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# Investigation of Mortar Using Rice Husk Ash As Partial Substitution of Porland Composite Cement

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***Abstract:***
***Background***: *Cement manufacturing uses non-renewable sources of raw materials. In addition, the cement loading process produces air pollution from carbon dioxide gas. This phenomenon has made environmentalists protest strongly against cement production. Many researchers used waste as a substitute for cement. One that has been tested to replace cement is rice husk ash waste. Because no studies have used RHA as a substitute for PCC types, this study evaluated its effect when used in mortar exposed to acid rain.*
***Materials and Methods***: *Tests for the properties of the PCC-RHA paste were carried out for normal consistency and setting time. Furthermore, a compressive strength test was carried out for mortar durability performance due to acid rain. The mortar will be immersed (acid rain simulation in the laboratory) in an acid solution for 28, 90, and 120 days. The test object consisted of four treatments according to the number of percentages, namely rice husk ash 0%, 5%, 7.5% and 10%.*
***Results***: *Replacing the amount of PCC cement with RHA up to 10% caused an increase in the value of the normal consistency of the paste, which was 13.33%. Meanwhile, the initial and final setting time increase was 27.78% and 10%. Specimen 7.5 RHA has the highest compressive strength and resistance to acid rain compared to other specimens. The decrease in compressive strength after soaking for 90 days and 120 days only decreased by 5% and 14%, respectively.*
***Conclusion:****RHA, as agricultural waste, can also be used as a substitute for PCC-type cement. In addition, the resulting PCC-RHA mortar can increase its durability against acidic environments compared to PCC mortar. However, the amount of PCC that RHA can replace is not as large as using OPC, which is 7.5%.*
***Key word***:*Rice huskash ;Mortar;PCC;Acidrain;Initialtime;Compressive strength.*

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## I. Introduction

The negative impacts of the cement industry include health problems and environmental pollution in the communities around the cement plant. In addition, cement production also produces emission gases during the combustion of lime at high temperatures, which produces $CO^2$ emission gases which impact global warming. Based on the description of the negative impacts of cement production, researchers are currently looking for alternative materials to replace cement. Incorporating waste and industrial by-products into concrete has become one of the alternatives to reduce cement consumption and, consequently, make it a more environmentally friendly material. Several previous researchers have widely used fly ash (FA) as a substitute for cement. FA mixed with metakaolin (MK) can be used as an alternative binder on mortar. The aim was to reduce the use of natural resources for cement production [1] and to create an environmentally friendly green mortar [2].

Geopolymer cement was also widely studied recently. The method used was to mix industrial waste in the form of FA granulated blast furnace slag (GBFS) and MK. The mixture was activated with an alkaline sodium silicate and potassium hydroxidesolution. The results showed that the geopolymer cement was suitable for a friendly mortar [3]. Furthermore, slag, activated with alkali, has also been successfully used to manufacture green mortar [4]. Alum sludge ash (ASA) that has been carbonated at a temperature of 200–300 ◦C has been used with Ground Granulated Blast Furnace Slag (GGBFS) as a cementitious material in green mortar. In this study, ASA and GGBFS wereused as up to 6.0% by Ordinary Portland Cement (OPC) weight.[5].Furthermore, recycled glass can be reused in construction for sustainability. The main component of glass is silica oxide; if activated, its pozzolan properties will appear. This condition causes the waste to be suitable to be used as a binding material on the mortar [6]. Another study developed a significant ultra-rapid hardening (URHM) hardening mortar known as fiber mortar. Polyethylene (PE) fiber, silica fume (SF), and cement kiln dust (CKD) were mixed for this purpose. The optimal amount of CKD and SF of 0.15 and 0.2, respectively, based on the weight ratio of cement, was determined to develop a strain-hardening URHM containing 2% PE fibers. [7].

The development of material technology today, in addition to making environmentally friendly materials,also makes high-performance materials. This goal led to many studies addressing the issue of material durability in aggressive external environments. Mortar performance containing ichu ash as a potential environmentally friendly alternative to traditional pozzolan (at a replacement level of 6% and 10%) worked well to hold $CO_2$ and chloride ions [8]. FA-based Portland Pozzolan Cement (PPC)[9] and mortar reinforced with Graphene Oxide [10]hadhigh resistance to exposure to sulfuric and chloride acid. Bio-based polyurethane (castor oil) wassuccessfully used to increase the durability of two types of cement mortar, namely: ordinary Portland cement (PCM- mortar) and fast hardening of Portland cement (RHPC-mortar)[11].Rice husk ash (RHA) is another pozzolan material that can substitute cement. RHA is a waste from rice processing containing the dominant element silica (SiO2), between 86.90-97.30%. Research using RHA as a substitute for cement in mortar has also been widely studied. Using RHA maximum of 15% by weight of cement was proven to have a higher compressive strength than 100% OPC [11].

