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Effectiveness of Rice Husk Ash and Glass Powder Waste as Partial Replacements of Cement in Concrete Construction

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ABSTRACT

The environmental impact of cement production has drawn attention to the use of glass waste and rice husk as a partial replacement for cement in concrete. According to research, the compressive strength of concrete containing GPW and RHA can increase up to 15-20%, after which it begins to decline. The objective of this study was to analyze the effectiveness of partial replacement of cement with GPW and RHA. Some of the factors considered in this study were compressive strength and specific gravity. The proportions of GPW and RHA used were 0%, 3%, 5%, 10%, 15%. Then concrete testing was done after 7 and 28 day. The maximum 28-day concrete compressive strength result for the addition of GPW and RHA at 5% mix proportion was 33.1 Mpa. The more the proportion of GPW and RHA mixture, the more the relative specific gravity of concrete decreases. Overall, this study found that the use of GPW and RHA in concrete had a significant effect on compressive strength and specific gravity. But do not forget to pay attention to how much GPW and RHA mix needs and the quality of concrete to be achieved.

Keywords: *Replacement for Cement; Glass Powder Waste; Rice Husk Ash; Compressive Strength; Bulk Density.*

INTRODUCTION

The use of alternative materials as a partial replacement for cement in concrete has gained significant attention in recent years due to the environmental impact of cement production. The cement manufacturing industry is a major contributor to global greenhouse gas emissions, responsible for about 7% of the world's total annual CO2 production [1], [2], [3], [4]. This has prompted researchers to look for sustainable alternatives that can reduce the environmental impact of concrete production. Waste glass and rice husk are two waste materials that have shown promise as a partial replacement for cement.

Several studies have investigated the use of glass powder waste (GPW) as a partial replacement for cement in concrete. Waste glass is a non-biodegradable material that poses significant disposal challenges[5], [6], [7]. Incorporating GPW into concrete can help address these environmental concerns while reducing the carbon footprint associated with cement production. The compressive strength of concrete with GPW as a partial replacement for cement has shown varying trends. Some studies have reported an initial increase in compressive strength up to a certain replacement level, usually around 15-20%, followed by a decrease as the GPW content increases [8], [9], [10]. This can be attributed to the pozzolanic reaction between amorphous silica in GPW and calcium hydroxide released during cement hydration, which can improve the microstructure and density of concrete [6], [11]. However, beyond the optimal replacement level, the reduction of cement content and potential alkali-silica reaction may lead to a decrease in compressive strength [3], [12], [13].

Rice husk ash (RHA) is another waste material that has been extensively investigated as a partial replacement for cement in concrete. Rice husk, a by-product of rice milling, is available in large quantities, especially in rice-producing areas [14], [15], [16], [17], [16], [18]. The incorporation of RHA in concrete has been shown to offer several benefits. RHA contains a high percentage of amorphous silica, which provides pozzolanic properties that can improve the mechanical characteristics and durability of concrete [14], [19]. The compressive strength of concrete with RHA as a partial replacement for cement has been widely investigated. Many researchers have reported an initial increase in compressive strength with increasing RHA content, typically up to 10-15% replacement level, followed by a gradual decrease as the RHA content increases, [14], [17], [16], [20], [21]. The pozzolanic reaction between RHA and calcium hydroxide can contribute to an increase in compressive strength up to an optimal replacement level [14]. This study aims to provide a effectiveness analysis of using GPW and RHA waste as a partial replacement for cement in concrete construction. Some of the factors considered in this study are compressive strength and bulk density.

METHOD

Experimental Details

This study uses an experimental method where the tests are carried out directly in the laboratory. The test object used for testing is a concrete cylinder with a height of 30 cm and a diameter of 15 cm. The proportion of GPW and RHA is 0%, 3%, 5%, 10%, 15% with each number of specimens used in the test is 3 pieces. Then concrete testing was carried out after the age of 7 and 28 days so that the total number of test objects was 30 pieces.

Experimental Sites

This research was conducted at the Laboratory of Structures and Materials, Department of Civil Engineering. Civil Engineering, University of Jember. The laboratory is located at Jalan Kalimantan 37 Bumi Tegal Boto Kotak Pos 159 Jember, East Java, Indonesia. The implementation of this research activity takes two months, starting from July 2024 to August 2024.

