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EFFECT OF SAWDUST, EGGSHELLS, RICE, HUSKS, AND CORN HUSKS AS FINE AGGREGATES ON THE MECHANICAL PROPERTIES OF CONCRETE

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Abstract

The purpose of this study was to determine the comparative effect of using sawdust, eggshells, rice husks, and corn husk on the mechanical properties of concrete. Concrete is made by refining, filtering, and mixing biomass materials (sawdust, rice husk, corn husk, and eggshells) with cement, water and gravel. The ratio used is sand: sawdust (1: 1), sand: sawdust: eggshells (2: 1: 1), sand: sawdust: rice husks (2: 1: 1), and sand: sawdust: corn husk (2: 1: 1). The mixture was moulded and dried in the sun for three days. Based on the compressive test, the results showed that the best concrete was obtained with a ratio of biomass sand: sawdust (1:1), which is 64,2 Newton. These results were obtained because sawdust contained levels of cellulose and hemicellulose, which could provide the binding strength between concrete particles. Based on the percentage of the water absorption test, concrete with fine aggregates sand gave the best results by absorbing as much as 1% water and passing water by 99%. With this research, the cost of making concrete can be reduced because of cheap and easy-to-find materials.

Keywords: Biomass, Concrete, Fine aggregate, Mechanical properties, Water absorption.

1. Introduction

Concrete is a composite building material made from a combination of aggregate (fine and coarse), water, and binder, namely cement [1]. The cement commonly used is Portland cement, consisting of mineral aggregates, water, and cement [2]. Concrete is a construction material that is still the main choice as a structural component of buildings in Indonesia [3]. Concrete is formed from a mixture of fine aggregate, coarse aggregate, cement, and water, which can affect the strength of concrete [4]. There are two different types of aggregate, they are coarse aggregate and fine aggregate. Coarse aggregates are usually greater than 4.75 mm in size, while fine aggregates are generally lesser than 4.75 mm in size [1].

Fine aggregate is one of the constituent materials that play a role in influencing the strength of concrete. Sand which has become the main source of fine aggregate is obtained by digging rivers. The removal of these river sands reduced the water head, so less percolation of rainwater in the ground, which resulted in lower groundwater level and also moving earth soil back to the river to replace the excavated earth, thereby causing erosion and impacted our environment [1]. Therefore, in this experiment, we use biomass as a part of fine aggregates.

Biomass can be used as a power generation material [5], fuel [6], and material to remove chromium from aqueous solutions [7]. Biomass additives such as sawdust, rice husks, and corn husks are fine aggregates that can be used as materials for making concrete. Variations in the addition of biomass as a building block for concrete can affect the compressive strength of concrete. Therefore, an understanding of the characteristics of the compressive strength of concrete to variations in the addition of biomass as the fine aggregate constituent of the concrete material is needed.

Concrete has been made using biomass as one of its constituent materials, for example making concrete using straw biomass [8], rice husks [9], and banana stem fibers [10]. The results of these studies indicated that the addition of straw biomass and banana stem fibers did not have a significant effect on the strength of the concrete. Meanwhile, studies using and comparing sawdust, rice husks, corn husks, and eggshells as fine aggregates in the manufacture of concrete have not been done. Therefore, this study tried to make variations of fine aggregate by combining the three biomasses with sand.

Rice is the main agricultural product in agricultural countries, including Indonesia. The rice mill produces 72% rice, 5% bran, and 20-22% husks [11]. Rice husks that are not handled properly will cause environmental pollution. Rice husks have a dominant content of silica (SiO_2) which is around 93% [12]. The content of silica or SiO_2 compounds in rice husks can contribute to the hardening process and increase the compressive strength of concrete [13].

Sawdust is mostly produced from the furniture industry. Although many people use sawdust, the presence of sawdust is still a lot. Sawdust has excellent lignocellulose content. In addition, the levels of cellulose and hemicellulose in sawdust provide the binding strength between particles when added to the cement mixture [14].

Eggshells can be used as an additional material for making concrete [15]. The composition of the eggshell itself is 98.2% calcium carbonate, 0.9% magnesium and 0.9% phosphorus [16]. Hunton [17] stated that the eggshell consists of 97% calcium carbonate which is similar to cement [18], and the average eggshell itself contains 3% phosphorus and 3% consists of magnesium, potassium, sodium, zinc, manganese, iron, and copper [19]. All the contents of the eggshell can affect the mechanical strength of the concrete.

