Engineering and Technology Journal e-ISSN: 2456-3358
Volume 09 Issue 09 September-2024, Page No.- 5206-5210
DOI: 10.47191/etj/v9i09.23, I.F. – 8.227

The Effect of Rice Husk Ash Addition on the Compressive Strength of Fly Ash-Based Geopolymer Concrete

Eliano Ratag*[1], Steenie Wallah*[2], Ellen J. Kumaat*[3]
[1,2,3] Sam Ratulangi University, Manado, Indonesia

ABSTRACT: The increasing demand for concrete has led to a surge in cement production. However, it is essential to note that this process releases significant amounts of CO_2 into the atmosphere, which has a detrimental impact on the environment. Rice husk ash and fly ash have the potential to replace Portland cement as they are pozzolanic materials, containing silica (Si) and alumina (Al). The objective of this research was to determine the compressive strength of fly ash-based geopolymer concrete with the addition of 10-30% rice husk ash at the age of 7 and 28 days. The results indicated that the addition of rice husk ash reduced the compressive strength of the geopolymer concrete, regardless of whether the specimens were cured at room temperature or in an oven. This reduction in compressive strength became more significant as the percentage of rice husk ash replacing fly ash increased.

KEYWORDS: Geopolymer concrete, fly ash, rice husk ash, compressive strength

INTRODUCTION

The increasing demand for concrete has led to a concomitant rise in cement production, given that cement is a primary constituent of concrete. However, it is crucial to note that the cement production process results in significant CO_2 emissions, which can have detrimental impacts on the environment. The production of one ton of cement results in the release of approximately one ton of carbon dioxide into the atmosphere, contributing to global warming and the greenhouse effect (Aprianti et al., 2015). To mitigate these environmental impacts, there is a pressing need for more sustainable alternatives to cement in concrete production.

There has been a surge in innovations in concrete development, utilizing binders such as alumina-silicates that play a crucial role in polymerization reactions, commonly known as geopolymers. Alternative materials to replace cement as a binder in geopolymer concrete include fly ash, rice husk ash, and others.

Fly ash have the potential to replace Portland cement as they are pozzolanic materials containing silica (Si) and alumina (Al). While pozzolans themselves do not possess binding properties like cement, their fine particle size and ability to react with alkaline activators such as NaOH and Na_2SiO_3 enable them to develop binding characteristics similar to Portland cement. Hardjito, D. and Rangan, B.V. (2005) reported that the chemical composition of fly ash was dominated by SiO_2 and Al_2O_3 with scores of 53,36% and 26,49%.

Rice husk combustion yields ash with a high silica content. This is due to rice plants absorbing silica from the soil and storing it in the grains and the husk that envelops the grains (Mohseni et al., 2019). According to Bakrie (2009) and Sandya, Y., with Musalamah, S. (2019), the high silica content in rice husk ash ranges from 72% to 82%.

Moreover, rice husk ash and fly ash are substantial waste products in Indonesia, which accumulate over time if not properly managed. By utilizing these materials in geopolymer concrete, the amount of waste and pollution in Indonesia can be significantly reduced. Alkali activators play a crucial role in the geopolymerization process. These chemicals initiate the reaction between silica (Si) and alumina (Al) present in the precursor, resulting in strong polymeric bonds that form the basis of geopolymer concrete. This study aims to investigate the compressive strength of fly ash-based geopolymer concrete at the ages of 7 and 28 days with the addition of 10-30% rice husk ash.

MATERIALS

Fly Ash

Fly ash testing was conducted at the North Sulawesi Police Forensic Laboratory. The results showed that the fly ash from PLTU II Amurang is classified as high-calcium fly ash due to its calcium (Ca) content of 21.5323%. This fly ash also falls under Class C and meets the criteria specified in ACI Manual of Concrete Practice Parts 1 226.3R-3 and ASTM C-618, which require a calcium content greater than 10% for Class C fly ash. For more detailed data, please refer to the table below.

