

Characteristics Comparison on Mechanical Properties of Mortars using Agriculture Waste as a Cement Replacement Materials

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1 Characteristics Comparison on Mechanical Properties of Mortars using Agriculture Waste as a Cement Replacement Materials

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Abstract. Excessive use of cement makes the price of construction projects expensive. Mortar making using high amounts of cement also has the potential to increase the price of the construction. This study discusses the use of agricultural waste as a substitute for cement in mortar production. The waste used in this study was bagasse ash, fuel ash palm oil, and rice husk ash. Each waste is added as much as 25%, 50% and 75% which are then tested for mechanical properties such as water content, unit weight, absorption, and IRS. Compressive strength was tested when the mortar was 28 days old with a cube-shaped specimen with a size of 50 mm x 50 mm x 50 mm. From the test results, it was found that all of this waste can be used as a substitute for cement. To produce a compressive strength of 100 kg/cm² can add each waste with a percentage range of 10-12% of the weight of cement.

Keywords: Mortars, Bagasse Ash, Fuel Ash, Rice Husk Ash

1 1. Introduction

Ordinary Portland Cement (OPC) is the basic cement which is currently the most produced in the world [1]. Higher demands for infrastructure and housing contribute greatly to the production of cement which is one of the ingredients of concrete manufacture [2]. As an effect, the release of CO₂ into the environment free of cement production continues to increase causing the level of global warming to be increasingly difficult to control [2, 3]. It has been reported that around 4.1 billion tons of cement are produced every day in 2015, with each 1 ton of cement producing 0.7-1.1 CO₂ emission [4, 5]. By continuing to increase gas production, this is certainly a special concern to maintain environmental conditions for the better and reduce the level of global warming.

In some tropical countries, agriculture is one of the reliable sectors. In Indonesia as a tropical country, it is very much developing the agricultural and plantation sectors. The plantation sector that develops is oil palm plantations, sugar cane plantations and rice farming which produce rice as one of the basic ingredients of food for the majority of the Indonesian people. In processing, the results of these



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1 plantations leave behind waste that has not been utilized so far. In general, plantation and agricultural waste in Indonesia has not been managed properly so that this waste will have a bad effect in the long term.

Mortar is a construction material component that is usually used not for structural components. The main material for making mortar consists of Portland cement, water and fine aggregate. In general, people in Indonesia use mortar as an adhesive for masonry on walls, whose function is not a structural component. Considering its function as an adhesive, the use of cement on mortar should be reduced or replaced with other materials that can reduce waste released into the wild so that it also has the potential to reduce the issue of global warming.

In the past few years, the use of pozzolanic materials in concrete or mortar constituents has become very essential and has experienced a significant increase [6]. Utilization of waste from agriculture as a mortar maker will certainly have advantages. Besides being able to reduce the composition of agricultural waste, the use of waste can also reduce the use of cement for material components that do not require high levels of strength. By utilizing these wastes it will produce new materials in the field of construction that are more environmentally friendly.

The use of bagasse ash as an added ingredient in the manufacture of concrete has been done before. Some researchers use this agricultural waste both on mortars and on concrete. Some of the studies that have been carried out include mechanical and durability properties of bagasse ash mortar [1, 7, 8], admixture in self-compacting concrete [9], high strength concrete with bagasse ash [6, 10]. In addition, the characteristics and microstructures of bagasse ash have also been carried out as a base for replacing Portland cement [11]. Based on several studies it can be concluded that this material has the potential to be used as a base for making mortar and concrete. However, with the condition of the origin of plants that are different locations with previous researchers, of course, they must be further investigated regarding capability of this material as an environmentally friendly mortar constituent.

In addition to bagasse ash, this study will compare the characteristics of other ingredients, namely palm oil ash and rice husk ash. In palm oil ash research has been carried out on its characteristics in making mortar [12-14], the use of palm oil ash as material for making concrete [15-17], and also making mortar with geopolymer systems [18, 19]. Through some of the results of the research, it is indicated that the material of palm oil ash has the potential to be used as one of the mineral substitute materials for cement. In addition to bagasse ash and palm oil ash, many wastes produced as a result of farming with rice husk ash are also not utilized optimally. Several studies on rice husk ash have also been carried out, including durability checks and microstructure rice husk ash mortar [20], physical, mechanical and chemical properties of rice husk ash mortar [21-24].