Based on the research results above, it can be concluded that waste material can partially replace OPC cement. Unfortunately, in the Indonesian market, it is tough to get OPC. The type of cement circulating is PCC. PCCor mixed cement is a hydraulic binder consisting of clinker, gypsum, and one or more inorganic materials where they fill, ranging from 6% to 35% of the total mass of PCC. Thus, it is necessary to study the effect of using waste as a substitute for PCC cement instead of OPC on mortar. The waste used is RHA which is very much available in Indonesia as a rice-producing country.Here, this study aims to determine the opportunity of RHA as a partial replacement material for PCCin mortar. Furthermore, an investigation into mortar durability against acid rain was done. Several major cities in Indonesia have experienced rain with a pH below five, classified as acid rain. This research method used various percentages of RHA in the mixture without using alkaline activation. Acid rain is simulated in the laboratory by immersion in sulfate and sodium solutions.Further, after immersing, specimens were tested for compressive strength. If RHA is proven suitable in mortar as a substitute for PCC cement, it can create an environmentally friendly mortar. Using this agricultural waste will help solve the problem of piling husks on the field without use. In addition, reducing the amount of cement used will automatically minimize air pollution. In addition, if using RHA can increase the resistance to acid rain, the formed mortar is categorized as high-performance.

## II. Material And Methods

This research is experimental research carried out in the laboratory. The materials used in this study were PCC cement, fine aggregate (sand), distilled water, and rice husk ash that passed the no. 200 sieve. Meanwhile, acid rain simulation was carried out by immersing the specimens in a mixture of sulfuric acid solution ($H2SO_4$) and nitric acid (HNO 3) with a pH below five. The specimens were cube-shaped with a size of 5cm x 5cm x 5cm consisting of 4 groups of samples—specimens without RHA as the control test piece. The percentage of RHA used is 5%, 7.5%, and 10% of the amount of PCC.

**Figure 1**. Vicat Test

The tests performed were Vicattests (Figure 1) and compressive strength (Figure 2). The Vicat test results were normal consistency (ASTM C-187) and cement / RHA time setting (ASTM C-403 ). Meanwhile, the compressive strength test (ASTM C-270) produced the compressive strength of each mortar with an RHA percentage. The mortars were pressed after immersing in an acidic solution for 28, 90, and 120 days.

**Figure 2**. Compression Test

## III. Result

**Vicat Test**

RHA was taken directly at random with a grayish-whitecolor. The ash was dried and filtered with sieve No.200 (Figure 3). Normal consistency testing was intended to determine the characteristics or moisture content needed when RHAwas substituted into the cement paste mixture as a substitute for cement.

**Figure 3**. Rice Husk Ash

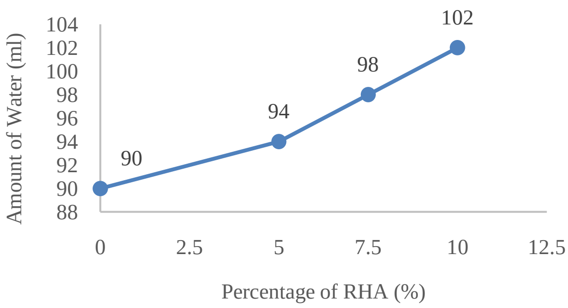


**Figure 4**. Amount of Water

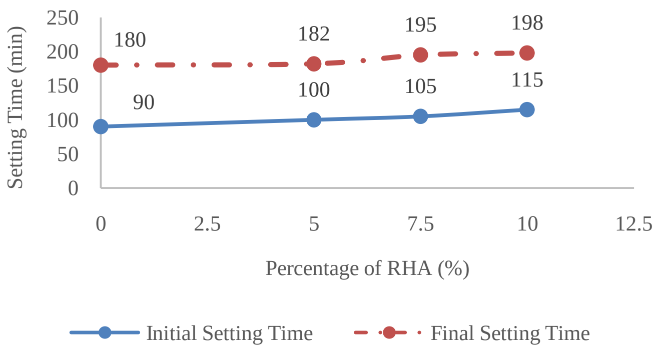


**Figure 5**. Setting Time PCC-RHA

Figure 4 shows that the more RHA was used, the more water was needed. The amount of water in control specimens required as much as 90 ml. Furthermore, the amount of water for the 5% RHA increased slightly to 94 ml. This value grew to 98 ml and 102 ml for 7.5% RHA and 10% RHA, respectively.

