)	Sand (%)	Poliester resin (%)	Asphalt (%)
IC10S50	10%	50%	30%	10%
IC20S40	20%	40%	30%	10%
IC30S30	30%	30%	30%	10%

2.3 Material characterization

Proximate analysis. This test aims to determine the nutritional content and chemical properties of hedge kale stems, including water content, ash content, lignin content, and cellulose content. The proximate analysis is performed on cleaned IC stems, which are then ground into powder and processed through a meshing step.

Density and porosity. Density and porosity measurements involve calculating density by measuring the mass of the dry sample and dividing it by its volume [16].

$$\rho = \frac{m}{v} \dots\dots\dots (1)$$

In this equation, ρ represents the density, m indicates the weight of the sample, and v is sample volume. To calculate the porosity, Equation (2) from reference [16] is used:

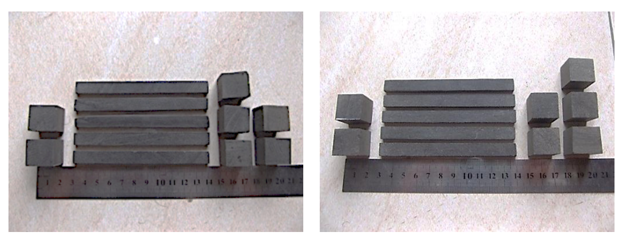
$$n = 1 - \frac{\rho}{\rho_{th}} \dots\dots\dots (2)$$

Surface Hardness. Hardness testing is conducted to determine the surface hardness of the composite sample. This is done using the Brinell hardness method.

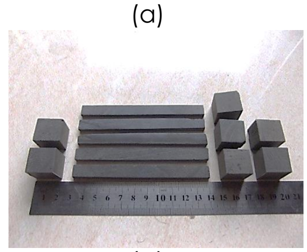
Flexural Strength. The purpose of this test is to assess the resistance and elasticity of the composite sample under a load. The method employed for this test involves three-point bending, as specified in the ASTM D790 standard. A diagram of the flexural test sample is shown in Figure 5. The flexural strength of the composite (σ_f) can be calculated using Equation (3) [17].

$$\sigma_f = \frac{3PL}{2bd^2} \dots\dots\dots (3)$$

Where, P is the bending load, L is the stretch length, b is the width of the specimen, and d is the thickness of the specimen.



(a) (b)



(c)

Figure 5. Flexural testing samples: (a) IC10S50, (b) IC20S40, and (c) IC30S30

3.0 RESULTS AND DISCUSSION

3.1 Proximate analysis

The results of the proximate analysis are presented in Table 2. The water content in IC plant is 22.57%. This high-water content suggests that the plant thrives in humid, wet environments. Water content reflects the presence of dissolved components such as carbohydrates, gums, tannins, starches, and dyes.

Table 2. Proximate analysis IC stems

Parameter	Results (%)	Method
Water content	22.57	SNI 08-7070-2005
Ash content	7.21	SNI 14-1031-1989
Solubility 1%NaOH	26.75	SNI 14-1032-1989
Solubility of alcohol benzene	6.46	SNI 14-1032-1989
Lignin	16.81	SNI 0492-2008
Holocellulose	65.88	SNI 0444-2009
Hemicellulose	19.96	SNI 0444-2009
Alphacellulose	43.95	SNI 0444-2009
Cellulose	29.97	SNI 0444-2009

The ash content in IC is 7.21%. Ash content refers to the chemical components that do not dissolve in water or organic solvents, including Na_2O, K_2O, MgO, and CaO. The high ash content is associated with increased silica content, which contributes to the hardness of the material.

The solubility of extractive substances, such as the 1% NaOH solubility at 26.75%, allows for the determination of low-molecular-weight carbohydrates and lignin, as well as the degree of degradation of chemical components caused by wood-destroying organisms or specific chemical processes. Additionally, the solubility in benzene alcohol, measured at 6.46%, indicates the presence of fats, waxes, resins, oils, and tannin components.

Lignin is an amorphous polymer with a chemical structure that is significantly different from that of cellulose and hemicellulose. In the cell wall, lignin constitutes 16.81% and acts as an adhesive between cells, providing structural strength. It helps reduce dimensional changes caused by fluctuations in water content and possesses anti-toxic properties, which enhance wood's resistance to insect attacks.

Holocellulose, which comprises a total of 65.88% of carbohydrates, includes both cellulose and hemicellulose. The hemicellulose content is 19.96%, while alpha-cellulose accounts for 43.95%. The cellulose content, at 29.97%, plays a crucial role in forming inter-fiber networks through hydrogen bonds between the hydroxyl groups of cellulose.

3.2 Density and porosity

Figure 6 illustrates that the density of the samples decreases as the composition of IC powder increases. The density of these samples is lighter than that of traditional clay roof tiles, which have a density of 1.50 g/cm³. This reduction in density is attributed to a decrease in sand content and an increase in IC powder content. It is well known that sand has a higher density than IC powder. This study agrees with research by Basumatary and Acharya, which indicated that density decreased as the content of IC powder increased [18].

The porosity value decreases as the proportion of the IC rod powder increases, as illustrated in Figure 7. This reduction in porosity occurs because the amount of powder used as filler exceeds the amount of sand. The hard nature of the sand contributes to a higher porosity in the composite, as sand particles are less compressible than IC particles.

