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Potential Rice Husk Ash (RHA) For Clinker Substitute in K400 Concrete Compressive Strength Applications

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Abstract: Rice husk ash is a waste of rice husk combustion with pozzolanic properties and contains relatively high silica. Therefore, rice husk ash can be used as a cement substitute to manufacture concrete. This study aims to determine the performance of rice husk ash as a clinker substitute for the compressive strength of the K400 concrete produced. Rice husk ash used in this study was first ground to pass a 45 µm sieve. Then the K400 concrete mix design was made with three variations of adding rice husk ash: 0%, 10%, and 20% of the total cement consumption. The tests carried out on the test objects included slump testing and compressive strength testing for concrete aged 3, 7, 28 days. Slump flow testing is carried out to see the ease of work. At the same time, compressive strength testing is carried out to determine the quality of the concrete itself. Based on the Compressive Strength tool observing, adding rice husk ash, as much as 10% has a strength value that reached the standard compressive strength determined at 28 days. On the other hand, adding rice husk ash more than 10% produces a lower compressive strength of concrete than the standard.

Keywords: *Aggregate; mix design; slump*

1. Introduction

Concrete technology is developing rapidly worldwide, and Indonesia is no exception [1]. Today, the world needs sophisticated infrastructure with small structural loads such as high-rise buildings (which require columns and precast concrete), long and wide span bridges, runways, and other facilities, requiring high-strength concrete or called K-400 [2]. Along with its development, various innovations related to additives appeared that can improve the mechanical properties and strength of concrete and are economical [3]. In general, concrete consists of aggregates, hydraulic cement, water and may contain other cementitious materials (pozzolan) and other chemical additives based on standards of SNI 7656-2012 [4]. The addition of chemicals and pozzolan materials aims to speed up, slow down, improve workability, reduce water use, increase strength, or change other properties of the resulting concrete [3]. Each constituent material has different functions and effects. The essential characteristic of concrete is its compressive strength [5]. The other properties are generally good with high compressive strength [6]. The factors that affect the compressive strength of concrete consist of the quality of the constituent materials, the value of the water-cement factor, the gradation of the aggregate, the maximum size of the aggregate, the working method (mixing, transportation, compaction, and treatment), and the age of the concrete. Additional materials used must meet the provisions contained in the SNI. Especially for chemical additives, they must meet the requirements given in ASTM C.494, namely, concerning Standard Specifications for Chemical Admixture for Concrete [7].

The use of pozzolanic materials in concrete production provides advantages for both the company and the environment [3]. The pozzolanic material mentioned can be in the form of natural pozzolan, which is material derived from weathering of volcanic ash resulting from volcanic eruptions, while artificial pozzolan is material derived from industrial waste from coal or agricultural waste products [8, 9]. This pozzolan material contains reactive elements of silica and aluminate [10]. This material will behave like cement through a hydraulic process, pozzolanic activity, or both. For companies, pozzolanic material provides benefits; namely, it can reduce the need for clinker to manufacture cement products so that production costs can reduce. In addition, CO_2 gas emissions resulting from the clinker combustion process can also reduce [3, 11].

Previous researchers reported that rice husk ash (RHA) has properties such as cement or materials containing chemical compositions that can increase the strength of concrete. RHA has a silica (SiO_2) content of more than 90%, and when mixed with cement, it can produce higher strength. [12, 13, 14]. Based on data from the Indonesian Central Statistics Agency (BPS), national grain production in 2017 is estimated to reach 57.05 million tons of dry milled grain (GKG) [15]. With a production growth of 5%, the national rice production target will reach 66.04 million tons in 2020. It was also reported that the rice milling process generally obtained about 20-30% of the husks by weight of GKG. Consequently, the amount of rice husk ash will also increase [15].

For that reason, rice husk ash is a potential alternative material as a partial substitute for cement in the manufacture of concrete rather than just as waste. In this study, RHA was added to concrete with a composition of 10% and 20% of the total concrete mix.

