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Manufacture of Polymer Concrete Based on Snake-Fruit Seeds (*Salacca zalacca*) and Sawdust with Polyester Resin as an Adhesive

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ABSTRACT
This study aims to determine the effect of adding snake-fruit (*Salacca zalacca*) seeds and sawdust on polymer concrete's physical and mechanical properties. The results showed that the highest physical properties were 1.27 g/cm^3 density, 12.5% porosity, and 13.22% water absorption. The lowest physical properties are a density of 0.85 g/cm^3, porosity of 2.65%, and water absorption of 2.07%. The highest mechanical properties are compressive strength of 16.70 MPa, tensile strength of 4.39 MPa, and flexural strength of 7.93 MPa. The lowest mechanical properties are compressive strength of 6.80 MPa, tensile strength of 1.11 MPa, and flexural strength of 1.50 MPa. SEM test results showed that the microstructure of polymer concrete showed differences between concrete samples A1 (consisting of 35 g of snake-fruit seeds, 15 g of sawdust, and 15 g of polyester resin) and polymer concrete samples B1 (consisting of 30 g of snake-fruit seeds, 15 g of sawdust, and 20 g of polyester resin). The SEM analysis of the A1 concrete sample reveals a dark surface color and conspicuous white lumps, which are attributed to polyester resin and arise from inadequate mixing of ingredients. In the case of sample B1, a higher concentration of visible resin lumps is observed.

Keywords: Polyester Resin, Polymer Concrete, Sawdust, Snake-Fruit Seeds

ABSTRAK
Penelitian ini bertujuan untuk mengetahui pengaruh penambahan biji salak dan serbuk gergaji terhadap sifat fisik dan mekanik beton polimer. Hasil penelitian menunjukkan sifat fisik tertinggi adalah densitas 1,27 g/cm^3, porositas 12,5%, dan daya serap air 13,22%. Sifat fisik terendah adalah densitas 0,85 g/cm^3, porositas 2,65%, dan daya serap air 2,07%. Sifat mekanik tertinggi yaitu kuat tekan 16,70 MPa, kuat tarik 4,39 MPa, dan kuat lentur 7,93 MPa. Sifat mekanik terendah adalah kuat tekan 6,80 MPa, kuat tarik 1,11 MPa, dan kuat lentur 1,50 MPa. Hasil uji SEM menunjukkan bahwa struktur mikro beton polimer menunjukkan perbedaan antara sampel beton A1 (terdiri dari 35 g biji salak, 15 g serbuk gergaji, dan 15 g resin poliester) dan sampel beton polimer B1 (terdiri dari 30 g biji salak, 15 g serbuk gergaji, dan 20 g resin poliester). Analisis SEM dari sampel beton A1 mengungkapkan warna permukaan yang gelap dan gumpalan putih yang mencolok, yang dikaitkan dengan resin poliester dan timbul dari pencampuran bahan yang tidak memadai. Dalam kasus sampel B1, terlihat konsentrasi gumpalan resin yang lebih tinggi

Keywords: Beton Polimer, Biji Salak, Resin Poliester, Serbuk Gergaji

1. Introduction

Construction work increases with development from time to time and technological advances from year to year. Generally, building materials are divided into 3: steel, wood, and concrete. Among the three, concrete is a material commonly used to construct buildings, bridges, piers, airports and reservoirs [1–5]. Concrete is often used because it has several advantages, such as the material being easy to obtain, the price being relatively low, it being resistant to weather, and it does not require special care compared to wood and steel [6–9].

Snake-fruit (*Salacca zalacca*) is a typical Indonesian fruit. Based on data from BPS [10], snake-fruit production in Indonesia reached 1,404,878 tons. A total of 295,993 tons are snake-fruit produced from the North Sumatra region. If this figure is calculated in percent form, the North Sumatra region is capable of producing 31.25% of snake-fruit fruit. The flesh of the snake fruit is processed into various preparations such as traditional cake, chips, candied fruit, drink, syrup, jelly, and juice. In contrast, the seeds from the snake-fruit are not processed and become waste that can be used as an added ingredient in the concrete mix [11], [12].

Sawdust in Indonesia has a high waste potential. Data from the Forestry Department of Indonesia shows that 261.99 million tonnes of biomass waste is produced annually [6]. Sawdust waste is usually produced as a byproduct of building houses and industrial wood production, such as plywood and furniture. Waste sawdust is usually used to wait for fuel (briquettes), planting media, or simply being burned and disposed of as garbage. Therefore, innovation is needed so that this wood waste has added value. So it is hoped that these materials will increase the mechanical strength of concrete [13].

To speed up the hardening time of concrete and seal the cavities in the concrete more tightly so that it can withstand high humidity, it is necessary to use cement with polymer materials. A polymer is a chemical substance consisting of large molecules, with carbon and hydrogen as the main molecules. Polymers have several advantages over cement: fast hardening, higher tensile strength and better flexibility [14]. Based on the above explanation, this study produced polymer concrete using sawdust, snake-fruit seeds, and polyester resin as the primary raw materials.