In this study will compare normal mortar without using added agriculture waste material against mortar by using each ingredient added by agriculture waste. Through this research, it is expected to produce optimum levels suitable for the utilization of waste agriculture as a mortar constituent. In addition, a fresh properties check will also be carried out and several mechanical properties checks such as water content, unit weight, and absorption value.

2. Materials and Test Method

The main materials used in this study are bagasse ash (BA), palm oil ash (POA), rice husk ash (RHA) and ordinary Portland cement (OPC). In addition, using water and fine aggregate with the same composition for all variations of the test object. Table 1 shows the results of examination of chemical properties for each of the main ingredients from previous studies. The ash baggage, palm oil ash and rice husk ash have a high SiO₂ value that exceeds 50%, whereas in Portland cement has a higher CaO content of 50.76% followed by SiO₂.

In this study using 12 variations where each of the added ingredients consisted of 4 variations. Variation used uses the percentage of volume, adding 25%, 50%, and 75% additional ingredients instead of cement. While 1 variation is used as a control using 100% Portland cement and without using added ingredients. In Table 2 shows the number of numbers for each of the 10 test items. In this study, testing of fresh properties and mechanical properties will be carried out on each variation of the test object used.

1 Fresh properties testing uses a flow table while mechanical properties are carried out by making specimens measuring 50 x 50 x 50 mm. Mechanical tests carried out in the form of examination of unit weight, water content, absorption, density and initial rate of suction (IRS). And compressive strength tested at the age of 268 days. Each test was carried out on 10 specimens which were then averaged to obtain results with standard deviations that met the specifications.

Table 1. Chemical properties of BA, POA, RHA, and OPC [2, 24, 25]

Materials	SiO ₂	K ₂ O	Fe ₂ O ₃	CaO	P ₂ O ₅	MgO	Al ₂ O ₃	TiO ₂	Na ₂ O	MnO
BA	56.37	0.92	5.04	2.36	0.12	1.43	14.61	0.25	1.57	0.06
POA	64.16	8.25	6.33	5.81	5.18	4.87	3.73	0.19	0.18	0.18
RHA	93.8	0.12	0.3	0.89		0.32	0.74		0.28	
PC	23.86	0.92	2.19	50.76	0.12	1.36	5.77	0.25	0.91	0.06

1 **Table 2.** Mix proportion for each variation

Variation	Materials for 10 specimens (ml)					
	Cement	Water	Sand	BA	POA	RHA
100PC 0BA	600	300	1800	0	-	-
75PC 25BA	450	300	1800	150	-	-
50PC 50BA	300	300	1800	300	-	-
25PC 75BA	150	300	1800	450	-	-
100PC 0POA	600	300	1800	-	0	-
75PC 25POA	450	300	1800	-	150	-
50PC 50POA	300	300	1800	-	300	-
25PC 75POA	150	300	1800	-	450	-
100PC 0RHA	600	300	1800	-	-	0
75PC 25RHA	450	300	1800	-	-	150
50PC 50RHA	300	300	1800	-	-	300
25PC 75RHA	150	300	1800	-	-	450

1 **3. Result and Discussion**

The slump test is done before the concrete is put into the mold. In Figure 1 is the slump flow test results. The results show that the added value of the added material indicates that the spread value in the specimen is getting higher. In a variation of 75% added ingredients, rice husk ash has the smallest slump value, followed by palm oil ash and bagasse ash. However, all specimens meet the minimum specifications required for mortar manufacturing.

