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# A Study on Performance of Concrete with Commercial Rice Husk Ash as Partial Cement Replacement

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**Abstract**

Concrete is a popular choice in the construction industry globally because of its excellent strength, long-lasting properties and their versatility in construction forms. However, the shortage of conventional cementing materials and the production of concrete itself has a significant impact on environmental problems. Consequently, there has been a search for sustainable alternatives, such as Rice Husk Ash (RHA), which is a waste material that can partially substitute cement and thus reduce the environmental footprint. The purpose of this study was to analyse the main characteristics of the RHA as partial cement replacement in concrete (the workability, the compressive strength and the quality of concrete). The experimental method have been conducted accordingly with different low percentage of RHA, ranging from 0 percent to 15 percent for 7, 14 and 28 days. The normal concrete grade (M30) and cube specimens (size 100 mm x 100 mm x 100 mm) was used for the experimental test throughout this study. The results showed that for all percentages of RHA cement replacement in concrete, workability declined as RHA levels increased. About 8 to 16 percent more strength was developed for 10% RHA compared to the control sample's value (0% RHA replacement). In addition, the Ultrasonic Pulse Velocity (UPV) quality test, which was carried out at 7 and 28 days, revealed that 10% is the possible ideal amount for RHA replacement. However, the 5% RHA and 15% RHA replacement, which showed a delayed and insignificant growth of strength, must be taken into account when assessing the validity of the data. For future reference, it is crucial for one to take note of and refer to these questionable parts.

**Keywords:** Rice Husk Ash (RHA), Concrete, Compressive strength, Cement replacement

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## 1. Introduction

Rice husk ash (RHA) is a residue produced in the rice milling process, derived from the husk of the rice grain. By subjecting rice husks to high temperatures, they are converted into ash containing a significant amount of silica (around 80-90%), rendering RHA a valuable resource for diverse industrial purposes. In the realm of construction, RHA serves as a beneficial supplementary cementitious material, capable of replacing a portion of conventional cement in concrete mixtures. This approach not only promotes sustainability by repurposing agricultural byproducts but also enhances the efficacy and resilience of concrete structures (Nzereogu et al., 2023). In Malaysia, rice cultivation plays a crucial role in the agricultural sector, generating a significant amount of rice husks. However, rice husks present environmental management issues because of their volume and resistance to decomposition.

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The lack of disposal technique have result in severe environmental contamination such as air and water pollution. Recycling waste materials for construction seems like a good practice to address these pollution issues as well as the cost-effectiveness of building design (Rahim et. al., 2022). Meanwhile, Portland cement is the most commonly used cementitious material in concrete. The manufacture of cement is somewhat costly and energy-intensive, and it also contributes to climate change and global warming by releasing a sizable amount of $CO^2$ into the environment (Addnan et. al., 2024). Therefore, using waste material with pozzolanic qualities such as RHA as part of some of the cement can help reduce manufacturing costs while also being environmentally benign (Hussin, 2018). A lot of studies have been performed to demonstrate the potential of RHA used in concrete as cement replacement. Study by Al-Alwan (2024) showed that increasing the RHA content increases the flexural, compressive, and tensile strength values with time and decreases the slump value and the chloride ion penetration rate. Meanwhile, Siddika (2021) also indicates that RHA has pozzolanic characteristics that can improve the resilience and longevity of concrete in term of their durability to environmental attack, as well as lower construction costs and carbon emissions. Finding is found that it can enhance the strength and durability of concrete by optimizing its pore structure and impeding capillary pores formation through the generation of *calcium silicate hydrate* (C-S-H) gel.

However, a thorough assessment of RHA's impact on the physical and mechanical properties of concrete is imperative to ensure its effectiveness as a material for cement. The varying compressive strength observed with different percentages of RHA necessitates comprehensive testing to ensure optimal performance and durability of concrete over time (Endale et al., 2023; Siddika et al., 2018). A few previous studies showed that the variation of 10% rice husk ash as a cement replacement yielded the comparable compressive strength as it did not affect the concrete performance that much (Nursyamsi & Aruan, (2021); Hussin (2018)). Study by Botchway et al., (2020) found that the 5% RHA replacement showed an increase of strength growth over control concrete and further increase in RHA (10% to 25%) resulted in decrease compressive strength. On the contrary, a concrete specimen with a 20–25 percent RHA substitution showed a reduction in compressive strength; where, the strength decreased as the RHA level increased (Zaid et al., (2021); Zareeia et al., (2017)). When RHA was added up to 20%, there was a drop in concrete density and an increase in volume voids and water absorption (Zaid et al., 2021). The variation of the effect of different percentage replacement of RHA in concrete shows that there is possible various factor that could influence the characteristic properties of the RHA in concrete.