Corn husks are the largest corn crop waste. Corn husks themselves are a lignocellulosic material. The uniqueness of corn husk waste is a porous, strong, and light structure because it contains 36.81% cellulose, 15.7% lignin, and 27.01% hemicellulose [20]. This content can affect water absorption.

The purpose of this study was to determine the effect of the addition of fine aggregate in the form of sawdust, rice husks, corn husks, and eggshells on the mechanical properties of concrete. Sawdust, rice husks, corn husks, and eggshells are used because of their easy availability and low price. By using these materials, the cost needed to make concrete can be reduced. The novelty of this study is the use of several fine aggregates of concrete, namely sawdust, eggshells, rice husk, and corn husk.

2. Materials and Method

2.1. Concrete making materials

The materials used in the manufacture of concrete were cement (obtained from PT. Indocement Tunggal Prakarsa Tbk.), water (obtained from Cianjur), gravel (obtained from Cianjur), sawdust (obtained from Cianjur), rice husks (obtained from Cianjur), corn husks (obtained from Cianjur), and eggshells (obtained from Cianjur).

2.2. Concrete fabrication process

Figure 1 shows the fabrication process of concrete with the addition of fine aggregate in the form of sawdust biomass, rice husks, corn husks, and eggshells. First, we dried the sawdust, rice husks, corn husks, and eggshells, then we ground the sawdust, rice husks, corn husks, and eggshells in 3 days to remove the maximum water content. After that, the mashed ingredients were filtered using a sieve to get the same size material, which is about 1×1 mm. The process of making the concrete dough was done by mixing cement, water, coarse aggregate (gravel), and various variations of fine aggregate in a ratio (2: 1: 4: 3).

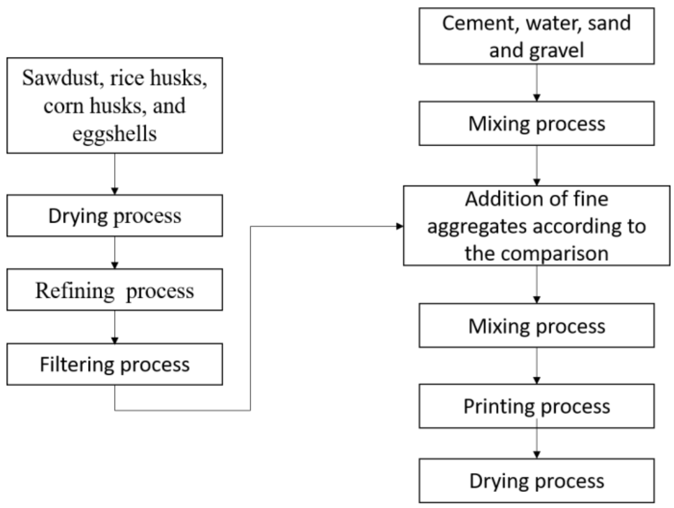

Fig. 1. Concrete fabrication process.

Table 1 shows the composition of each material in the fabrication of 400 gr of concrete. Variations of fine aggregate used were sand, sand: sawdust (1: 1), sand: sawdust: rice husks (2: 1: 1), sand: sawdust: corn husks (2: 1: 1), and sand: sawdust: eggshells (2: 1: 1). The mixed dough was then modelled using a mold measuring 3.5×3.5×3 cm and the top surface was flattened. Then, the dough that has been moulded was removed from the mold and dried by leaving the concrete for three days until it becomes solid and hardens.

Table 1. Compositions of materials for the manufacture of 400 gr of concrete.

Treatment (type of fine aggregate)	Cement (g)	Water (mL)	Gravel (g)	Sand (g)	Sawdust (g)	Rice husks (g)	Egg shells (g)	Corn husks (g)
Sand	80	40	160	120	-	-	-	-
Sand + sawdust	80	40	160	60	60	-	-	-
Sand + sawdust + rice husks	80	40	160	60	30	30	-	-
Sand + sawdust + eggshells	80	40	160	60	30	-	30	-
Sand + sawdust + corn husks	80	40	160	60	30	-	-	30

2.3. Mechanical properties

To determine the mechanical properties of the concrete that has been made, the concrete is analysed using a compressive test and a water absorption test.