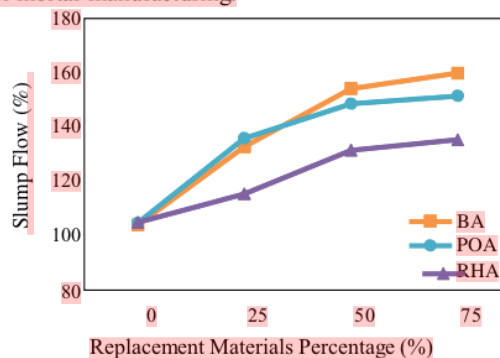


Figure 1. Flow test for each specimen

¹ In Figure 2 shows the results of examination of fresh concrete, from these results it can be explained that in making mortar it is necessary to pay attention to the amount of water used. In this study using the same amount of water for each specimen. However, the more ingredients added, the more water will be needed. In Figure 2 it can be seen that the mortar is not plastic and tends not to fuse between parts. In addition, because of the higher pozzolanic properties, the mortar will react longer. During the stirring process, the water content in the ingredients is very small so that during the stirring process, this added material absorbs more water and has an effect on the value of the workability. It is recommended for the next study, by using different variations of the mixture, the amount of water used must also vary according to the type of material and the value of the expected workability.



Figure 2. Flow test specimen (a) 100% Portland cement; (b) 25% palm oil ash; (c) 50% palm oil ash; (d) 75% palm oil ash

The next test is the mechanical properties of mortar using ingredients added to agriculture waste as a substitute for cement. Examinations carried out in the form of unit weight, water content, absorption, mass density and IRS.

The results of unit weight testing as shown in Figure 3 (a) indicate that the more increasing the level of added material used will result in smaller unit weight or the mortar will be lighter. Mortars using this added material cannot be concluded with added ingredients such as what will produce lighter mortars because the results obtained tend to have a fluctuating pattern but with the longer trend will decrease. Mortar using bagasse ash has a tendency to decrease smaller than mortar using other added ingredients. Water content testing is also carried out with the results seen in Figure 3 (b). The results show that the higher the content of the added ingredients the higher the water content obtained in the mortar. This is because the more pores produced by the mortar because in this study using waste materials with a grain size not smaller than Portland cement. So that for further research it is necessary to pay attention to the grain size of the admixture material used. Increased water content by mortar from bagasse ash and rice husk ash tended to experience a similar increase, but the increase in water content in oil ash pump mortars tended to be smaller than the two previous materials.

The mass density test results show that for bagasse ash and rice husk ash tend to have a fluctuating pattern but will continue to decline the more added ingredients are used, while the mortar using palm

1 oil ash will decrease if more ingredients are added. Palm oil ash mortar has the smallest type of rice compared to mortar using other added ingredients. The results of the examination can be seen in Figure 3 (c). Basically, the lighter this material will be the better for construction material, but it needs to pay attention to its strength.