Table 1. Chemical Composition of Fly Ash

Fly Ash PLTU Amurang	
Chemical	Percentage (%)
As	0,0545
Ca	21,5323
Cd	0,01132
Cr	0,01751
Cu	0,0072
Fe	48,4447
Ga	0,00443
Hg	0,00254
K	1,02397
Mn	0,64231
Pb	0,02161
Rb	0,0222
S	5,61601
Sb	0,06742
Si	21,2572
Sr	0,52263
Ti	0,73016
Zn	0,022

Rice Husk Ash

Rice husk ash, a byproduct of rice milling, was used as a supplementary material in this study. The ash was sourced from a rice mill located in Watuliney Village, Belang. To prepare the ash for the experiments, it was dried in an oven for 24 hours and sieved using a No. 50 sieve.

Cement

Cement is a fine powder consisting primarily of calcium silicates, aluminates, and ferrites. When mixed with water, it undergoes a chemical reaction known as hydration, forming a paste that hardens and binds other materials together. This process, known as setting, results in the formation of a strong, durable matrix that is essential for the construction industry.

Alkaline Activator

The alkali activators employed in this study were sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). Natrium hidroksida (NaOH) dan natrium silikat (Na2SiO3) berfungsi sebagai aktivator alkali, memulai dan mengkatalisis reaksi geopolymerisasi.

Aggregate

Aggregates were categorized into two types: coarse and fine aggregates. For this study, were used coarse aggregates retained on a No. 4 sieve and passing a 3/4-inch sieve. Fine aggregates were those passing through a No. 4 sieve. tolong translate ke bahasa Indonesia.

Superplasticizer

According to ASTM C494, superplasticizer is an additive in concrete that consists of chemicals aimed to enhance the effectiveness and quality of the concrete. The use of superplasticizer significantly influences the workability of concrete by limiting the impact of water that can degrade the quality of the concrete.

3. METHODS

Compressive strength tests were conducted on 10 cm x 20 cm cylindrical specimens at the ages of 7 and 28 days. The following binder mix variations were used:

a. 10% cement, 90% fly ash
b. 10% cement, 80% fly ash, 10% rice husk ash
c. 10% cement, 70% fly ash, 20% rice husk ash
d. 10% cement, 60% fly ash, 30% rice husk ash

Mix Design

To date, there is no standardized mix design for geopolymer concrete. To achieve the desired characteristics, a trial mix is necessary. This trial mix is typically based on the mix proportions proposed by B.J. Soentpiet in his study on "Modulus of Elasticity of Fly Ash-Based Geopolymer Concrete from Amurang Power Plant".

Table 2. Reference Mix Design of Geopolymer Concrete

Composition	Spesific Gravity (Kg/m^3)	%
Fly Ash	476	17,21%
Fine Aggregate (Sand)	554	20,10%
Coarse Aggregate (Gravel)	1294	46,95%
NaOH (14 M)	120	4,35%
Na_2SiO_3	300	10,88%
Superplasticizer	12,2	0,44%
TOTAL	2756,2	100,00%

(**Source:** Soentpiet, 2018)

From four trial mixes conducted in this study, referencing the mix design in Table 3.2, the highest compressive strength was obtained from the 0% fly ash concrete at 18.28 MPa, while the highest compressive strength for 30% rice husk ash concrete was 11.08 MPa. Based on the trial mix results, several optimal mix designs can be established for this study by incorporating 10% cement of the total binder to enhance the compressive strength of the concrete to reach 20 MPa.

Table 3. 0% Rice Husk Ash Mix Design

Composition	Spesific Gravity (Kg/m^3)	%
Fly Ash	428,4	15,54%
Cement	47,6	1,73%
Fine Aggregate (Sand)	554	20,10%

Coarse Aggregate (Gravel)	1294	46,95%
NaOH (14 M)	120	4,35%
Na_2SiO_3	300	10,88%
Superplasticizer	12,2	0,44%
Total	**2756,2**	**100,00%**

Table 4. 10% Rice Husk Ash Mix Design

Composition	Spesific Gravity (Kg/m^3)	%
Fly Ash	380,8	13,82%
Rice Husk Ash	47,6	1,73%
Cement	47,6	1,73%
Fine Aggregate (Sand)	554	20,10%
Coarse Aggregate (Gravel)	1294	46,95%
NaOH (14 M)	120	4,35%
Na_2SiO_3	300	10,88%
Superplasticizer	12,2	0,44%
Total	**2756,2**	**100,00%**