2. Research Methods

2.1. Tools and chemicals

The Equipment used in this study consists of a Sieve Shaker; Sieve; Pans and covers; Scales with an accuracy of 0.1 grams; Oven; Pycnometer (for gravimetric procedures) 500 cm^3; Volumetric flask for testing 55 g of test sample; mold and impact. The materials used include Tiga Roda brand Cement PCC; Coarse aggregate size 10 – 20 mm; fine aggregate from Bangka Island; Water; Rice husk ash obtained from a rice mill in Cianjur, West Java.

2.2. Aggregate Preparation

The aggregate to be analyzed consists of coarse and fine aggregate, which results from sampling representing the entire sample. Weigh fine aggregate at least 300 grams after drying at 100°C for 24 hours. Meanwhile, coarse aggregate accepting on the largest aggregate size. To determine coarse and fine aggregates size distribution or gradation of concrete mixtures, refer to ASTM C136-06 and SNI 03-2834-2000. The sludge content in the aggregate must comply with ASTM C142/C142M. Meanwhile, relative density (specific gravity) and water absorption in coarse aggregate must meet the provisions in ASTM C127 [7].

Fig. 1. (a) Coarse Aggregate Sieve ; (b) Fine Aggregate Sieve

2.3. Rice Husk Preparation

The rice husks used were taken from rice mills in the Cianjur West Java area. The husks were first washed to remove adhering dirt. Then clean husks are dried in an oven at a temperature of 150°C for 3-4 hours to remove water content in the husks. Feed 200 grams of dry husk into the furnace with condition 900°C so that all the husks turn to ash. Rice husk ash then enters the mill to get a 45 μm 5% size.

2.4. Concrete Mix Design

The primary purpose of a mixed design is to obtain concrete with an aggregate composition with well-mixed gradations, namely gradations with the smallest aggregate pore space, so that the minimum amount of cement is required. This study's concrete mix design method refers to the SNI standard 03-2834-2000 [4].

2.5. Sample Test Preparation

The procedure used to make concrete cube specimens for compressive strength tests refers to SNI 2493:2011 and ASTM C192/C192M-13. Tests were carried out on concrete aged 3, 7, and 28. The specimen consisted of fine aggregate, coarse aggregate, and cement mixture. Coarse aggregate in the form of 10 - 20 mm split while fine aggregate in the form of Bangka sand. The type of cement used is the Portland Composite Cement (PCC. Water is added little by little to the mixture until it reaches the desired slump value. If the dough meets the standard, put it in a cube mold. Put 1/3 of the concrete mixture into the mold while being pierced -puncture 25 times, then add 2/3 more and stab 25 times again. Puncture the side of the test object and vibrate it with a vibrator to remove air bubbles contained in the test object. The concrete test sample is stored in a humid room for 24 hours. The concrete surface is covered with plastic to prevent water evaporation and maintain the Concrete moisture. If it is 24 hours (1 day), the mold is opened, and the concrete cube is immersed in a curing tank for tests 3, 7, and 28 days. For easy identification, test objects are coded, dated, and arranged in an orderly. Figure 2 shows Equipment for the manufacture of test objects.

Fig. 2. Equipment set for the manufacture of test objects

2.6. Testing Procedure

After being old enough, the test object is removed from the immersion water in a humid room. Dry the test object in a cool place, do not dry it in a hurry or heat it. Turn on the computer and the Compressive Strength tool with the following steps: Observe the movement of the graph shown on the computer screen, record the maximum load that the test object can withstand (until the test object breaks). After dividing by the cross-sectional area of the test object, the value of the compressive strength of the concrete characteristics is obtained [16].

2.7. Aggregate Sludge Content Analysis

Analysis of sludge content in aggregate refers to ASTM C142/C142M. For coarse aggregate, it comes from the material retained on the No. 4 sieve, and for the fine aggregate, it out from the No. 50 sieve. Calculate the sludge content using the following equation:

$$\text{Sludge content} = \frac{B}{A} x100\ \% \tag{1}$$

Where: A is an initially empty cup, and B is a cup + test object (clean and dry).