2.3.1. Friction drag coefficient

A compressive test is a mechanical test conducted to determine the properties of the material used in structural analysis and material development. In this study, the compressive test was carried out by testing five variations of concrete using a Screw Stand Test Instrument (Model I ALX-J, China) equipped with a digital force measuring instrument (Model HP-500, Serial, No H5001909262). The compressive test is carried out by applying a compressive force to each concrete.

2.3.2. Friction drag coefficient

The percentage of passing water is a test that is carried out to find out how much water can be absorbed, and which cannot be absorbed by the concrete. This test is carried out by pouring 100 ml of water on the concrete surface gradually, then calculating the water that is not absorbed by the concrete. The percentage of water escapes can be calculated using the formula [21]:

$$\text{Percentage of water escapes} = \frac{\text{the amount of water not absorbed by concrete (ml)}}{100} \times 100\% \quad (1)$$

3. Result and Discussion

3.1. Characteristics of concrete

Concrete with fine aggregates in the form of variations of sand, sawdust, rice husks, corn husks, and eggshells is shown in Fig. 2. Visually, concrete with fine aggregate additives in the form of variations in biomass of sawdust, rice husks, corn husks, and eggshells has a brown colour, in contrast to concrete which is only given fine aggregate sand which has a grey colour. Figure 2 is the appearance of concrete with fine aggregate (a) sand, (b) sand: sawdust (1: 1), (c) sand: sawdust: eggshells (2: 1: 1), (d) sand: sawdust: rice husk (2: 1: 1), and (e) sand: sawdust: corn husk (2: 1: 1).

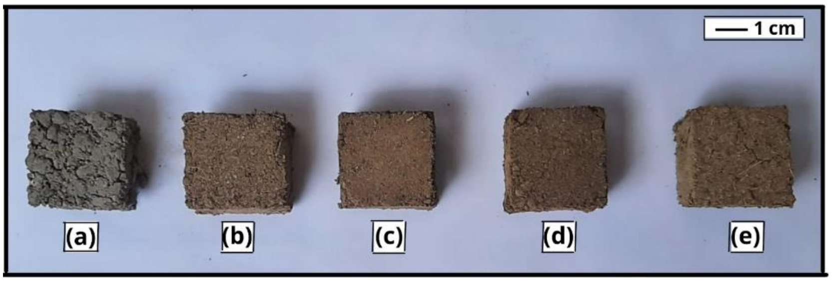

Fig. 2. The visual appearance of concrete with various variations of fine aggregates.

3.2. Compressive test

Figure 3 shows the compression test results to determine the texture and mechanical properties of the concrete that has been made. The greater the force, the higher the resistance and strength of the tested concrete [22]. Conversely, a smaller force indicates lower resistance and strength of the concrete. Saifuddin stated that the compressive strength of the concrete increased more after the addition of the sawdust mixture compared to the concrete that had not been added with the sawdust mixture [14].

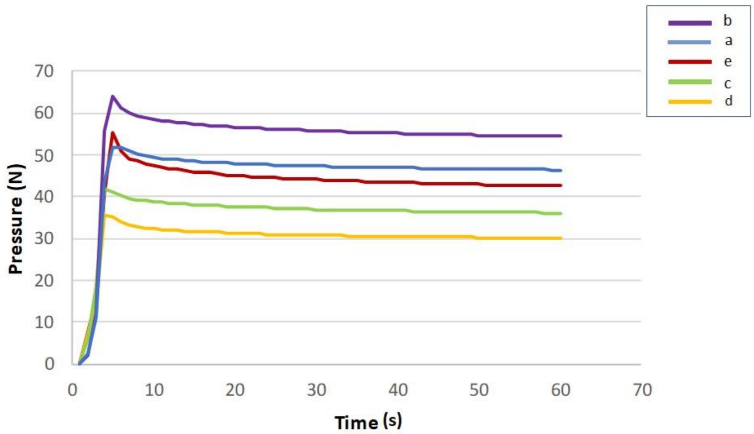

Fig. 3. Concrete compressive test results with various variations of fine aggregates.

Based on these results, it shows that the highest curve peak is obtained by concrete made with a ratio of fine aggregate sand and sawdust (1: 1). The concrete mixture of sand and sawdust concrete has the highest force, which is 64.2 Newton. This indicates that the use of a mix of sand and sawdust has a significant effect on increasing the strength of concrete. Sawdust contains lignocellulose which consists of cellulose, hemicellulose, and lignin which can have a good effect in increasing the strength of concrete [23]. The levels of cellulose and hemicellulose contained in sawdust provide the binding strength between particles when added to the cement mixture [14]. However, the addition of eggshells and rice husks as a fine aggregate did not increase the strength of the concrete.

