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THE EFFECT OF RICE HUSK COMPOSITION ON POROUS CONCRETE PERFORMANCE

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Abstract

This study aims to determine the effect of rice husk composition on porous concrete. Rice husks were dried in an electric furnace (200-250°C) for 90 minutes, sieved with a size of 500 µm, and mixed with gravel, cement, and water. The mixture is then poured into molds and dried for 2 days. Several porous concretes were made with different compositions of rice husks (i.e., 1.5; 3; 4.5; 6; and 7.5%). To analyse the hardness and characteristics of the porous concrete, a compressive strength test and the percentage of water passing through were carried out. The results showed that increasing the percentage of rice husks made the processed concrete have a brown colour, rough surface, and high compressive strength. The high silica content in rice husks contributes to the compact structure of the prepared concrete, increasing its compressive strength. The highest density value is 2.167 g/cm, namely 1.5% rice husk percentage with 975 g concrete mass and the lowest density value is 1.978 g/cm in the variant with 7.5% rice husk percentage with 890 g concrete mass. The highest percentage of loose water is found in the percentage of rice husks of 1.5; 3% with the results of 100% the percentage of water that passes and the lowest percentage is found in the percentage of rice husks 4.5; 6; 7.5% with a percentage yield of 0% of water pass. The highest percentage of water absorption with a total of 1.657% was produced by variants with a percentage of rice husks of 7.5% and vice versa, the lowest percentage of water absorption with a total of 0.307% was produced by variants with a percentage of 1.5% rice husks. This study demonstrates waste biomass as a substitute aggregate to improve the mechanical strength and performance of porous concrete.

Keywords: Composition, Compressive strength, Particle size, Porous concrete, Rice husk.

1. Introduction

Concrete is a component in construction [1]. In general, concrete has a dense texture and is watertight, which affected the density of the concrete itself. The density of concrete tends to be high, affecting the load received by the foundation [2]. Another type of concrete, porous concrete, was developed to support land development and surface runoff management [3]. The hollow cavities in porous concrete caused the compressive strength to be relatively low [4]. Porous concrete consisted of fine, coarse, cement, and water aggregates. Fine aggregate is one of the constituent materials that play a role in influencing the strength of porous concrete [5]. Besides the high density of concrete, concrete materials are also reliant on natural resources [2]. One of the natural resources used is rice husks, a cheap material collected from agricultural waste, which can be used for concrete [6].

Indonesia is an agricultural country, where most of the population works as farmers [7]. From the data obtained by the Indonesian Ministry of Agriculture, rice is the most dominant agricultural commodity [8]. When processing rice into rice through a milling machine, a by-product is produced in the form of rice husks. Not only rice husk is generated during the harvesting and processing, but rice straw is also generated. Several research works were also conducted to investigate the potential use of rice straw for the development of eco-friendly materials and products, such as the influence of extraction parameters on spent coffee grounds as a renewable tannin resource [9] and the evaluation of rice straw as a natural filler for injection molded high-density polyethylene bio-composite materials [10]. Rice husks are waste from the rice milling process which weighs 20-22% of the weight of rice [11]. Every ton of dry rice produces 300 kg of rice husks, meaning that the production of rice husks is about 30% of the total weight of the rice harvest. Thus, the production of rice husk waste in Indonesia is very large [12]. However, the use of rice husks was still not optimal. This is due to the characteristics of the rice husks, which are coarse, have low nutritional value, have a low density, and have high enough ash content [3].