Table 5. 20% Rice Husk Ash Mix Design

Composition	Spesific Gravity (Kg/m^3)	%
Fly Ash	333,2	12,09%
Rice Husk Ash	95,2	3,45%
Cement	47,6	1,73%
Fine Aggregate (Sand)	554	20,10%
Coarse Aggregate (Gravel)	1294	46,95%
NaOH (14 M)	120	4,35%
Na_2SiO_3	300	10,88%
Superplasticizer	12,2	0,44%
Total	2756,2	100,00%

Table 6. 30% Rice Husk Ash Mix Design

Composition	Spesific Gravity (Kg/m^3)	%
Fly Ash	285,6	10,36%
Rice Husk Ash	142,8	5,18%
Cement	47,6	1,73%
Fine Aggregate (Sand)	554	20,10%
Coarse Aggregate (Gravel)	1294	46,95%
NaOH (14 M)	120	4,35%
Na_2SiO_3	300	10,88%
Superplasticizer	12,2	0,44%
Total	2756,2	100,00%

Curing

In this research, the specimens were cured under two conditions: (1) at room temperature for 7 and 28 days, and (2) at 60°C in an oven for 1 day and then at room temperature for 6 days.

4. RESULTS AND DISCUSSIONS

Density

The unit weight of concrete refers to the mass of concrete contained in a specific volume. In construction, we often use the unit weight of concrete to measure how heavy the concrete is per unit volume. The commonly used unit is kilograms per cubic meter (kg/m^3).

Table 7. Average Volume Weight of Oven-Cured Concrete

Rice husk ash addition	Average
	Kg/m^3
0%	2359,6
10%	2295,84
20%	2227,91
30%	2213,28

Table 8. Average Unit Weight of 7-Day Concrete Cured at Room Temperature

Rice husk ash addition	Average
	Kg/m3
0%	2393,93
10%	2373,5
20%	2212,66
30%	2297,77

Table 9. Average Unit Weight of 28-Day Concrete Cured at Room Temperature

Rice husk ash addition	Average
	Kg/m3
0%	2300,05
10%	2204,47
20%	2360,92
30%	2214,89

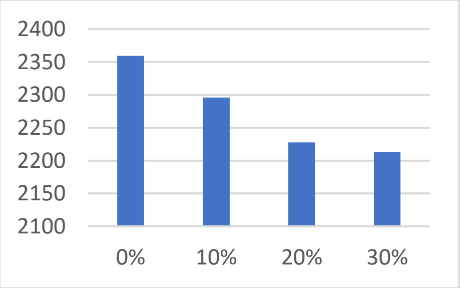

Figure 1. Average Volume Weight of Oven-Cured Concrete Diagram

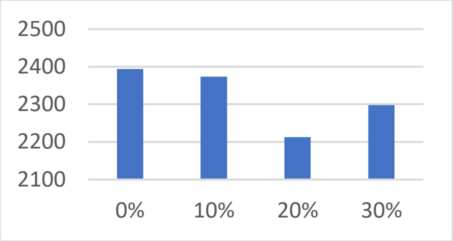

Figure 2. Average Unit Weight of 7-Day Concrete Cured at Room Temperature Diagram

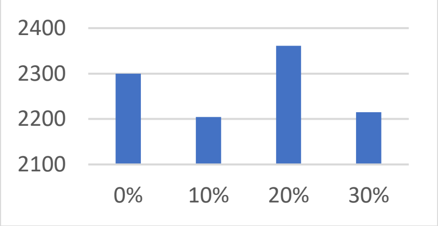

Figure 3. Average Unit Weight of 28-Day Concrete Cured at Room Temperature

Effect of Rice Husk Ash Addition on Compressive Strength

The compressive strength testing in this study employed cylindrical specimens with a diameter of 10 cm and a height of 20 cm. These specimens were cured in an oven at 60°C and tested at the age of 7 days, as well as at room temperature and tested at the ages of 7 and 28 days. To ensure even distribution of axial load across the entire compressive surface, the specimens were coated with sulfur. The table below presents the results of the compressive strength tests on the geopolymer concrete.