2.8. Aggregate Density and Absorption Analysis

The procedure for analyzing the density and absorption of coarse aggregate refers to ASTM C127. The formula used for the calculation is as follows:

$$\text{Density (SSD)} = \frac{997.5\ A}{B-C}, \frac{kg}{m^3} \tag{2}$$

$$\text{Absorption (\%)} = \frac{B-A}{A} \text{ x } 100 \tag{3}$$

Where: A is dry aggregate and B is wet aggregate.

While the analytical procedure for fine aggregate refers to ASTM C128-12, the formula used for the calculation is as follows:

$$\text{Density (SSD)} = \frac{997.5\ x\ A}{(B+A-C)}, \frac{kg}{m^3} \tag{4}$$

$$\text{Absorption (\%)} = \frac{A-G}{G} \text{ x } 100 \tag{5}$$

Where: A is the weight of the test object in a dry surface condition (gr), B is the weight of the pycnometer filled with water (g), C is the weight of the pycnometer with the test object, and water up to the reading limit (g), and G is the weight of the oven-dry test object (gr).

3. Result and Discussion

3.1 An Rice Husk Ash Characterization

Table 1 shows the physical and chemical properties of rice husk ash obtained X-Ray type Energy-dispersive X-ray Fluorescence (EDXRF). In this study, the silica content of RHA was 89.92%. Based on ASTM C.494, this figure has fulfilled the requirements as a pozzolanic substitute for clinker. In addition, the particle size and density have also met the standard.

Table 1. Physical and Chemical Properties of Rice Husk Ash

Components	Percentage (w/w)	Physical Properties	Measurements
SiO_2	89.92	color	grey
Al_2O_3	1.92	shape	*Powder*
Fe_2O_3	1.50	Particle size	45µm
CaO	0.87	Density	2.3 kg/m^3
MgO	0.73		
SO_3	0.01		
K_2O	1.28		
Na_2O	0.01		
TiO_2	0.15		

3.2 Aggregate Test Results

The data collected in this study were tested for specific gravity, water absorption, fine aggregate slurry content, Testing the organic content of fine Aggregate, Coarse and fine aggregate sieve analysis test. Therefore the Aggregate quality has a significant impact on the properties of the concrete. For this reason, the coarse and fine aggregate specifications in this study must be ensured to meet the standard requirements [17]. Table 2 shows that most of all parameters fulfilled the standard, but sludge content was an exception. Calculations obtained those data based on equations 1 – 5 above. Table 3 shows the mix design used in this research, which refers to SNI 03-2834-2000.

Table 2. Aggregate Properties

Parameter	Unit	Fine Aggregate		Coarse Aggregate	
		experimental	standard	experimental	standard
SSD	g/cc	2.56	2.5-3.0	2.62	2.41-2.71
Absorption	%	2.27	2.0-2.5	1.66	1.5-3.0
Zone Grading Curve		2	2	7.07	7
Fine Modulus (FM)		2.77	2.5-3		
Sludge Content	%	6.45	<6%		
Organic Content		No.2	No.2		

Table 3. Mix Design Concrete K400 based on SK.SNI 03-2834-2000

Variable	PPC (kg)	RHA(kg)	water (lit		er) Fine aggregate (kg)	Coarse aggregate (kg)	Admixture (gr)
			calculation	actual			
0% ASP	14.8	0	7,38	7,38	22.18	40.28	44.3
10% ASP	13.3	1.5	7,38	7,72	22.18	40.28	44.3
20% ASP	11.8	3.0	7,38	9,03	22.18	40.28	44.3

Coarse aggregate was evaluated qualitatively for shape and surface texture. The maximum particle size of each coarse aggregate is 20 mm, and the maximum is 4 mm for fine aggregate, as shown in Figure 3 and Figure 4. Refers to the ASTM standard for concrete, the analysis results show that both types of aggregate have met the specifications according to the standard [18].