Based on research conducted by Dewi et al. [24], the use of eggshells has no significant effect on the mechanical strength of concrete. Excessive levels of Calcium Oxide (CaO) in eggshells will react with water and during the hydration process only form calcium hydroxide ($Ca(OH)_2$). Excess Calcium Hydroxide does not react with silicate (SiO_2) so that the calcium silicate hydrate (C-S-H) bond which plays a role in the process of developing the compressive strength of concrete is not completely formed [25]. In processing eggshells into powder, it is necessary to have more treatment so that the eggshells are smoother, and they can be mixed with the concrete mixture. However, from testing the compressive strength of concrete, it can be concluded that concrete with eggshell material can be used as structural or non-structural construction material such as buildings that require general loads such as housing, sculpture, and house interiors [15].

The addition of rice husks to concrete can increase the value of its compressive strength, but the addition with a large enough scale makes the compressive strength of concrete decrease. This happens because the chemical reaction of binding the concrete-forming material that occurs is disrupted by the nature of rice husks which can absorb quite large [26]. In addition, special treatment is needed, such as complete combustion, on rice husks so that the silica content contained in them can be released [27].

Based on Maghfirah's research [28], with the increasing number of corn shell fibers, the mechanical properties of concrete decrease. This condition causes the concrete to become lighter and increase its water absorption value. However, based on the results obtained from this study, the addition of corn shell fiber made its mechanical strength increase, even exceeding the mechanical strength of concrete with fine aggregate in the form of sand. However, over time the mechanical strength of concrete with the addition of fine aggregate of corn shell fibers decreased faster than concrete with a fine aggregate of sand: sawdust (1: 1) and sand.

3.3. Water absorption test

The percentage of water escapes is shown in Fig. 4. Concrete with fine aggregates sand passes 99% and absorbs 1% of the water through its surface. The concrete with the ratio of fine aggregate sand: sawdust: eggshells (2: 1: 1) produces the lowest percentage of water pass from all variations of fine aggregate. Overall, concrete with the addition of sawdust, namely concrete (b), (c), (d), and € has a smaller percentage of water passage than concrete which only has fine aggregate in the form of sand. Cellulose and hemicellulose content found in sawdust can inhibit water diffusion due to its hydrophobic nature [29, 30]. This study is in line with previous studies [31-42].

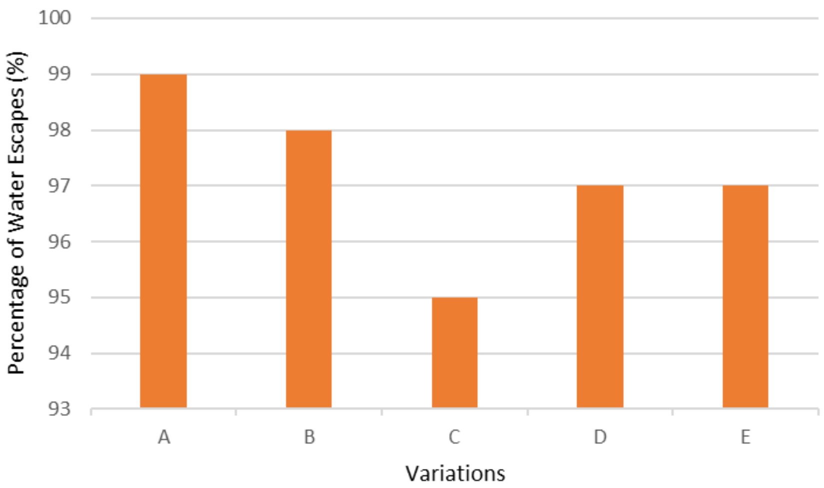

Fig. 4. Water absorption test.

4. Conclusions

The effect of the addition of fine aggregate in the form of sawdust, rice husks, corn husks, and eggshells on the mechanical properties of concrete has been investigated. The results showed that the addition of fine aggregate in the form of sawdust containing cellulose and hemicellulose levels produced the best concrete strength based on the compressive test. Based on the water absorption test, concrete with fine aggregates in the form of sand gave the best results. Concrete with the addition of sawdust as a fine aggregate actually gives results that are not better than fine aggregate in the form of sand.

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