Experimental Test Materials and Samples

The materials used in this study were cement, coarse aggregate (gravel), fine aggregate (sand), glass waste, and rice husk ash. Portland cement with Semen Gresik brand was obtained by ordering from the cement manufacturer. Fine and coarse aggregates are obtained from suppliers who produce materials. The fine and coarse aggregates came from Mayang Village, Jember Regency. The coarse aggregate used has a maximum size of 10 mm. The water used was from the Structures and Materials Laboratory, Department of Civil Engineering, University of Jember. Mineral additives in the form of rice husk ash (RHA) were rice husk ash obtained from combustion waste at a red brick making factory in Kertosari Village, Jember City, East Java. Meanwhile, glass waste was obtained from a landfill in Pakusari Village, Jember City, East Java. GPW and RHA were then pulverized and sieved using a no.200 sieve to obtain a fineness level resembling cement. GPW and RHA were then crushed and sieved using a no.200 sieve

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to obtain a fineness level resembling cement.
For concrete samples that have been made then removed from the curing tank a day before testing. tank a day before testing. Then Universal Testing Machine (UTM) testing was carried out for concrete compressive strength test. The specimens were carefully placed in the testing machine to achieve uniform load distribution.

Mix Design

The planning of concrete mix design and material testing in this study refers to SNI 03-2834-2000 [22]. Mixed materials such as cement, fine aggregate, coarse aggregate, GPW, and RHA were tested first in order to get the right proportion. In this study, a compressive strength of 30 Mpa was determined.

Table 1. Proportions Concrete Mix for 1 m^3

Replacement Materials (%)		Weight (kg/m^3)					
GPW	RHA	Cement	Fine Aggregate	Air	Coarse Aggregate	GPW	RHA
0	0	413,47	741,94	192,27	1024,59	0	0
3	3	388,67	741,94	192,27	1024,59	12,40	12,40
5	5	372,13	741,94	192,27	1024,59	20,67	20,67
10	10	330,77	741,94	192,27	1024,59	41,35	41,35
15	15	289,43	741,94	192,27	1024,59	62,02	62,02

Table 2. Proportions Concrete Mix for 6 Cylinder (0.03179 m^3)

Replacement Materials (%)		Weight (kg/m3)					
GPW	RHA	Cement	Fine Aggregate	Air	Coarse Aggregate	GPW	RHA
0	0	13,15	23,59	6,11	32,57	0	0
3	3	12,35	23,59	6,11	32,57	0,40	0,40
5	5	11,83	23,59	6,11	32,57	0,66	0,66
10	10	10,51	23,59	6,11	32,57	1,32	1,32
15	15	9,21	23,59	6,11	32,57	1,97	1,97

RESULTS AND DISCUSSION

Material Test Data

This material testing is to ensure the concrete mix achieves the set targets and quality standards. This process includes examining the characteristics of the aggregates to determine if they conform to the required specifications. This testing is crucial, as materials that do not meet the criteria cannot be utilized in the concrete mix. Therefore, the characteristics of the aggregates must be examined in detail using various testing methods to ensure that they conform to the set standards [21].

Tests include analyzing the size, shape, and texture of the aggregate, as well as determining its strength, durability, and water absorption capacity. Each of these aspects has a significant impact on the final performance of the resulting concrete. For example, aggregate size can affect the density and strength of the concrete, while aggregate shape and texture can affect the bond between the aggregate and the cement paste.

Aggregate size analysis is performed to ensure that the particle size distribution is within the desired range, which can affect the workability and strength of the concrete. Aggregate shape testing, on the other hand, aims to assess whether the aggregate has an ideal shape, such as round or cubical, which can improve interlocking and reduce cement demand.

The texture of the aggregate is also important to check, as a coarse texture can improve the adhesion between the aggregate and the cement paste, while a fine texture may not provide a strong enough bond. In addition, aggregate strength testing is conducted to ensure that the aggregate can withstand the applied load without being damaged. The aggregate's resistance to

environmental conditions, such as freezing and thawing cycles, should also be tested to ensure that the aggregate will not deteriorate over time.