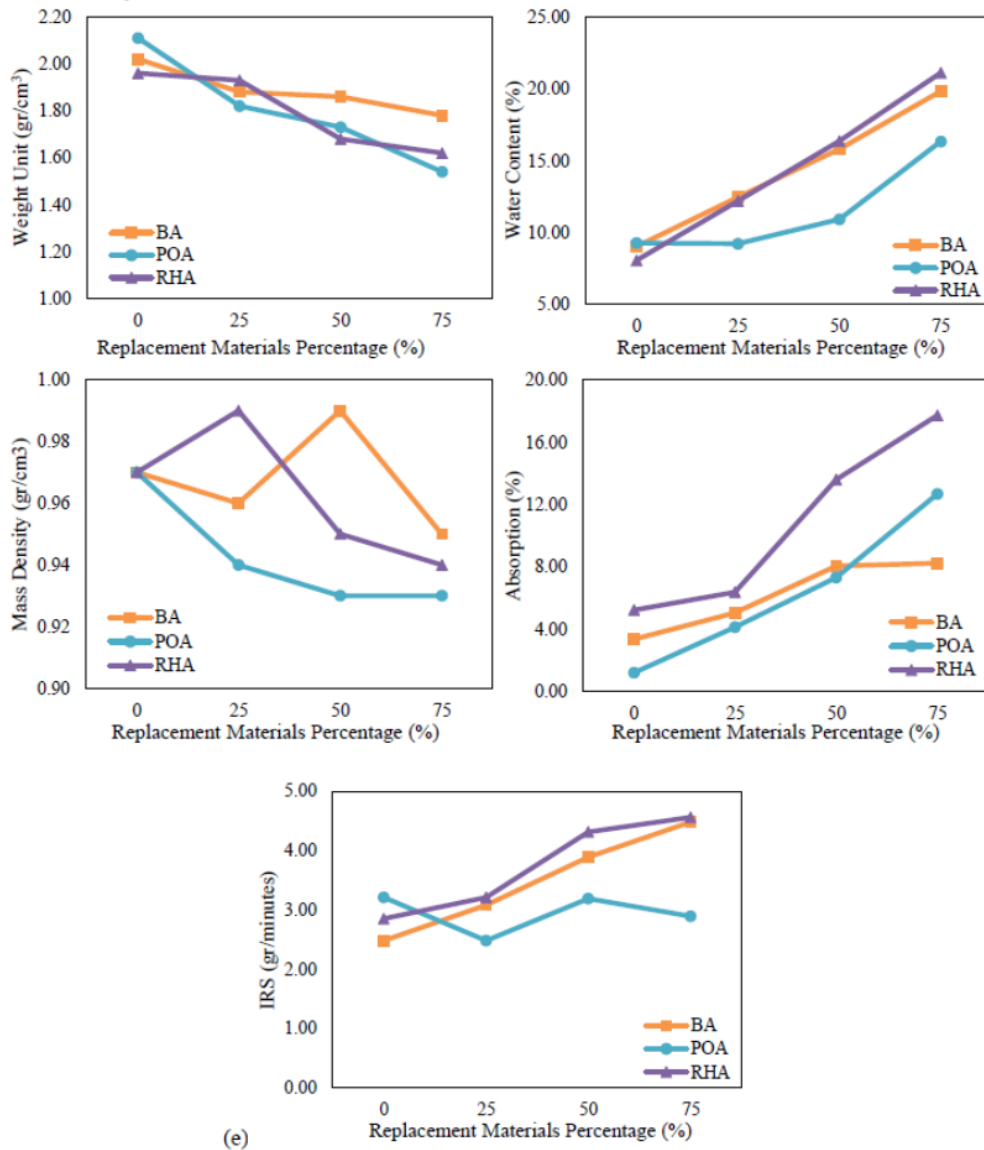


Figure 3. Mechanical properties of mortar (a) weight unit; (b) water content; (c) mass density; (d) absorption; (e) initial rate of suction

In Figure 3 (d) shows the results of absorption that occurs in mortar. The results show that the more added ingredients used will increase the absorption value, even if seen from the condition of the water content that is contained in the mortar also increasing. Of course the higher the absorption value indicates

that the mortar will more easily absorb water. Mortar using rice husk ash admixture has the highest absorption value compared to other materials. The pore produced by this material is much higher than other materials, besides, the size of the grain also affects the absorption value produced. The more pore and the ease of material absorbing water will cause the mortar to absorb water more easily.

In Figure 3 (e) shows the IRS results where the more added ingredients are used, the higher the absorption rate (IRS) will also be. However, palm oil ash has a smaller IRS value compared to other higher materials even though the values are not much different. In addition, ingredients added to palm oil ash have a smaller increase in value compared to using other added ingredients which tend to increase faster.