2. Method

2.1. Treatment of Snake-fruit Seeds

The snake-fruit seeds are cleaned of adhering dirt, then washed. After that, it was dried in the sunlight. After drying, it was roasted until it turned black, then crushed using a mortar and blended to get smooth and ready-to-use zalacca seeds.

2.2. Treatment of Sawdust

The sawdust was washed, cleaned of soil impurities, and dried in the sun. After drying, grind it using a blender and sift using a 120 mesh sieve, and it was ready for use.

2.3. Mixing of Raw Materials

The raw materials that have been sieved were then weighed according to the composition in Tables 1 and 2. Then they are mixed evenly using a mixer for 3 minutes. The raw materials that have been mixed were then put into a mold coated with aluminum foil and smeared with wax, then dried in a hot compressor with a temperature of 90°C for 25 minutes.

Table 1. The composition of the sample uses 15 grams of polyester resin.

Samples' code	Sand (g)	Snake-fruit Seeds (g)	Sawdust (g)	Polyester Resin (g)	Thinner (g)
A1	35	35	15	15	7.5
A2	35	33	17	15	7.5
A3	35	31	19	15	7.5
A4	35	29	21	15	7.5
A5	35	27	23	15	7.5
A6	35	25	25	15	7.5
A7	35	23	27	15	7.5
A8	35	21	29	15	7.5
A9	35	19	31	15	7.5
A10	35	17	33	15	7.5

Table 2. The composition of the sample uses 20 grams of polyester resin.

Samples' code	Sand (g)	Snake-fruit Seeds (g)	Sawdust (g)	Polyester Resin (g)	Thinner (g)
B1	35	30	15	20	10
B2	35	28	17	20	10
B3	35	26	19	20	10
B4	35	24	21	20	10
B5	35	22	23	20	10
B6	35	20	25	20	10
B7	35	18	27	20	10
B8	35	16	29	20	10
B9	35	14	31	20	10
B10	35	12	33	20	10

3. Results and Discussion

3.1. Density Testing

The density test results can be seen in Figure 1 and Figure 2.

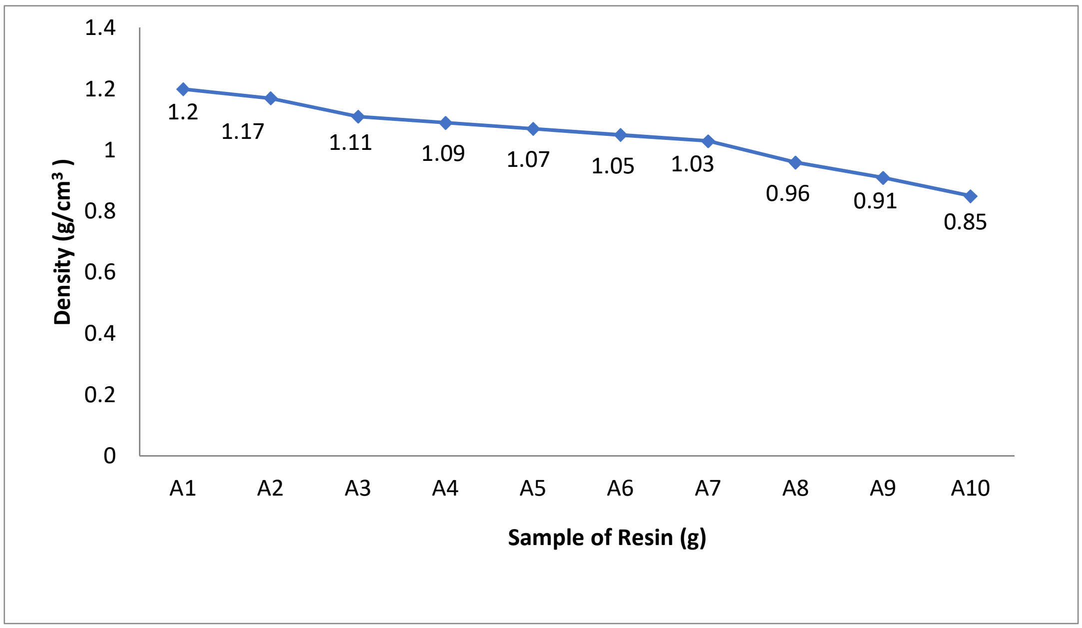

Figure 1. Graph of density vs sample composition.

Figure 1 shows the results of the highest density test is 1.20 g/cm^3 in sample A1, and the lowest density is 0.85 g/cm^3 in sample A10. The results of the density test in the study decreased due to the increase in the composition of the sawdust and the decrease in the composition of the snake-fruit seed powder in the sample mixture.