This research focuses on examining the characteristics of concrete incorporating RHA, specifically concentrating on workability, quality, and compressive strength. Through various tests like the slump test, ultrasonic pulse velocity (UPV) test, and compressive strength test, the study aims to identify the optimal proportion of RHA that can be utilized without compromising the quality of concrete and also to determine the strength and the quality of the blended RHA concrete relationship . The outcomes of this investigation will offer valuable insights into the enhancement of concrete's structural properties through the use of RHA, while also promoting environmental sustainability. The importance of this study lies in its potential to promote sustainable construction practices. By integrating RHA into concrete mixtures, this research addresses environmental and economic challenges, providing a feasible solution to reduce carbon emissions and enhance waste management practices. The results of this study will contribute to the advancement of more durable and sustainable concrete materials, supporting the construction industry's transition towards eco-friendly and efficient building materials. Ultimately, this research aims to advocate for the responsible utilization of agricultural byproducts, paving the way for a more sustainable future in the construction sector.

## 2. Methods

This section provides a detailed exploration of the potential use of Rice Husk Ash (RHA) as a partial substitute for cement in concrete. To accomplish the objectives of this paper, a comprehensive literature review was conducted to investigate and analyze previous research. The study approach includes the material preparation, concrete mix design, mixing and curing procedures, as well as general testing protocols to assess the physical and mechanical properties of the concrete. This study intends to provide a thorough assessment of RHA incorporation in concrete by using standardized methodologies and experimental testing. The materials, preparation techniques, and particular tests carried out to meet the research goals will be described in detail in the sections that follow.

### 2.1 Sample of Ingredients

i. Cement

OPC 43 grade, which complies with ASTM C150/C150M-21 Type I, is extensively utilized in various construction projects due to its strong and efficient performance. It is particularly suitable for concrete grades up to M20, such as in the case of grade M30.

ii. Fine aggregates

Natural sand is employed in compliance with the ASTM C778-21 as graded sand, featuring a standardized dimension ranging from 1.18 mm to 150 μm. The size that had been used in this study is 150 μm.

iii. Coarse aggregates

Crushed granite is employed in accordance with the ASTM C33/C33M-18 Standard, which specifies the aggregate size to be within the range of 4.75 mm to 37.5 mm. The research utilized coarse aggregates with a diameter of 20 mm.

iv. Water

Pure water is a crucial element in the process of blending with cement to form pastes that efficiently unite all the constituents.

v. Rice Husk Ash (RHA)

The commercial ready-made RHA in grey/black colour was obtained from an internet-based gardening supplier and was subjected to burning and sieving with particles of different sizes (see Figure 1). The recommended size particle of RHA is 45µm for actively posses the pozzolanic reaction (Siddika et al., 2018), however, due to limitation of time for extra grinding process, the particle sizes of rice husk ash utilized in this study only range from 0 µm to 63 µm (due to size of sieve available in laboratory during conducted the study) and sieved through ASTM E11-24 standard sieve size.

**Figure 1.** Graded Rice Husk Ash (RHA) passing 63 μm sieve.

### 2.2 Preparation of Rice Husk Ash (RHA)

i. Pre-drying

The moisture content of the rice husk ash (RHA) was eliminated by pre-drying it in an oven at a temperature of 150°C prior to its combustion in the furnace.

ii. Calcination

The rice husk ash (RHA) underwent a calcination process in a furnace, where it was exposed to a temperature of 600 °C for a duration of 3 hours as prescribe from past studies (Das et al., (2022), Miller et al., (2019) and Akeke et al., (2012)). This controlled environment ensured complete combustion, resulting in the transformation of the partially burned black RHA into a fully burned grey RHA. Subsequently, the RHA was left to cool down for a period of 6-8 hours (see Figure 2 (a) and (b)).

(a) (b)

**Figure 2.** (a) RHA burned in furnace for 3 hours (b) Complete combustion of grey RHA

### 2.3 Mix Design

In this study, Ordinary Portland Cement (OPC) was substituted with low percentage of 0%, 5%, 10%, and 15% RHA in four different mix ratios. Every fresh batch of RHA concrete is compared to the OPC control mix. The normal strength of concrete with a density of 2440 kg/m$^3$ is indicated by the concrete design strength of 30N/mm$^2$. The desired slump range, meanwhile, is between 30 and 60 mm. The Slump test and Ultrasonic Pulse Velocity (UPV) were used to examine the workability of fresh concrete and the qualitative characteristics of hardened concrete after 7 and 28 days, respectively. In the meantime, tests are conducted on 7, 14, and 28 days to determine the compressive strength. Table 1 presents a comparison of the material composition and total quantity of material required for producing all test specimens.