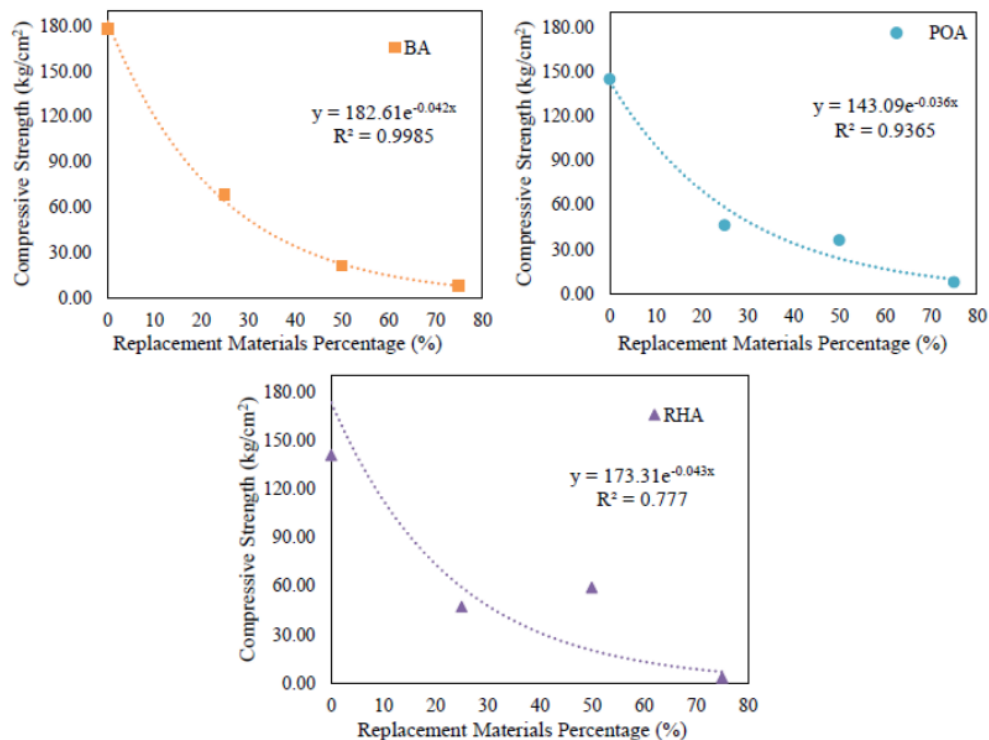


Figure 4. Compressive Strength (a) bagasse ash; (b) palm oil ash; (c) Rice Husk ash

In Figure 4 is the relationship between compressive strength at the age of 28 days with the percentage of added ingredients used. The results show that the results obtained are that the more added ingredients used, the less compressive strength produced. The highest compressive strength is produced by normal mortar without using ingredients added to agriculture waste. Table 3 is a standard mortar for buildings in Indonesia. Through this standard shows that to produce mortar does not have to use cement with a high compressive strength. So that it can be replaced with other pozzolan ingredients.

Through Figure 4, it can be calculated how many percent of the added material that can be used in accordance with the standard data in Table 3. Strengths that want to be produced adjust to the needs of the construction site. For example, if you want to produce mortar with B100 quality, which means compressive strength of 100 kg/cm². So from Figure 4, using bagasse ash can replace cement by 12%, as well as using rice husk ash. While using palm oil ash will only be able to add about 10% of the total percentage of cement used. This will greatly help reduce the use of cement and can help reduce the cost

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of producing mortar in construction which is commonly used in some nonstructural components specifically in infrastructure.

Table 3. Mortar standard in Indonesia [26]

Class	Minimum Compressive Strength (kg/cm ²)		Maximum Absorption (%)
	Average for 5 sample	Each Sample	
B25	25	21	-
B40	40	35	-
B70	70	65	35
B100	100	90	25

4. Conclusion

Through the results and discussion above, it can be concluded that the increasing volume of material is added, the higher the flowability produced. However, this is due to the lack of water used, so the resulting mortar has a very small degree of plasticity. In the next study, it is necessary to consider the water binder ratio for each use of different added ingredients.

Through testing the mechanical properties show that the results obtained using materials are no better than mortars using 100% cement Portland, this is because mortars tend to lack water, resulting in large pores and no control on the size of the added material.

Through the results of the compressive strength it can be concluded that the more volume the admixture material increases, the smaller the compressive strength it will produce, but for some mixtures it still meets the specifications required by the applicable standards in Indonesia. In each ingredient added has the same characteristics of compressive strength produced at the age of 28 days.

At 100 kg cm² compressive strength, it can be applied to bagasse ash and rice husk ash to replace cement by 12% while mortar with palm oil ash can replace cement by 10%. For further research, this percentage can be used by examining the effect of cement water factor and grain size of admixture material to further examine so that it can improve the characteristics of mortar

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