Different biomasses and their extracts had been used as natural materials in the development of different eco-friendly materials, such as the plasticizer type for biobased microcrystalline cellulose filled polylactic acid composite [13], carboxymethyl cassava starch/polyurethane dispersion blend as surface sizing agent [14], tea waste/kapok fiber composite paper [15], and tree pruning waste for papermaking [16]. The addition of rice husk as the biomass into the porous concrete can affect the strength and hardening of porous concrete [17]. Rice husks can be used as fine aggregate in porous concrete materials [18]. Porous concrete is used as a unique and effective road material that is environmentally friendly [19]. It captured rainwater and allowing rainwater to seep into the ground. Porous concrete material can help replenish groundwater reserves and reduce surface runoff [20]. When applied to the road's shoulder, the water runoff from the road can be absorbed into the ground and reduce the drainage channel's water discharge [21]. There are several studies of modified concrete using biomass such as sugarcane ash [22, 23], olives [24], banana leaves ash [25], vegetable fiber [26], and palm fibers [27]. However, there has been no research on the effect of the ratio of rice husks to the strength of porous concrete with different variations. Based on previous studies [28-38], the purpose of this study was to determine the effect of rice husk composition on porous concrete performance. In this study, porous concrete with 1.5; 3; 4.5; 6; and 7.5% of rice husk were prepared. The compressive strength, porosity, and water pass percentage test were carried out to analyse the porous concrete's hardness and interaction with water. This research was expected to investigate the potential of rice husk as porous concrete material that can capture rainwater, allow rainwater to seep into the soil, fill groundwater reserves, and reduce surface runoff.

2. Materials and Method

2.1. Material

The materials used in this study are coarse aggregates such as gravel and fine aggregates such as cement (Portland Type 1; Holcim; TB. Galunggung Tasikmalaya) and rice husk. Water was used to mix all materials. All materials were purchased from local markets in Tasikmalaya, Indonesia.

2.2. Method

Figure 1 shows the diagram of experimental methods conducted in this study. Gravels were washed and dried in the sun for 2 hours, then mixed with cement and water. Prior to use, the rice husks were put in the electrical furnace (200-250^{0}C) for 90 minutes. Thereafter, the rice husks were sawmilled, sieved using a test sieve (500 µm), and mixed with gravel, cement, and water. Five mixtures were prepared with varying percentages of rice husk (1.5; 3; 4.5; 6; and 7.5%). % rice husk added to the concrete is calculated based on the mass of water used in the formulation. The composition of gravel, cement, water, and rice husk carried out are shown in Table 1. The mixture was poured into a mold made of wood (15×10×3 cm) and dried in the sun for 2 days.

2.3. Compressive strength test

The compressive strength value was obtained from the results of the concrete compressive test using Screw Stand Test Instrument (Model I ALX-J, China) equipped with a digital force gauge instrument (Model HP-500, Serial, No H5001909262). The test was carried out by applying a compressive force to the prepared porous concrete. Hardness is expressed by the curve peak value (maximum force applied in Newton (N) units) during the test.

2.4. Water pass percentage test

The water pass percentage (%WPP) test was conducted by pouring water gradually (100 mL) on the surface of the porous concrete, and the volume of the passing water (V_{PW}; mL) was measured. The WPP calculated by Eq. (1):

$$\%WPP = \frac{V_{PW}}{100} \times 100 \quad (1)$$

2.5. Density test

Mathematically, density (Eq. (2)) can be expressed in terms of mass divided by volume. This formula applies to the density of liquids, gases, and also solids.

$$\rho = \frac{m}{v} \quad (2)$$

where ρ is the density (kg/m^3), m is the mass (kg), and V is the volume (m^3).

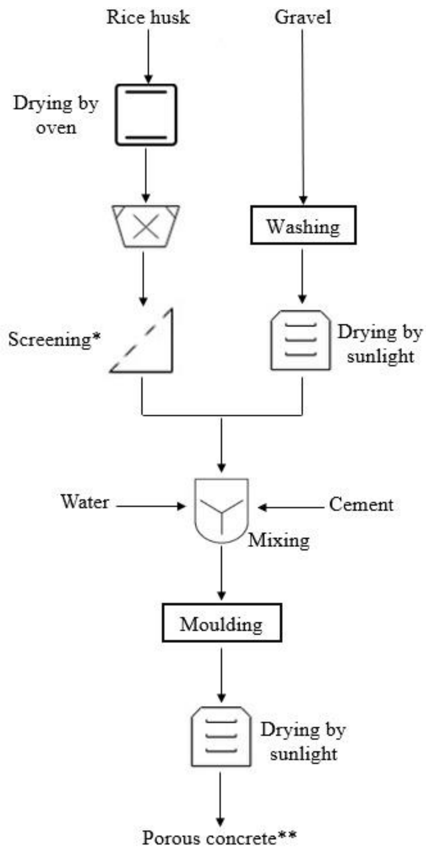

Fig. 1. Flow diagram of the experimental method.

