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Physical Properties of Polymer Concrete Utilizing Pahae Natural Zeolite, Corn Husk Fiber, and Polyurethane Resin Adhesives

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ABSTRACT

This study aimed to determine the optimum composition in the manufacture of polymer concrete using Pahae natural zeolite, corn husk fiber, and polyurethane resin adhesives. This study used the hot-press method at 170°C for 30 minutes. The compositions of zeolite and corn husk fiber tested were varied under three different additions of polyurethane resin of 15 g, 20 g, and 25 g, while the composition of sand was fixed at 60 g. The inclusion of corn husk fiber content reduces the density of the concrete and increases the porosity and water absorption. The physical properties analysis showed that the polymer concrete samples showed the highest density was 1.89 g/cm^3 from 20 g of polyurethane resin and no addition of corn husk fiber; the highest porosity was 6.15% from 15 g of polyurethane resin and 10 g of corn husk fiber; and the highest water absorption was 5.85% from 15 g of polyurethane resin and 10 g of corn husk fiber. Because improved material quality and durability are linked to reduced water absorption rates in polymer concrete, the most favorable composition with minimal water absorption (0.51%) came from the sample utilizing 20 grams of polyurethane resin without incorporating corn husk fiber.

Keywords: Corn Husk Fiber, Pahae Natural Zeolite, Physical Properties, Polymer Concrete, Polyurethane Resin Adhesives

ABSTRAK

Studi ini bertujuan untuk menentukan komposisi optimum dalam pembuatan beton polimer menggunakan zeolit alam Pahae, serat jerami jagung, dan perekat resin poliuretan. Studi ini menggunakan metode hotpress pada suhu 170°C selama 30 menit. Komposisi zeolit dan serat jerami jagung yang diuji divariasikan dalam tiga tambahan resin poliuretan yang berbeda, yaitu 15 g, 20 g, dan 25 g, sementara komposisi pasir tetap pada 60 g. Penambahan kandungan serat jerami jagung mengurangi densitas beton dan meningkatkan porositas dan absorpsi air. Analisis sifat fisik menunjukkan bahwa sampel beton polimer dengan densitas tertinggi ad lah 1,89 g/cm^3 dari 20 g resin poliuretan tanpa penambahan serat jerami jagung; porositas tertinggi adalah 6,15% dari 15 g resin poliuretan dan 10 g serat jerami jagung; dan absorpsi air tertinggi adalah 5,85% dari 15 g resin poliuretan dan 10 g serat jerami jagung. Karena peningkatan kualitas dan daya tahan bahan dikaitkan dengan penurunan tingkat penyerapan air pada beton polimer, komposisi yang paling disukai dengan penyerapan air minimal (0,51%) berasal dari sampel yang menggunakan 20 gram resin poliuretan tanpa memasukkan serat kulit jagung.

Kata kunci: Beton Polimer, Perekat Resin Poliuretan, Serat Kulit Jagung, Sifat Fisik, Zeolit Alam Pahae

1. Introduction

Amidst the ongoing development of construction projects, there is a rising supply of buildings, with advancements in concrete technology being notable among them. This is owing to concrete's widespread use as the primary building material in construction endeavors. The fundamental constituents of concrete are formulated by combining various component mixtures. This selection process must be meticulous, as concrete should be easy to manipulate, meet design specifications upon hardening, and remain cost-effective [1], [2]. Natural raw materials for concrete production are decreasing due to exploitation. Manufacturing waste for the concrete mixture was able to increase the compressive strength. The added material can be in the form of fiber [3], [4].

Corn husk waste can be a substitute for concrete aggregate, especially polymer concrete made from waste corn husk fiber, sand, pumice, and resin. Corn husk has a chemical composition consisting of The dominant element, which can increase the resulting tensile strength [5], [6].

Polymer concrete is a monomer that polymerizes in situ in the presence of other components. In situ polymerization occurs by heat, catalyst, or radiation. When polymerized, the monomer can be used as a binder component and does not require water to set or harden. Polymer concrete consists of a polymer binder, hardener, and aggregate. Since the late 70s, epoxy and acrylic polymer concretes have replaced traditional materials because they cure quickly and bond very well with cement concrete [7].