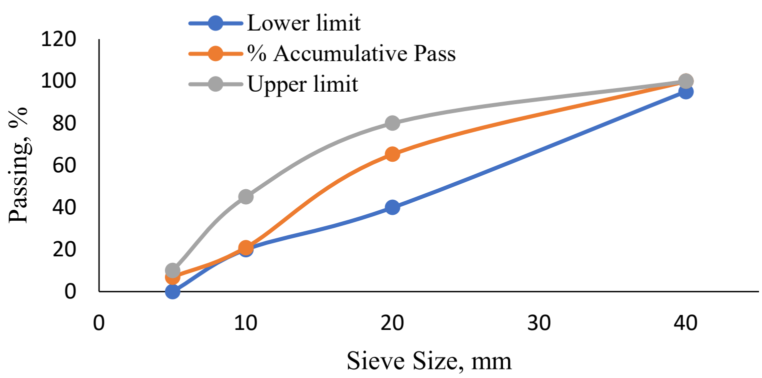

Fig. 3. Coarse Aggregate Gradation Analysis

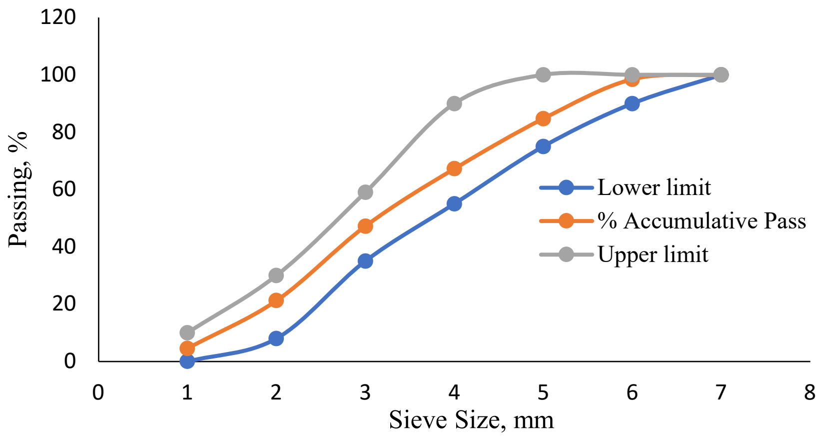

Fig. 4. Fine Aggregate Gradation Analysis

3.3 Fresh Concrete Testing (slump test)

The slump value is obtained directly when the mixing process is completed. This value aims to measure the level of workability of the fresh concrete mixture [14]. The higher the slump value means, the higher the level of ease of work, but unfortunately, this indicates that the compressive strength of the concrete is decreasing. These results were very close to the study reported by [8]. Table 4 shows the results of the mix design calculations that have been made. The slump value was set at 10±2 cm. So to get the desired slump results, 9 liters of water were added for each design. Therefore Table 5 shows are obtained from the average three data of each.

The slump test values in Table 4 and Figure 5 show that with an increase in the percentage of adding rice husk ash to the concrete mixture, there is an increase in the slump value. This condition is due to the nature of rice husk ash, which tends to absorb water so that it requires additional water with an increase in the amount of RHA.

Table 4. Slump Test Result (m^3 Concrete**)**

% RHA Substitute	Water (liter)	Slump value (cm)
0	7,38	9
10	7,72	10.5
20	9,03	11,7