The water absorption capacity of the aggregate is also an important parameter to be considered. Aggregates with high water absorption capacity can affect the water-cement ratio in the mix, which in turn can affect the strength and durability of the concrete. Therefore, these tests not only provide information on the physical characteristics of the aggregates, but also help in designing the optimum concrete mix.

Table 3. Aggregates test result

Parameter	Unit	Coarse Aggregate	Fine Aggregate
Spesific gravity	g/cm3	2.68	2.803
Water Content	%	3.553	9.030
Absorption	%	1.53	6.332
Mud Content	%	0,144	1.177
Volume weight	kg/m3	1567	1495
Zone Analysis	Zone	3	2

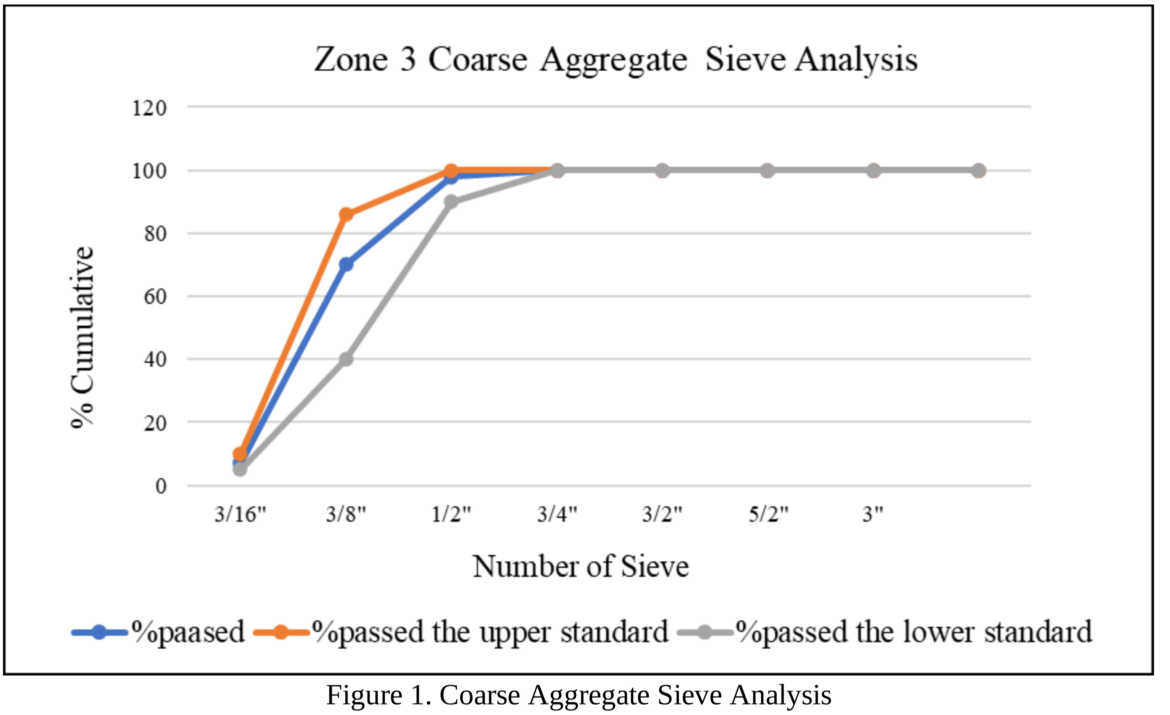

Figure 1. Coarse Aggregate Sieve Analysis

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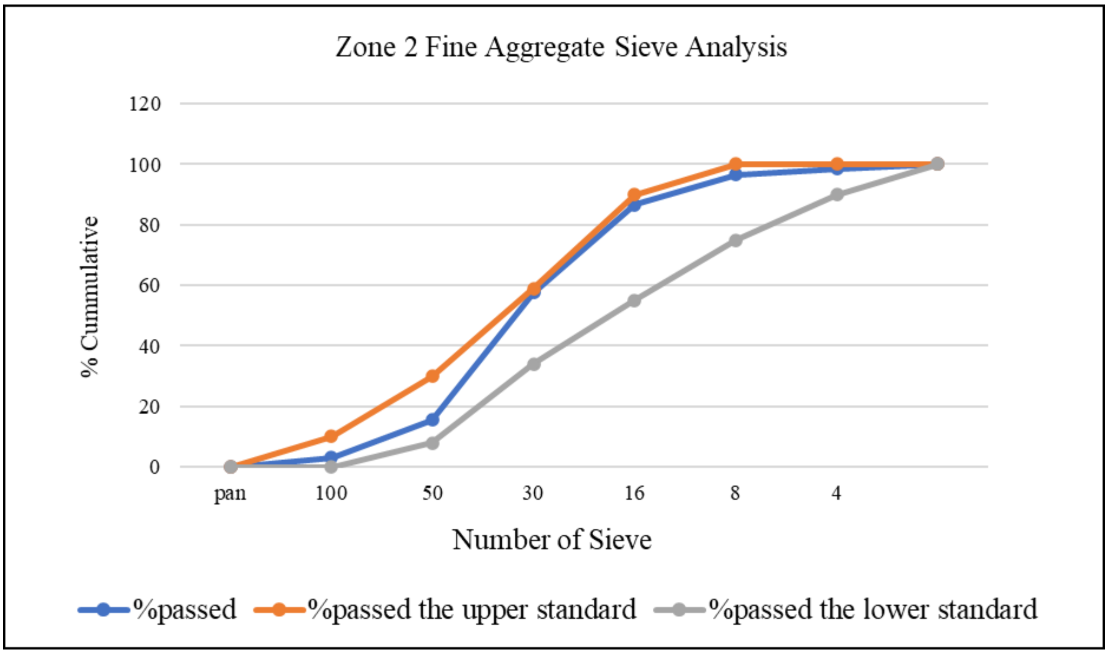

Figure 2. Fine Aggregate Sieve Analysis

Compressive Strength Testing

In this study, the compressive strength of concrete specimens made from various blends of GPW and RHA specified in table 2 with replacement of cement and properly cured in accordance with the implementation method and measured at 7 and 28 days of age. The test results are presented in figure 3 which shows that the maximum results at 7 and 28 days of concrete age were achieved at 0% and 5% GPW and RHA replacement i.e. compressive strength reached 19.4 MPa and 33.1 MPa respectively. Meanwhile, the lowest compressive strength results at the age of 7 and 28 days of concrete were found in the mixture of 10% GPW and RHA with compressive strengths of 13.3 MPa and 21.7 Mpa, respectively.