Table 10. Results of Oven-Cured Compressive Strength Tests

Rice husk ash addition	Age of concrete	Average
	(Days)	(MPa)
0%	7	22,7
10%	7	18,4
20%	7	15,15
30%	7	10,56

Table 11. Results Compressive Strength Tests of 7-Day Concrete Cured at Room Temperature

Rice husk ash addition	Age of concrete	Average
	(Days)	(MPa)
0%	7	17,75
10%	7	15,22
20%	7	10,68
30%	7	9,71

Table 12. Results Compressive Strength Tests of 28-Day Concrete Cured at Room Temperature

Rice husk ash addition	Age of concrete	Average
	(Days)	(MPa)
0%	7	22,73
10%	7	21,51
20%	7	16,7
30%	7	12,78

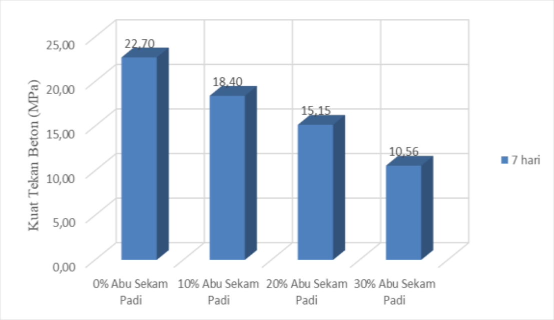

Figure 4. Effect of RHA Addition (Curing Oven)

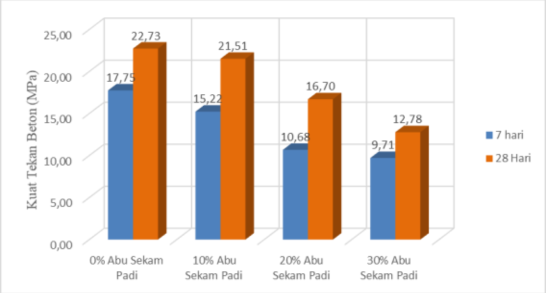

Figure 5. Effect of RHA Addition (Room Temperature)

Table 13. Correlation Factor of Concrete Age (Cured at Room Temperature)

0% Rice Husk Ash	7 Days	28 Days
	0,883	1
10% Rice Husk Ash	7 Days	28 Days
	0,872	1
20% Rice Husk Ash	7 Days	28 Days
	0,846	1
30% Rice Husk Ash	7 Days	28 Days
	0,957	1

The addition of rice husk ash generally reduces the compressive strength of concrete. This is evident in Figures 1 and 2, both for concrete cured at room temperature and in an oven. The decrease in compressive strength becomes more significant with increasing percentages of rice husk ash replacing fly ash.

Analysis of Downtrends

Several factors contribute to the observed decreasing trend, including:

Influence of Rice Husk Ash Percentage

As the percentage of rice husk ash increases, the compressive strength of concrete decreases. This indicates that while rice husk ash possesses pozzolanic properties, it is less effective than cement and fly ash in forming a strong concrete structure.

Influence of Curing Conditions

- Room Temperature Curing: Under these conditions, the decrease in compressive strength due to the addition of rice husk ash tends to be slower compared to oven curing conditions. This suggests that curing temperature and humidity affect the rate of hydration reaction and silica gel formation.
- Oven Curing: In oven curing conditions, the decrease in compressive strength is more significant. The high temperature during oven curing accelerates the hydration reaction but can also cause microcracking in concrete due to NaOH crystallization.

A similar study conducted by Samsudin and Sugeng Dwi Hartantyo (2017), titled "The Effect of Rice Husk Ash Addition on Concrete Compressive Strength" also demonstrated a decrease in compressive strength with increasing amounts of rice husk ash in conventional concrete.

Table 14. Results of the study by Samsudin and Sugeng Dwi Hartantyo (2017)

Rice husk ash addition	Age of concrete	Average
	(Days)	(MPa)
0%	7	11,218
8%	7	10,142
10%	7	9,527
12%	7	8,759
Rice husk ash addition	Age of concrete	Average
	(Days)	(MPa)
0%	14	15,187
8%	14	13,731
10%	14	12,898
12%	14	11,858
Rice husk ash addition	Age of concrete	Average
	(Days)	(MPa)
0%	28	17,258
8%	28	15,603
10%	28	14,657
12%	28	13,475

5. CONCLUTIONS

Based on the analyzed research data, it can be concluded that the addition of rice husk ash reduces the compressive strength of concrete. This is evident in both graphs, for concrete cured at room temperature and in an oven. The decrease in compressive strength becomes more significant as the percentage of rice husk ash replacing fly ash increases. However, with proper optimization, rice husk ash can be used as an admixture in concrete to reduce cement consumption and enhance other concrete properties, such as durability and sulfate resistance.

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