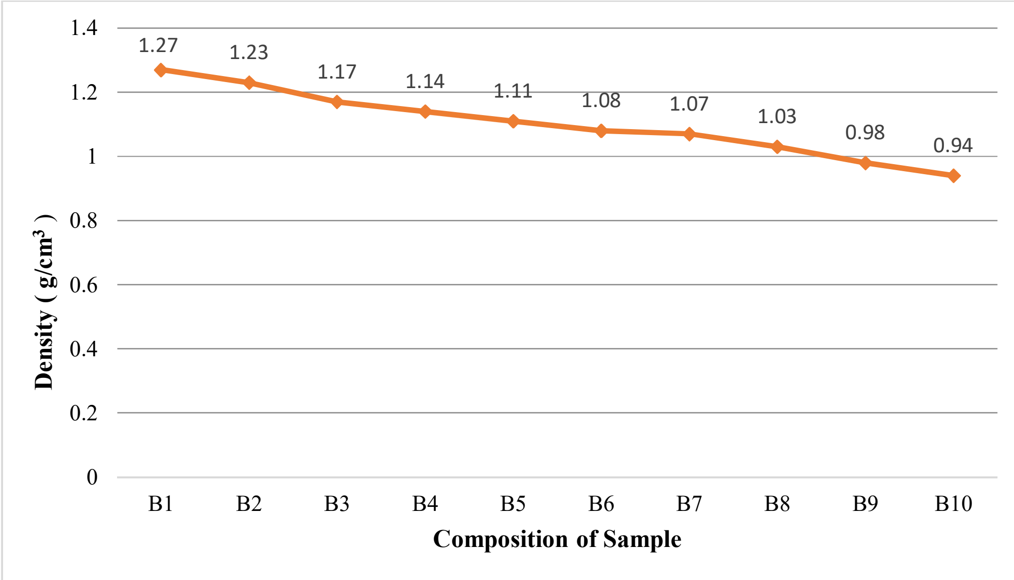

Figure 2. Graph of density vs sample of resin.

Figure 2 shows the results of the highest density test is 1.27 g/cm^3 in sample B1, and the lowest density is 0.94 g/cm^3 in sample B10. The results of the density test decreased due to an increase in the composition of the sawdust and a decrease in the composition of the snake-fruit seed powder in the sample mixture. Sawdust has a lighter density than other materials. The more sawdust added, the other material in the concrete will be occupied by sawdust which causes the concrete to become lighter.

3.2. Porosity Test Results

The porosity test results can be seen in Figure 3 and Figure 4.

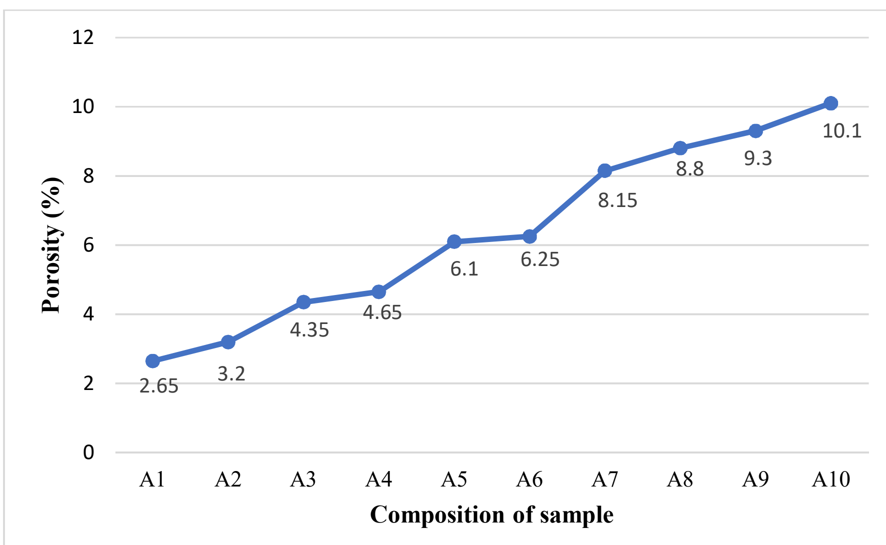

Figure 3. Graph of porosity vs sample of resin.

Figure 3 shows the lowest porosity value of 2.65% in sample A1 and the highest porosity value of 10.1% in sample A10.