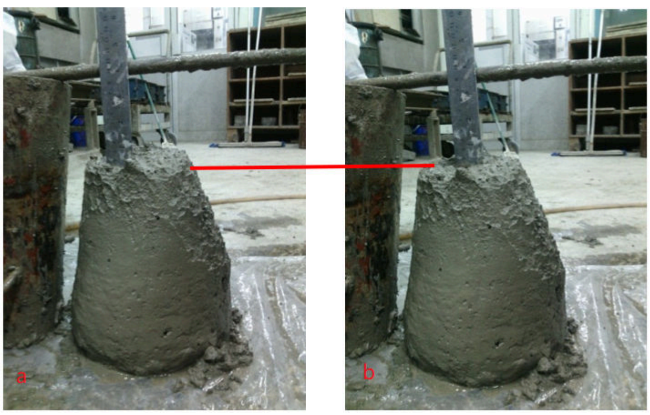

Fig. 5. Slump Flow Test (a) 10 % RHA, 10.5 cm, (b) 20 % RHA, 11.7 cm

3.4 Concrete Compressive Strength Test

Testing of hardened Concrete using the method specified in the SNI standard 03-2834-2000. The Concrete design is K-400, with the type of cement used being PCC originating from the Citeureup Cibinong Plant site, and Sika is used as an admixture. Table 5 results from testing the compressive strength of concrete at the age of 3, 7, and 28 days with three repetitions for each data. The results show that the compressive strength of concrete decreases progressively with increasing RHA. Fortunately, based on the Strength Activity Index (SAI) of pozzolan through ASTM C595/C595M-12, substitute clinker by RHA at any percentage still gives positive results for ages 7 and 28 days. Formula (6) is used to determine the SAI value [19], where A values blank concrete compressive strength and B values of 20 % RHA substituted concrete compressive strength. For example, an additional 20% RHA at age seven days produces an SAI value of 84.47. This figure, of course, meets the standard requirements, namely, the SAI value must be more than 80% to be accepted.

$$\text{SAI} = \frac{A}{B} x\ 100\% = \frac{261}{309} x 100\% = 84.47\% \quad (6)$$

Table 5 and Figure 6 show the effect of adding rice husk ash on the compressive strength of concrete for each test age. For the age of 3 days, it can be seen that the compressive strength value exceeds the specified standard, namely the addition of rice husk ash with a percentage of 10%, but for a percentage of 20%, it is not in the standard range. For the test age of 7 and 28 days with the addition of 10% and 20% rice husk ash, both did not meet the typical compressive strength values. This result could be due to the cement used, namely PCC cement. This cement contains various additives so that if rice husk ash is used as additional material in the concrete mix, it will not function as expected [20]. In addition, it is also seen that the water-cement ratio (w/c) in the concrete mixture increases with the increase in the percentage of rice husk ash. The more significant amount of water in the concrete mix can impact the decrease in the compressive strength of the concrete itself, as reported by previous researchers [21].

Table 5. Compressive Strength Test Results (n = 3; ± SD)

% RHA	Compressive Strength K400		
	3 days	7 days	28 days
0	192±5.148	309±13.21	415±24.01
10	178±3.464	294±10.075	396±11.726
20	136±6.124	261±13.058	320±13.748

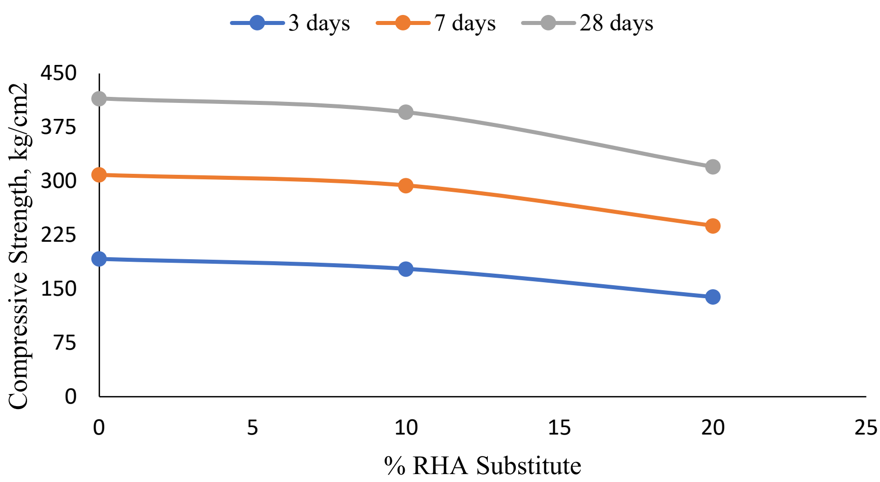

Fig. 6. Effect of adding Rice Husk Ash to K400 Concrete Compressive Strength

4. Conclusion

From a series of experiments and analyses, it can be concluded that by adding rice husk ash to the concrete mixture, the optimum compressive strength value is achieved at the age of 28 days with 10% RHA. However, for the test at the same age of 28 days, an additional 10 % RHA could reach a higher compressive strength than 20% RHA. In addition, the water-cement factor affects the strength of concrete, namely, the higher the w/c ratio, the more water used in the mix. If this happens, pores or cavities will arise in the concrete mold, which results in easy cracking of the concrete.

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