Table 1. The composition used for prepared porous concrete.

Percentage of Rice Husk (%)	Rice Husk (g)	Gravel (g)	Cement (g)	Water (g)
1.5	15	700.00	285.00	100.00
3.0	30	692.50	277.50	100.00
4.5	45	685.00	270.00	100.00
6.0	60	677.50	262.50	100.00
7.5	75	670.00	255.00	100.00

2.6. Water absorption test

The absorption test can be calculated using Eq. (3).

$$W_A = \frac{W_2 - W_1}{W_1} \times 100\% \quad (3)$$

where W_A is the water adsorption percentage (%), W_1 is the dry sample weight (g), and W_3 is the wet sample weight (g).

3. Results and Discussion

3.1. Porous concrete appearance

Figure 2 shows the physical appearance of prepared porous concrete. The concretes have a grey and brown colour. The brown colour in the prepared concrete was due to the rice husk percentage in the mixture. Concrete with a higher percentage of rice husk appeared coarser and rougher than the low percentage of rice husk. Increases in rice husk percentage in porous concrete mixture resulted in browner colour and coarse surface.

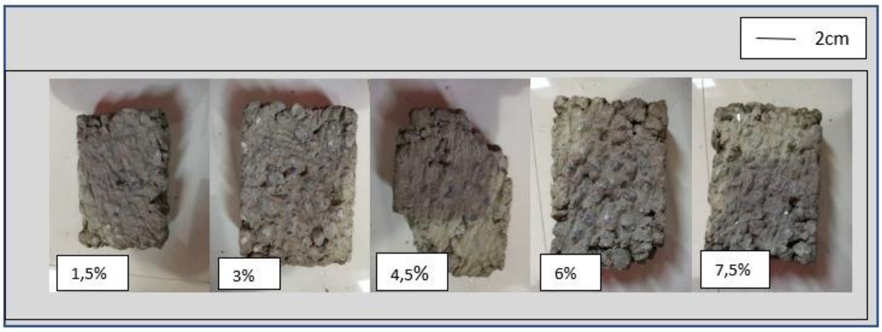

Fig. 2. Photograph of prepared porous concrete.

Figure 3 shows the microscope observation of rice husk particles and cement used in this study. The rice husk particle has a brown colour, therefore contributing to brown features in prepared porous concrete.

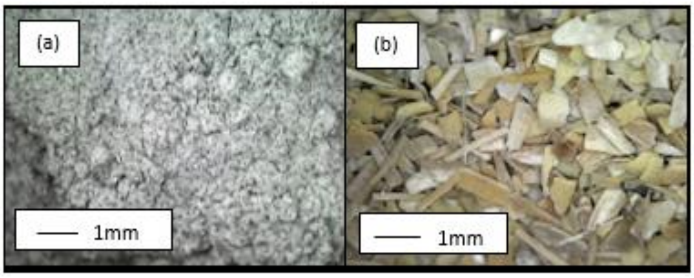

Fig. 3. Microscope photograph of cement (a) and rice husk particle (b).

3.2. Compressive strength

The compressive strength result is shown in Fig. 4. The hardest porous concrete was achieved by the 7.5% sample whereas the lowest was achieved by the 1.5% sample. Higher rice husk percentage improved the compressive strength of porous concrete. This hardness feature was correlated to the adhesion factor of the aggregates. Rice husk has high silica content (80%), making them a reactive pozzolan [39]. The silica in rice husk reacts with the side products of cement and water. Hydration results between cement and water produce calcium hydroxide ($Ca(OH)_2$). $Ca(OH)_2$ can be turned into $Ca(OH)_2$ hydrate, making the concrete's structure more compact and improving its compressive strength [39].