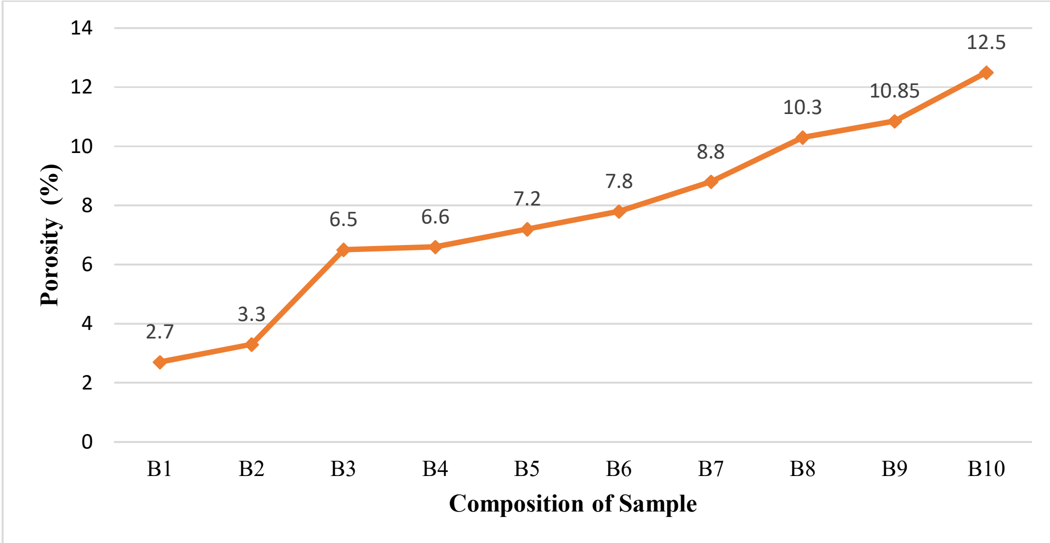

Figure 4. Graph of porosity vs composition sample.

Figure 4 shows the lowest porosity value of 2.7% in sample B1 and the highest porosity value of 12.5% in sample B10. Adding sawdust fibers will produce polymer concrete with more pores or cavities. The increase in sawdust fiber causes the number of air voids to increase, increasing the porosity. The test results obtained a minimum porosity percentage of 2.65% in sample A1 with a 15 g polyester resin variation. This shows that in this composition, the ingredients are evenly mixed, and the ability of the resin to bind sand, snake-fruit seed powder, and sawdust is quite good and thorough so that few pores are formed.

3.3. Water Absorption Test

The water absorption test aims to determine the percentage of water absorbed by the sample soaked for about 4 hours at room temperature. The results of the water absorption test can be seen in Figure 5 and Figure 6.

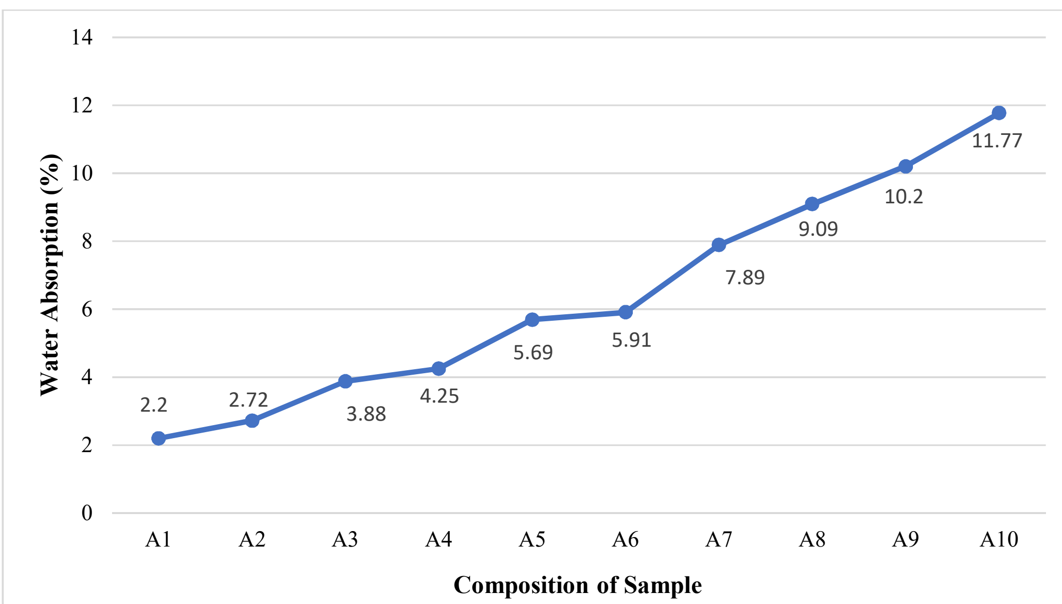

Figure 5. Graph of water absorption vs composition of sample.

Figure 5 shows that the lowest flow absorption value is 2.07% for composition A1 and the highest water absorption value is 11.77% for sample A10.