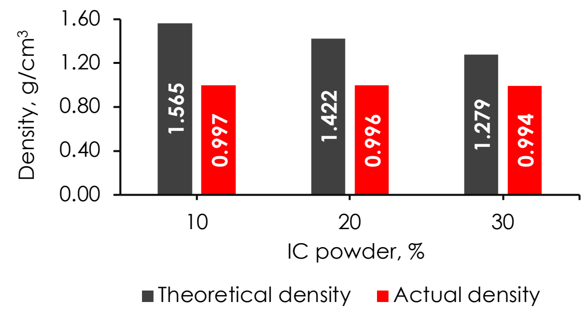


Figure 6. Density of roof tile composites

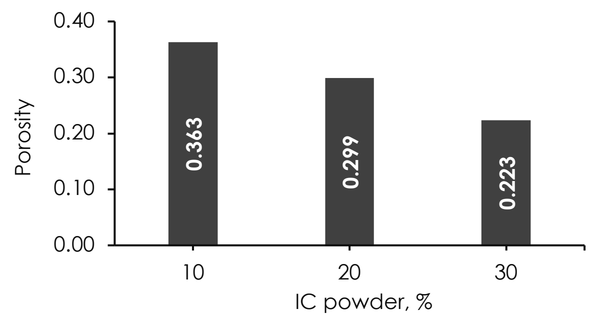


Figure 7. Porosity of roof tile composites

3.3 Flexural strength

Figure 8 indicates that the flexural strength of the composite decreases as the amount of IC particles increases. The flexural strength of the composite produced is still lower than that of commercially available roof tiles. This reduced flexural strength can be attributed to the IC particles functioning as fillers, which diminishes their role in reinforcement.

Furthermore, the flexural strength value of the composite is significantly lower than that of the commercial roof tiles available on the market. This suggests that the quality standard of the developed roof tiles still falls short of the required tensile strength. The flexural strength of roof tiles using IC powder contrasts with previous research, which indicated that the addition of IC fiber to the epoxy composite would enhance flexural strength [18, 19].

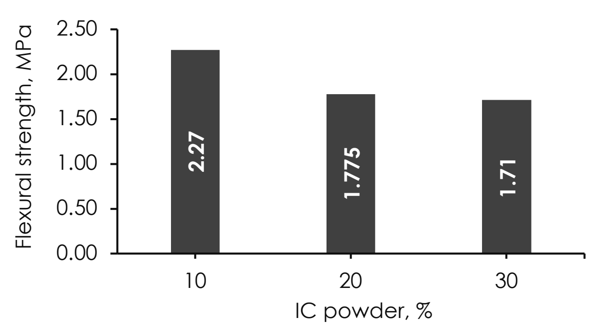


Figure 8. The flexural strength of roof tile composites

3.4 Surface hardness

Figure 9 illustrates that the surface hardness of the roof tile composite increases with the addition of IC particle content. However, the increase in composite hardness is relatively modest. The hardness of the reference roof tiles currently available on the market exceeds 32 BHN. The addition of IC powder to the epoxy composite beyond 30% decreases its wear resistance due to inadequate interfacial bonding of the composite materials [20, 21].

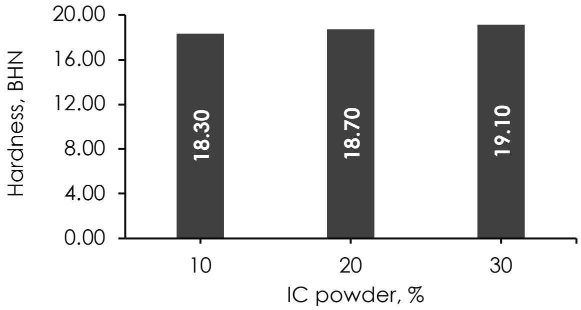


Figure 9. Comparison of the surface hardness of composites

3.5 Statistical analysis

To identify the optimal parameters for roof tiles, the DEAR method is employed. For composite density, we adopt a "smaller is better" approach, while for flexural strength and surface hardness of the composite, we use a "larger is better" criterion. Table 4 shows that the combination of IC particles and sand yields optimal performance.

Table 3. Density, flexural strength, and hardness of roof tile composites

Sample	Density (DS)	Flexural strength (FS)	Hardness (H)
IC10S50	0.997	2.270	18.30
IC20S40	0.996	1.775	18.70
IC30S30	0.994	1.710	19.10

Table 4. Weight of density, flexural strength, and hardness of roof tile composites

Sample	W_D	W_{FS}	W_H	MRPI
IC10S50	0.333	0.394	0.326	20.58
IC20S40	0.333	0.308	0.333	20.43
IC30S30	0.334	0.297	0.340	21.12

4.0 CONCLUSION

Based on the research conducted on the use of Ipomoea Carnea powder as a reinforcement in the manufacturing of polymer roof tiles, the following conclusions have been drawn:

1. Ipomoea Carnea particle, sand, polyester resin, and asphalt can serve as alternative materials for producing polymer roof tiles. The optimal formulation identified in this study is IC30S30, which demonstrates density, flexural strength, and hardness values of 0.994 g/cm³, 1.710 MPa, and 19.10 BHN, respectively.
2. The incorporation of Ipomoea Carnea particles as a reinforcement has not significantly enhanced the mechanical properties of the polymer roof tiles, it has improved their physical properties when compared to reference roof tiles.

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