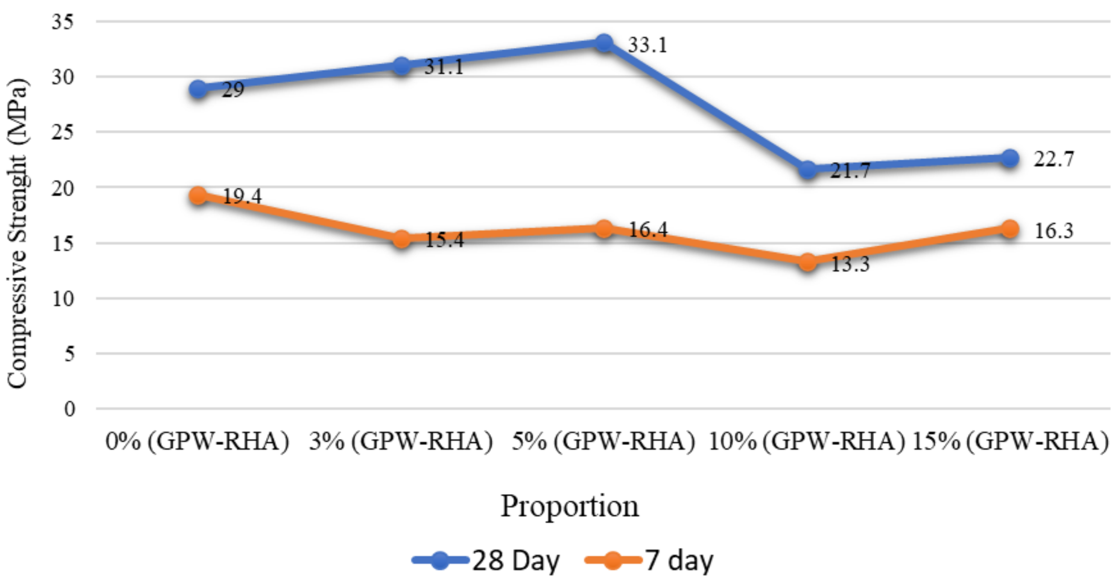

Figure 3. Compressive strength variation with various GPW and RHA

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Bulk Density

Based on the test results, the relative volume weight of concrete decreased with the addition of GPW and RHA mixtures, but the decrease was not so significant. The volume weight of concrete for all variations of GPW and RHA admixtures is included in the normal concrete category. The bulk density at the age of 28 days concrete obtained the lowest value of 2329 Kg/m^3 and the highest 2434 Kg/m^3.

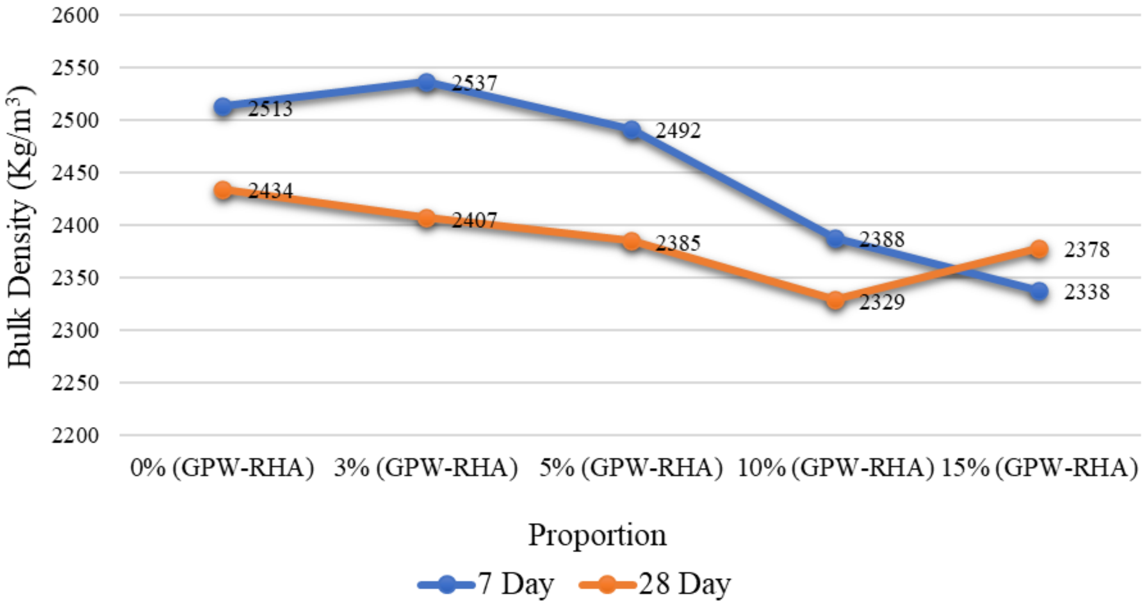

Figure 4. Bulk density variation with various GPW and RHA

CONCLUSION

This study investigated the effectiveness analysis of using GPW and RHA as partial replacement of cement in concrete construction. The effectiveness is seen from the compressive strength of concrete and the resulting bulk density. The tests were carried out on 5 different proportion samples were tested at 7 and 28 days of age. The findings of this study are summarized as follows:

The results of tests carried out with GPW and RHA concrete mixtures in the laboratory have met SNI 03-2834-2000. The results of the compressive strength of 28 day concrete for the addition of GPW and RHA at a mixture proportion of 3% and 5% have increased. But at a mixture proportion of 10% and 15% decreased compressive strength of concrete. With these results, the maximum proportion for partial replacement of cement is the proportion of GPW and RHA as much as 5%. The more the proportion of GPW and RHA mixture, the relative bulk density of concrete decreases. This shows that this addition has a very good effect on concrete applications in the field such as the construction of column structures, beams, plates, sloofs and building foundations, but do not forget to pay attention to how much GPW and RHA mix needs and the quality of concrete to be achieved.

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