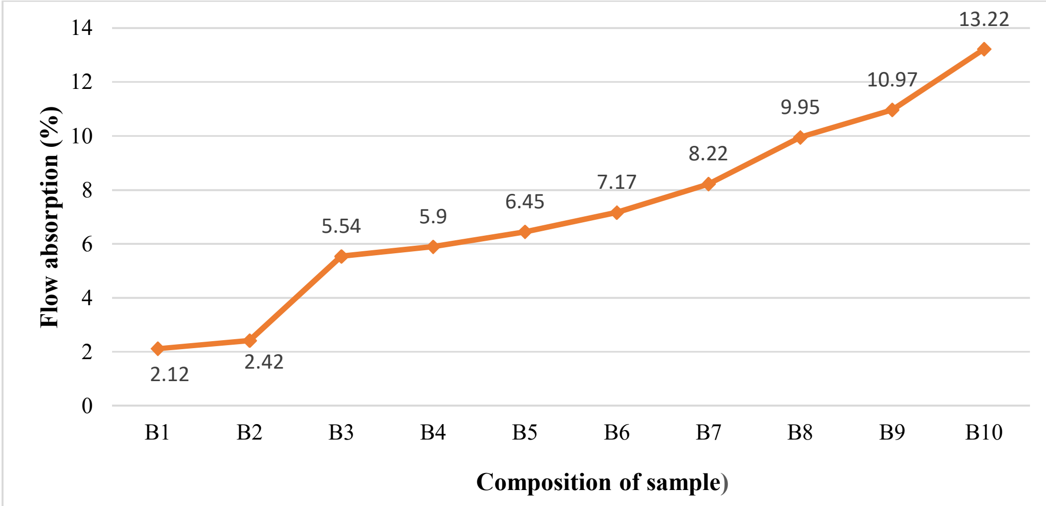

Figure 6. Graph of flow absorption vs composition of sample.

In Figure 6, the flow absorption values vary across the sample compositions, with the lowest value of 2.12% observed in sample B1 and the highest value of 13.22% in sample B10. This phenomenon can be attributed to relatively larger amounts of alkaline samples, forming a porous structure that promotes flow absorption, as discussed in reference [15].

3.4. Compression strength Testing

The Compression strength testing assesses the material's ability to withstand load or force until failure occurs. The results of the Compression strength testing are presented in Figure 7 and Figure 8.

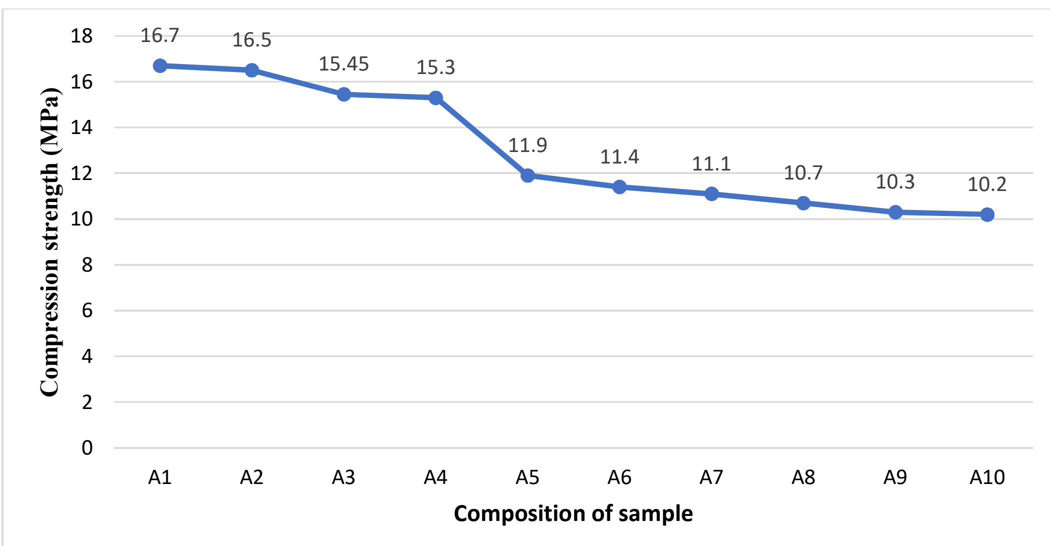

Figure 7. Graph of strength testing vs composition sample.

As depicted in Figure 7, the highest compressive strength value is recorded in sample A1, measuring 16.7 MPa, while the lowest value is observed in sample A10, at 10.2 MPa.

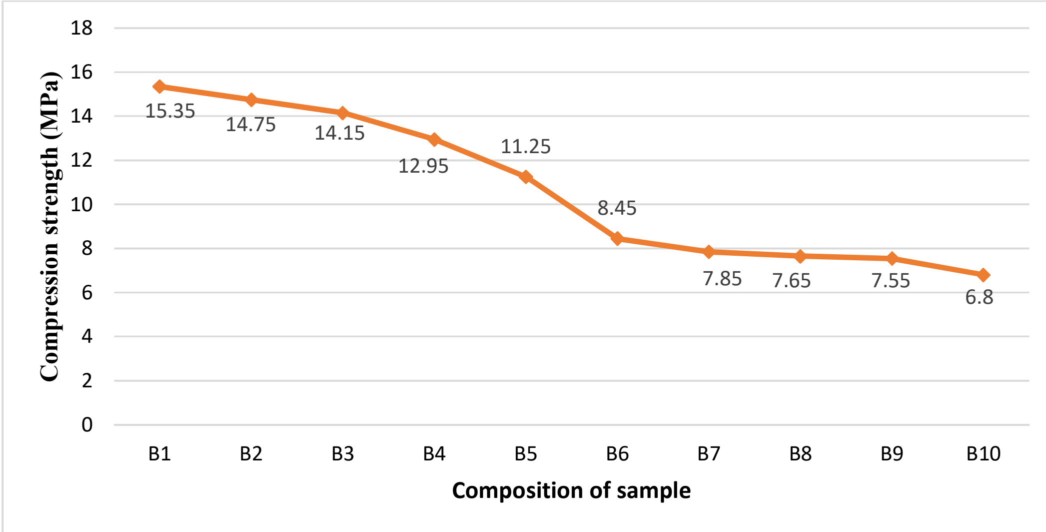

Figure 8. Compression strength vs composition of sample.