The setting time test aims to determine the time required for cement to change its properties from liquid to hardened. Figure 5reveals the time needed for PCC-RHA to reach the initial and final setting times. There was no significant difference between the specimens without RHA and with RHA. It can even be said that the setting time values were almost the same for both the initial and final setting times. The initial setting time for specimens without RHA was 90 minutes and slightly increased by 100 minutes for 5% RHA. This initial time increasedto105 minutes and 115 minutes for 7.5% RHA and 10% RHA,respectively. Final setting times for specimens 0% RHA, 5% RHA, 7.5% RHA, and 10% RHA were 180 minutes, 182 minutes, 195 minutes, and 198 minutes, respectively.

**CompressionTest**

The test object was soaked with plain water for 28 days, then proceeded with the addition of a solution of sulfate (H2SO $_4$) and a solution of Nitric Acid ($HNO_3$) with a pH below 5.6 (Figure 6 ).

**Figure 6**. pH Test of Sulfate and Natrium Solution

Based on table 4.3. The highest mortar compressive strength at 28-day soaking with 7.5% rice husk ash treatment in the mortar mix with the average compressive strength value of the mortar was 5.33 Mpa. At the same time, the lowest compressive strength value at the 0% treatment of rice husk ash in the mortar mix with the average compressive strength value was 4.45 Mpa.

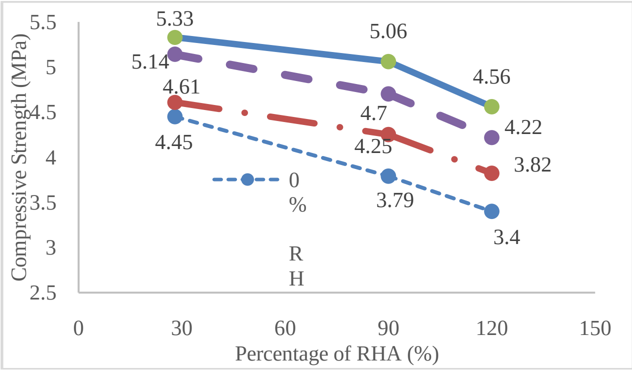


**Figure 7**. Compressive Strength Mortars

Figure 7indicates that the compressive strength decreased with increasing immersion time in acidic solutions. The 7.5% RHA test piece had the highest compressive strength even though it had been immersed for 120 days, from 5.33 MPa to 4.56 MPa. In contrast, the specimens without RHA had the lowest compressive strength compared to other test objects, which from 4.45 MPa decreased to 3.4 MPa.

## IV. Discussion

**Setting Time Paste PCC-RHA**

Cement paste is a mixture of water with cement and sand. This paste serves as a filler for pores between fine aggregate grains. In addition, cement paste is a binder in the hardening process, which can cause mutual gluing of aggregate grains. The specimens in this study used the substitution of RHA that had been filtered using sieve no. 200 as a condition for material smoothness as a substitute for cement.

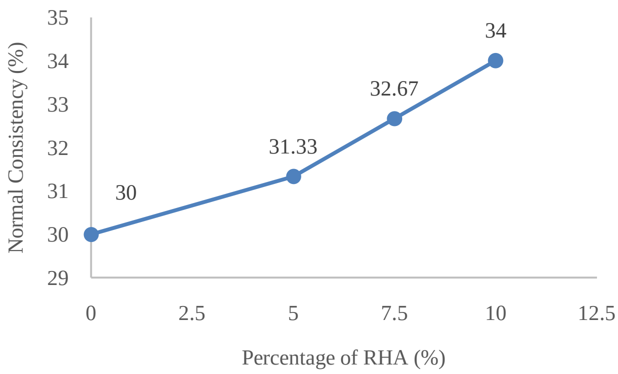


**Figure 8**. Normal Consistency of PCC-RHA

In line with the amount of water needed, the percentage of normal consistency also increased if the ratio of RHA increased (Figure 8). Furthermore, Figure 9finds the magnitude of the increase in the paste with RHA compared to that withoutRHA. The normal consistency value of 5% RHA was 4.43% greater than the paste without RHA. Furthermore, the normal consistency values of 7.5% RHA and 10% RHA were 8.90% and 13.33% greater than pasta without RHA.