Methyl methacrylate, unsaturated polyester resins, epoxy resins, furan resins, polyurethane resins, urea-formaldehyde resins, and polyester/styrene mixtures are generally being explored as concrete system polymers. The advantage of polyurethane resins is their high mechanical strength, longevity, and resistance to chemical attack [8].

Natural zeolite is a rock mineral that is commonly found in Indonesia. Zeolites, crystalline aluminosilicates, can be found in nature and are widely used in industry, agriculture, and wastewater treatment [9]. Using 10% natural zeolite in the manufacture can increase the compressive strength at 28 days by 11.22%, but using more than 10% will decrease the compressive strength. According to another study, 20% of zeolite is used to manufacture lightweight materials [10].

In this study, our focus was to ascertain the optimal formulation for the mixed design of polymer concrete. To achieve this, a series of experiments were conducted wherein we systematically varied the polymer-to-filler ratio, maintaining all other ingredients constant. Through this methodical approach, we sought to identify the combination that yielded the most favorable properties for our intended application.

2. Method

2.1. Preparation of Corn Husk Fiber

To prepare the corn husk fibers, the mature and yellowish husks were first cleaned by rinsing them with running water. Subsequently, they were soaked in distilled water for a week. After the soaking period, the husks were carefully combed to remove any impurities and then dried under the sun until completely dry. Once dried, the corn husk fibers were cut into pieces measuring approximately 0.7 cm to 1 cm in length.

2.2. Preparation of Zeolite

In this study, we used natural zeolite, which is still in lump form from North Tapanuli or the Pahae region. The zeolite, still in chunks, was crushed first before further processing using a mortar and pestle. A 200-mesh sieve was used to refine the zeolite. After that, the zeolite impurities were washed three times with distilled water. Then, the impurities were dried in the oven for one hour at 100°C. A 1 M NaOH solution was chemically activated for one hour at 60°C with a 120 rpm magnetic stirrer. Then, the solution was filtered with 150-micrometer filter paper and washed with aquadest until the pH was neutral. Then, the chemically activated Pahae natural zeolite with a neutral pH was dried in an oven for one hour at 100°C.

2.3. Preparation of Concrete

Materials such as sand, zeolite, corn husk fiber, and polyurethane resin have been processed and weighed according to a predetermined composition. The sand: zeolite: corn husk fiber ratios investigated are given in Table 1. The ingredients given in Table 1 were then dried. After the dried ingredients were evenly distributed and free from lumps, they were weighed and added to the mixed ingredients.

Once the iron plate and the sample mold had been made, the metal plate was coated with wax, and the mold was wrapped in aluminum foil. Then, the concrete mixture was mixed into the iron plate, and the mixture was spread evenly over the entire surface of the mold. The hot compress machine was heated to 170°C after inserting the mold and pressing it for 30 minutes.

Table 1. Sample composition of the synthesized polymer concrete.

Sample Label	Polyurethane Resin (g)	Sand (g)	Zeolite (g)	Corn Husk Fiber (g)
A1			20	0
A2			18	2
A3	15	60	16	4
A4			14	6
A5			12	8
A6			10	10
B1			25	0
B2			23	2
B3	20	60	21	4
B4			19	6
B5			17	8
B6			15	10
C1			15	0
C2			13	2
C3	25	60	11	4
C4			9	6
C5			7	8
C6			5	10

3. Results and Discussion

3.1. Density Test Results Analysis

Figure 1 depicts that the density of the polymer concrete produced varies depending on the ingredients used.