Figure 8 highlights the variation in compressive strength across different compositions. Sample B1 exhibits the highest compressive strength value at 15.35 MPa, whereas sample B10 displays the lowest value at 6.8 MPa. The test results of sample A1 with 15 g polyester resin have the highest quality pressure value. The results of the compressive strength test of polymer concrete decreased as the snake-fruit seed powder decreased and the wood powder fiber increased, forming gaps or cavities in the concrete. The compressive strength of concrete decreases due to the addition of more sawdust so that the compressive strength of the concrete produced is lower.

3.5. Compression strength Testing

Tensile strength testing involves assessing the maximum stress a material can endure when stretched or pulled before it fractures. The outcomes of the tensile strength test are presented in Figures 9 and 10.

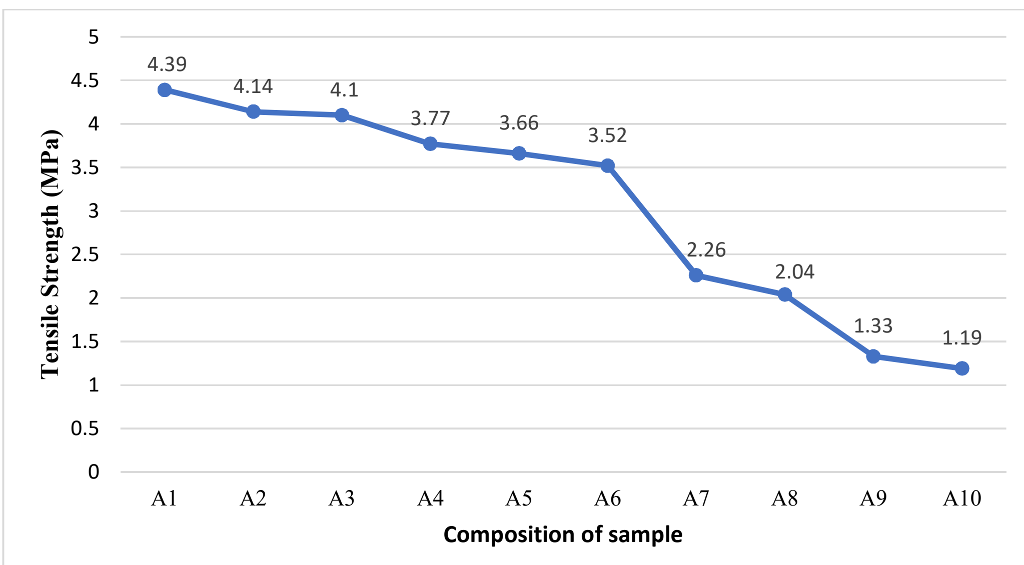

Figure 9. Graph of tensile strength vs composition of sample.

The tensile test results revealed the highest tensile strength in sample A1, reaching 4.39 MPa, and the lowest in-sample A10, measuring 1.33 MPa.

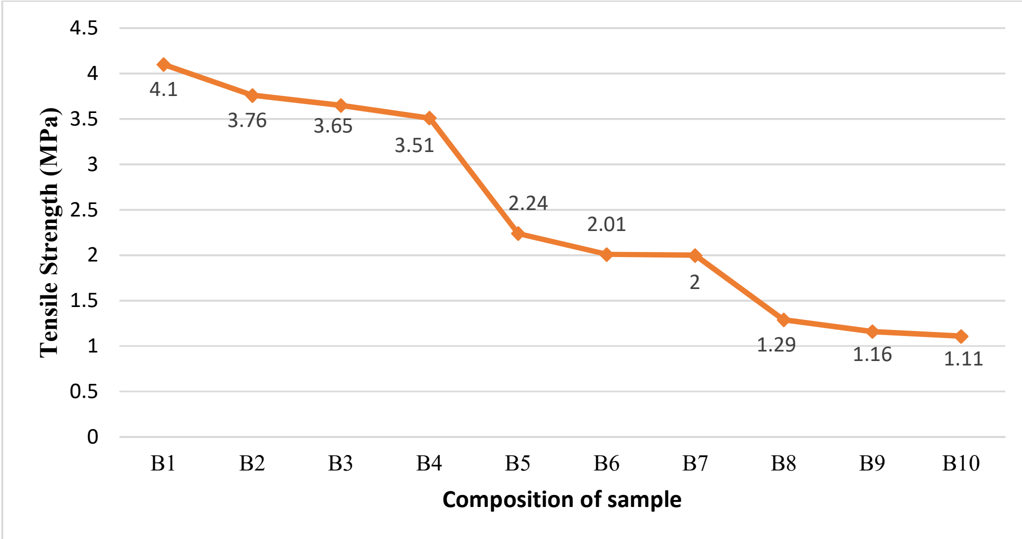

Figure 10. Graph of tensile strength vs composition of sample.