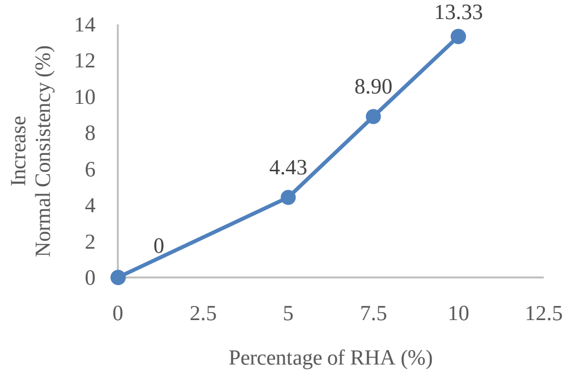


**Figure 9**.Increase in Normal Consistency

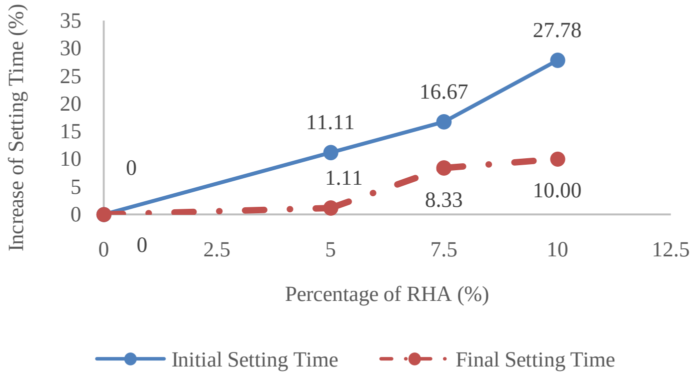


**Figure 10**. Increase of Setting Time

Figure 10shows that the initial setting time of the mortar with 5% RHA was 11.11 % higher than that of the mortar without RHA. The initial setting time value of the mortar with 7.5% RHA and 10% RHA increased by 16.67% and 27.78%. Meanwhile, the magnitude of the increase in the final setting time was not as large as in the initial setting time. The final setting time for 5% RHA increased slightly by 1.11%. The growth experienced by 7.5& RHA and 10% RHA was also tiny, namely only 8.33% and 10%. It was concluded that along with adding rice husk ash as a cement substitution to the mortar mixture, the need for water (normal consistency) and the length of binding time also increased.

**Compressive Strength**

Loading was carried out until the test object became destroyed and could no longer withstand the given load, so the maximum load held by the specimen was obtained. Figure 11describes that the compressive strength value of mortar without RHA decreased by 15% and 24% after immersingfor 90 days and 120 days. Meanwhile, the decrease for specimens with a lower RHA was smaller than 10% and 20%. This condition shows that specimens using RHA were more resistant to acidic environments than specimens without RHA. Furthermore, the 7.5% RHA has the highest resistance among other samples. If using OPC, the compressive strength of the 10% RHA specimen gives a higher value than without RHA [12]. Hence, it can be concluded that if mortar use PCC, the percentage of RHA is only under 10% by cement weight.

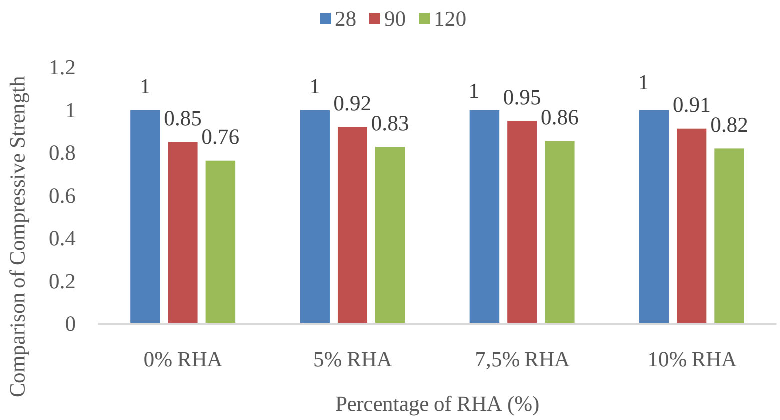


**Figure 11**. Comparison of Compressive Strength Mortar

## V. Conclusion

Based on the analysis of test data, the conclusions of this study are as follows:

1. Replacing the amount of PCC cement with RHA up to 10% caused an increase in normal consistency, equal to 13.33%. The length of the setting time increased with the increase in the percentage of RHA in the paste. Initial and final setting time increased was 27.78% and 10%. The 7.5% RHA achieved the highest compressive strength and the highest resistance to acid solutions. After immersing for 90 and 120 days, compressive strength decreased only by 5% and 14%.
2. 7.5% RHA specimenachievedthehighestcompressivestrengthandthehighestresistancetoacidsolutions. After immersingfor 90 and 120 days, the compressivestrengthdecreasedby 5% and 14%.

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