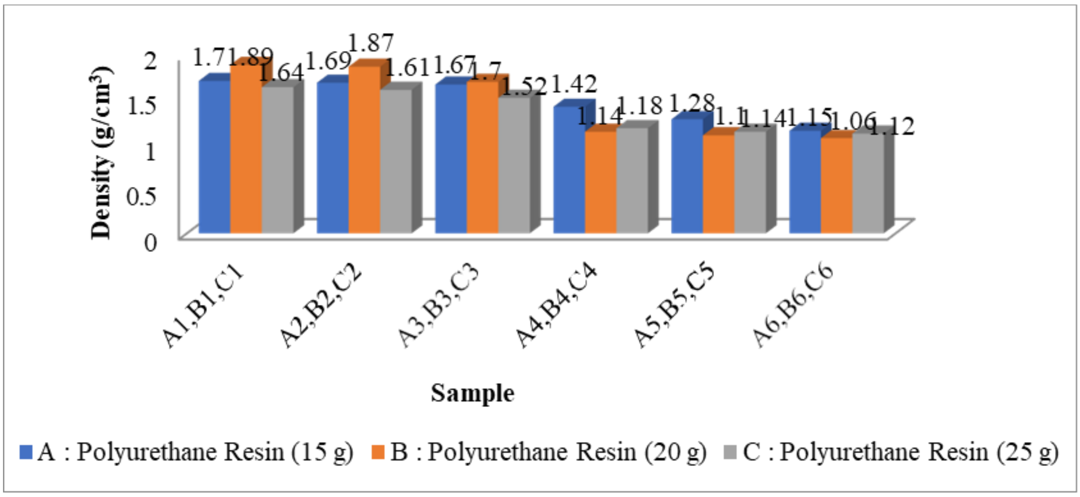

Figure 1. The density of the synthesized polymer concrete under different ingredients' compositions.

According to Figure 1, the density of samples A1-A6 in polymer concrete ranges from 1.15 to 1.71 g/cm³. Samples B1-B6 span a range of 1.06 to 1.89 g/cm³, while C1-C6 fall between 1.12 and 1.64 g/cm³. As seen, the inclusion of fiber content reduces the concrete's mass, subsequently leading to a decrease in its density. All compositions of polymer concrete samples demonstrate optimal density values, with sample B1 showcasing a 1.89 g/cm³ density. However, this sample's density fluctuates between higher and lower values, at 1.06 g/cm³.

3.2. Porosity Test Results Analysis

The difference between the total volume of the composite board and the volume occupied by pores is referred to as porosity. Figure 2 shows the porosity test results of the synthesized polymer concrete.

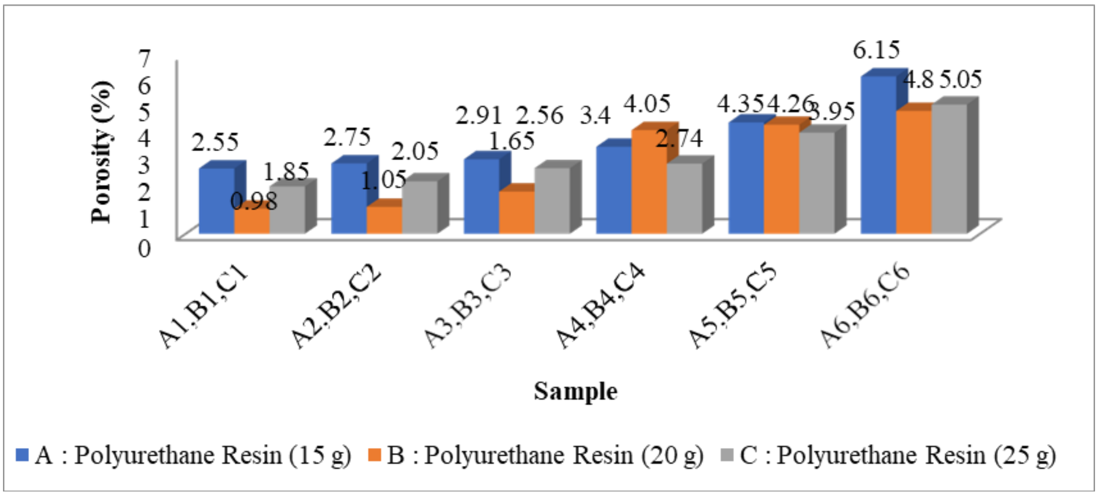

Figure 2. The porosity of the synthesized polymer concrete under different ingredients' compositions.