The tensile test outcomes displayed the greatest tensile strength in sample B1 at 4.10 MPa, whereas the lowest tensile strength was observed in sample B10 with a value of 1.11 MPa. In the case of sample A1, which consists of sand, snake fruit powder, sawdust, and 15 g of polyester resin, a well-balanced mixture was achieved, leading to exceptional homogeneity and, consequently a higher tensile strength compared to other sample compositions.

3.6. Bending Strength Testing

Bending strength testing assesses the resistance of polymer concrete to point loading, determining its bending point capacity. Additionally, this testing is conducted to evaluate a material's elasticity. The results of these tests are depicted in Figures 11 and 12.

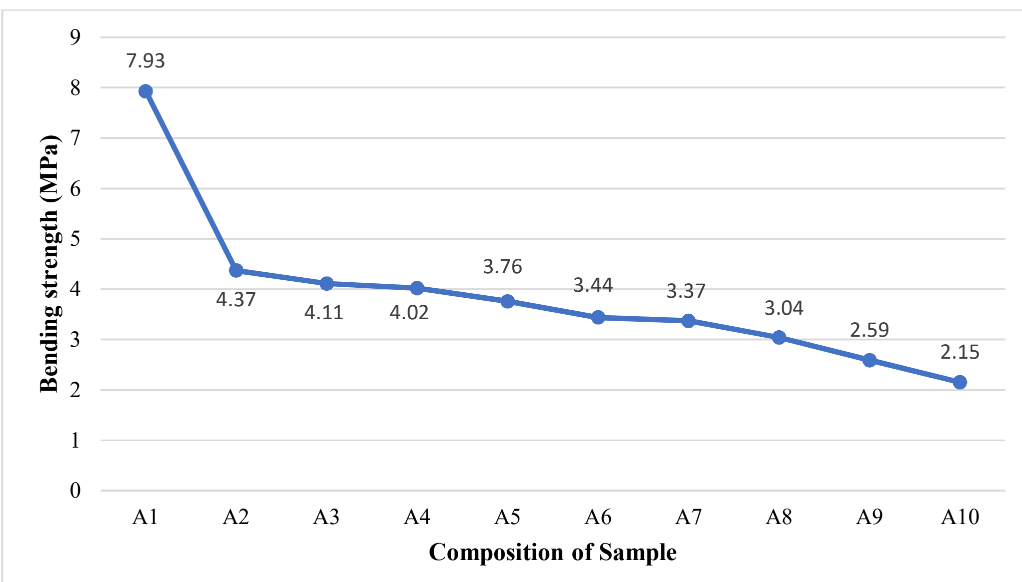

Figure 11. Bending strength vs composition of sample.

Figure 11 illustrates the outcomes of the Bending strength test on sample A, which range between 2.15 and 7.93 MPa. The highest Bending strength value is in sample A1, composed of sand, snake-fruit seed powder, and sawdust, yielding 7.93 MPa. Conversely, the lowest Bending strength value is recorded in sample A10 at 2.15 MPa.

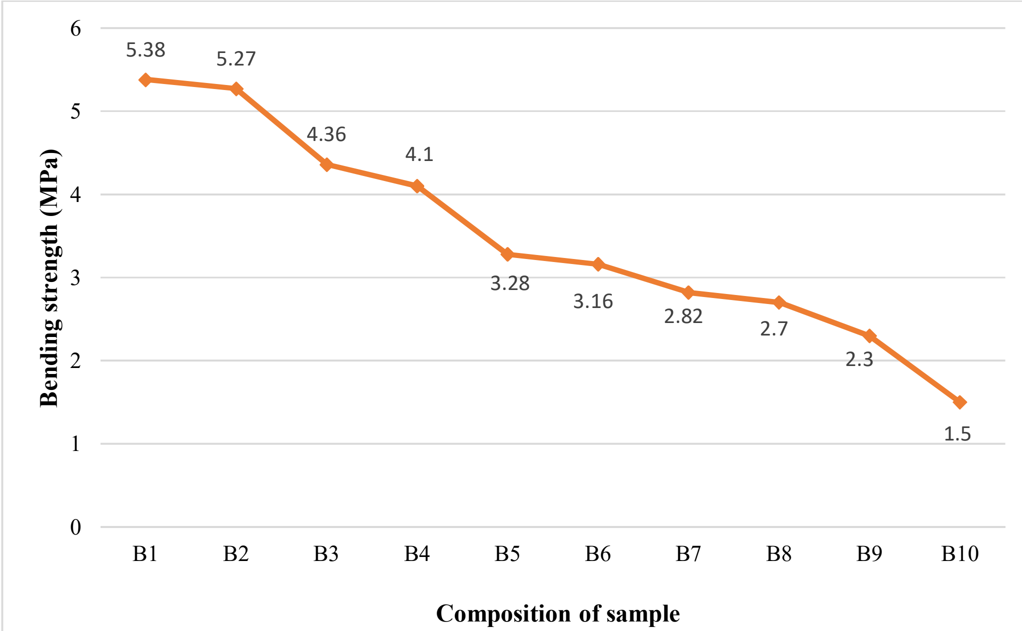

Figure 12. Graph of bending strength vs composition of sample.