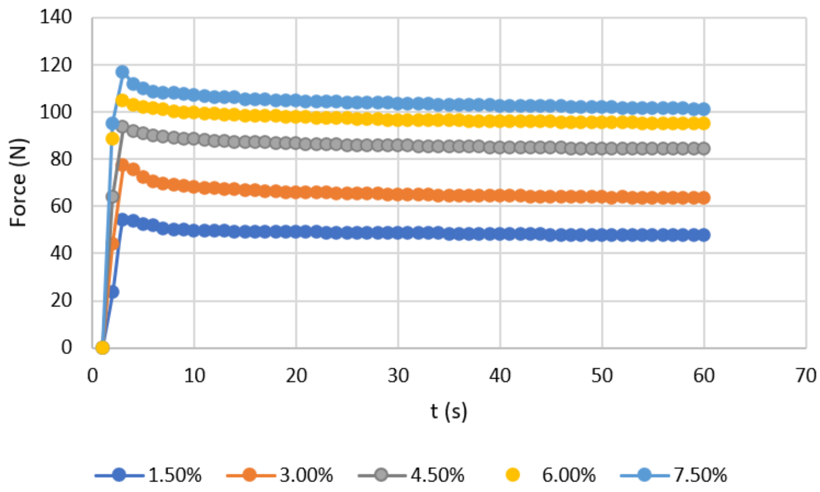

Fig. 4. Compressive strength result.

3.3. Density, water percentage, and water adsorption test

Table 2 shows the density value, the percentage of water passed, and the percentage of water absorption. The results obtained decreased density along with the addition of rice husk composition and reduction of coarse aggregate mass. This reduction in coarse aggregate is proportional to the decrease in concrete mass. Thus, the lower the mass of the concrete, the lower the density value obtained.

The highest density value, namely 2.167 g / cm³, was owned by the percentage of rice husks 1.5% with a concrete mass of 975 g and the lowest density value, namely 1.978 g / cm³ in the variant with a percentage of 7.5% rice husk with a concrete mass of 890 g. It can be seen that for porous concrete the addition of rice husks (500 μm) with different variations experienced different results in the percentage of water escaped. As can be seen, the higher the percentage of rice husk, the lower the percentage of water escaping. This is due to the composition of coarse aggregate which is also getting reduced along with the addition of rice husks. The coarser aggregate used; the more pores are produced [40]. Therefore, the highest percentage of escaped water was in the coarsest aggregate variants (the smallest percentage of rice husk).

Regarding the pores in the water pass test, it was also found that the rice husk filled the pores in the concrete. Based on these facts, it is proven that the greater the percentage of rice husks, the higher the water absorption capacity of the concrete. This is confirmed by the statement that rice husks can absorb much water because they have a very high porosity (about 79%) [41].

Water absorption in concrete is greater due to the high porosity value of rice husks. The highest percentage of escaped water was found in the percentage of rice husks 1.5; 3% with the results of 100% the percentage of water escaped, and the lowest percentage was found in the percentage of rice husks 4.5; 6; 7.5% with a result of 0% percentage of water escaped. Meanwhile, the results of the percentage of water absorption with the addition of rice husks (500 μm) with different variations experienced differences. This is because the higher the percentage of rice husks, the more water are absorbed by the concrete. The highest percentage of water absorption with a total of 1.657% was produced by a variant with a percentage of rice husk of 7.5% and vice versa, the lowest water absorption with a total of 0.307% was produced by a variant with a rice husk of 1.5%.

Table 2. The results of density, water pass percentage, and water absorption percentage.

Percentage of Rice Husk (%)	Density (g/cm^3)	Water Pass Percentage (%)	Water Absorption Percentage (%)
1.5	2.167	100	0.307
3.0	2.138	100	0.417
4.5	2.300	0	0.617
6.0	2.127	0	1.340
7.5	1.978	0	1.657

The successful preparation of porous concrete from rice straw is not only good for industrial perspective but also for education. The simple preparation can be done used commercially apparatuses, making it suitable for practicum. Indeed, it can help improving curriculum [42-46].

4. Conclusion

Effects of rice husk composition on the performance of porous concrete were investigated. Concrete with a higher percentage of rice husk is brown and has a rough surface. Higher percentage of rice husk addition has impact on the higher compressive strength value and percentage of water absorption, while the percentage of water escapes is less. The addition of rice husks (500µm) to the concrete mixture is recommended because rice husks contain silica that can react with the results of the reaction of cement and water, namely calcium hydroxide, turning it into hydrated calcium silicate, making the concrete denser, and increasing the compressive strength of the concrete and its porosity value.

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