The data reveals that the porosity value of samples A1-A6 ranges from 2.75% to 6.15%, samples B1-B6 range from 0.98% to 4.8%, and samples C1-C6 range from 1.85% to 5.05%. The porosity value of each of these variations tends to increase with the addition of fiber mass to the polymer concrete composition. For instance, samples A6, B6, and C6 exhibit a much higher corn husk fiber content, as depicted in Table 1, with sample A6 resulting in the highest porosity of 6.15%. Additionally, the hot-pressing molding method causes the concrete resin to evaporate, in addition to adding corn husk fiber.

3.3. Water Absorption Test Results Analysis

The water absorption factor is one of the most crucial parameters in predicting and assessing the strength and quality of polymer concrete produced. Figure 3 depicts the water absorption test results of the synthesized polymer concrete.

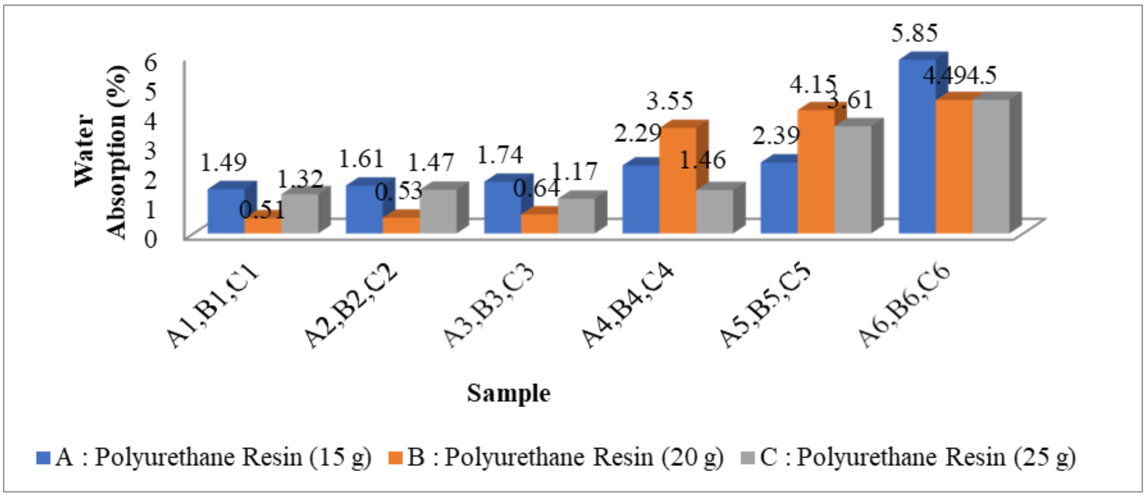

Figure 3. The water absorption of the synthesized polymer concrete under different ingredients' compositions.

As illustrated in Figure 3, the introduction of corn husk fiber tends to elevate the water absorption value. Enhanced material quality and durability are associated with lower water absorption rates in polymer concrete [11], [12]. By adding 20 grams of polyurethane resin to the total weight, sample B1 achieved an optimal yield of 0.51%, while the highest water absorption was from sample A6. Consequently, the resulting polymer concrete surface exhibits minor voids. Essentially, the chosen composition of corn husk fiber significantly influences the air absorption capacity of the sample. With increased fiber content, the bonding between sand and zeolite becomes more uniform, forming smaller pores within the polymer concrete. Smaller pores correspond to reduced water absorption by the sample.

4. Conclusion

This study successfully fabricated polymer concrete production using Pahae natural zeolite, corn husk fiber, and polyurethane resin adhesives. The addition of corn husk fiber decreased concrete density while increasing porosity and water absorption. Analysis revealed the highest density (1.89 g/cm³) was achieved with 20 g of polyurethane resin without corn husk fiber, while the highest porosity (6.15%) and water absorption (5.85%) resulted from 15 g of polyurethane resin combined with 10 g of corn husk fiber. As enhanced material quality and durability correlate with lower water absorption rates in polymer concrete, the composition yielding the least water absorption (0.51%) was found in the sample employing 20 grams of polyurethane resin without the inclusion of corn husk fiber.

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