Figure 12 presents the bending strength test results for sample B, with values spanning from 1.50 to 5.38 MPa. Among these, sample B1 stands out with the highest bending strength at 5.38 MPa, while sample B10 exhibits the lowest bending strength strength value of 1.50 MPa.

3.7. Microstructural Testing

The SEM testing of concrete samples containing a mixture of balsam, calcium powder, snake-fruit seed, polyester resin, and an adhesive base was conducted on the A1 sample at a heating temperature of 90°C for 25 minutes. The SEM images are presented in Figure 13.

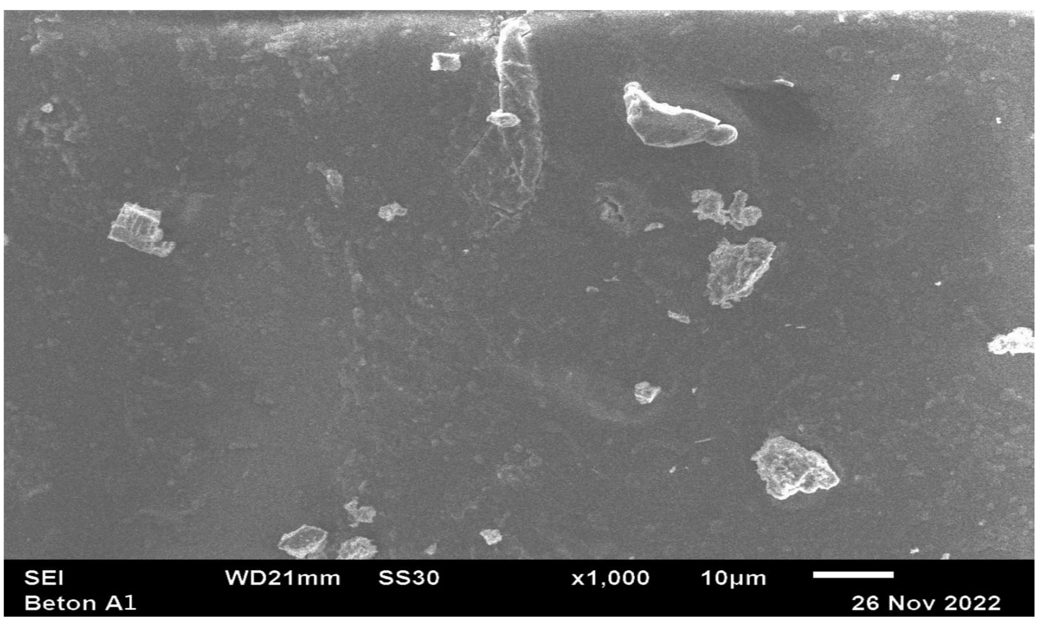

Figure 13. SEM test results for sample A1.

Figure 13 displays the SEM test at 1000X magnification of sample Al1, incorporating 15 g of polyester resin. This sample exhibited a compressive strength value of 16.7 MPa and a porosity value of 2.65%. The SEM analysis revealed a dark surface color and visible white lumps identified as polyester resin. These visual characteristics were attributed to an insufficient mixing process, leading to inadequate dispersion of the ingredients.

4. Conclusion

In conclusion, embedding snake-fruit seeds, coal powder, and polyester resin has a discernible impact on polymer concrete's physical and mechanical characteristics. Regarding the composition variations, it is noteworthy that the inverted composition parameter significantly influences the overall physical test results, particularly evident in sample A1 with a resin variation of 15 grams. Similarly, when it comes to mechanical testing, such as tensile and flexural qualities, the effects of composition inversion are pronounced in sample A1 with the same 15 grams of resin variation. The findings from the SEM test shed light on the underlying causes of observed surface features. Dark surface coloration and visible white lumps are attributed to the incorporation of polyester resin, a result of inadequate stirring during the mixing of constituents. Sample B1 further exemplifies this phenomenon, revealing distinct lumps of resin on the surface caused by insufficient mixing. Despite some improvement, a few remaining voids are evident on the sample's surface, attributed to challenges in achieving uniform coverage of pores by the polyester resin, leading to uneven ingredient distribution. These insights collectively underscore the intricate interplay between material composition, mixing techniques, and resulting physical and mechanical attributes in the production of halosylated polymer concrete. Further refinement of the manufacturing process is recommended to optimize the desired properties of the final product.

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