**Table 1.** The composition of RHA in concrete mixing

| Mix Code | w/c ratio | Dosage of RHA (%) | Weight of RHA (kg) | Cement (kg) | Water (kg) | Fine Agg. (kg) | Coarse Agg. (kg) |
|---|---|---|---|---|---|---|---|
| 0% | 0.5 | 0 | 0 | 4.18 | 2.09 | 9.06 | 11.55 |
| 5% | 0.5 | 5 | 0.21 | 3.97 | 2.09 | 9.06 | 11.55 |
| 10% | 0.5 | 10 | 0.42 | 3.76 | 2.09 | 9.06 | 11.55 |
| 15% | 0.5 | 15 | 0.63 | 3.55 | 2.09 | 9.06 | 11.55 |

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## 2.4 Preparation of specimen

Throughout the study, only cube specimens type has been prepared for Ultrasonic Pulse Velocity (UPV) and Compressive Strength test. The total number of cube specimens used in the study is 36, and each specimen has dimensions of 100 mm x 100 mm x 100 mm, following the guidelines provided by ASTM C39/C39M-21 (see Figure 3). Initially, the desired quantity of fine aggregates, coarse aggregates, water, cement and Rice Husk Ash (RHA) were accurately measured based on the suggested mix design. Subsequently, the fine aggregates, coarse aggregates, cement, and RHA were combined in a mixing machine. The mixer was then activated, and water was gradually introduced into the mixture.

**Figure 3.** Sample of cube specimen

## 2.5 Testing Phase

One crucial parameter that may be used to evaluate the ease and homogeneity of a freshly mixed matrix is workability. The workability of the concrete or mortar must not be very stiff or fluid, as this will negatively impact production efficiency. The Slump test was performed according to the guidelines outline in ASTM C143/C143M-20 in order to determine the flowability and workability of the fresh concrete. The height difference between the initial cone height and the concrete's height after slumping was compared and measured using a measuring tape. The slump value as measured in millimeters was noted down. This measurement provides valuable information about the workability and consistency of the concrete mixture containing RHA, without causing any damage (see Figure 4).

**Figure 4.** The slump after cone was lifted-up

Meanwhile, for the UPV test, the method use is the dynamic method that measures the time of travel of pulse generated by cracks and shocks. Therefore, this method is mainly used in assessing the strength and durability of the concrete materials while using non-destructive test (Ofuyatan, 2021). The UPV device was calibrated as per the manufacturer's instructions, with a pulse frequency of 1 Hz and a low gain setting. The concrete surface was cleaned with a cloth to ensure proper contact with the transducer, and a thin layer of grease was applied to eliminate air gaps and improve the accuracy of pulse transmission. In the measurement phase, the transducers were positioned with the transmitting and receiving transducers properly aligned on opposite sides of the concrete specimen. The time it took for the ultrasonic pulse to pass through the concrete was then displayed on the UPV instrument. To assure accuracy, several readings were obtained at various points on the sample, and each measurement's time of flight (TOF) was noted (Figure 5).

**Figure 5.** Time of Flight taken from UPV apparatus

The compressive strength of 100 mm cube concrete specimens was determined by following the standard procedure outlined in ASTM C39/C39M-21. Testing was carried out using a calibrated machine that adhered to procedure standards. The cross-sectional area of the cube specimen was accurately measured, and it was positioned on the lower platen of the machine for testing. During the experiment, a steady load was gradually applied at a rate of 0.6 ± 0.2 MPa/s until the specimen failed, which usually happened within a timeframe of 30 to 90 seconds. The maximum load at the point of failure, along with the specimen's dimensions, were carefully noted down. To maintain accuracy, several tests were carried out on different specimens, and the average outcomes were utilized for further analysis. The study reported the final compressive strength values, mix proportions, curing conditions, and test dates for comprehensive documentation.

## 3. Results and Discussion

### 3.1 Workability

The fresh characteristics of the concrete mixtures, as presented in Figure 6, demonstrate the impact of RHA on consistency of fresh concrete (measures of its ease of mixing, placing, compacting, and finishing) where the design slump is between 30 and 60 mm. The control mix, which did not contain RHA, exhibited a slump height (S) of 58 mm, indicating a medium level of workability and within the intended design range. Upon the addition of 5% RHA, the slump height decreased to 50 mm, indicating a slight reduction in workability. With further increases in the RHA percentage to 10% and 15%, the slump values continued to decrease to 45 mm and 31 mm, respectively. By comparison of the data validity, ASTM C143-20 did state that the slump value should not less than 15mm and higher than 230mm, where indicate that the concrete may not adequately plastic and may not be adequately cohesive, respectively. In overall, all the concrete samples having slump within the design intended value and within the criteria specified by the standard code. In addition, it is clearly shows from the finding, the incorporating and increasing of the RHA % in concrete will reduce the slump value. The results showed a good agreement with (Nagrale et al., (2012); Siddika et al., (2015); Krishna et al., (2016) and Al-Alwan et al., (2024)) that utilization RHA in concrete. Finding shows that the use of RHA results in higher water demand and the absorption of mixing water. Consequently, this leads to a decrease in the amount of free water and an increase in the viscosity of the concrete. Regression analysis is also performed to establish linear relationships of amounts of RHA with slump value, where a close relationship is observed in terms of coefficient of determination ($R^2=0.958$). The proposed fit-curved representing this relationship is given as; $S=-8.6x+ 67.5$. It has been noted that as more RHA is added to concrete in place of cement, workability decreases.

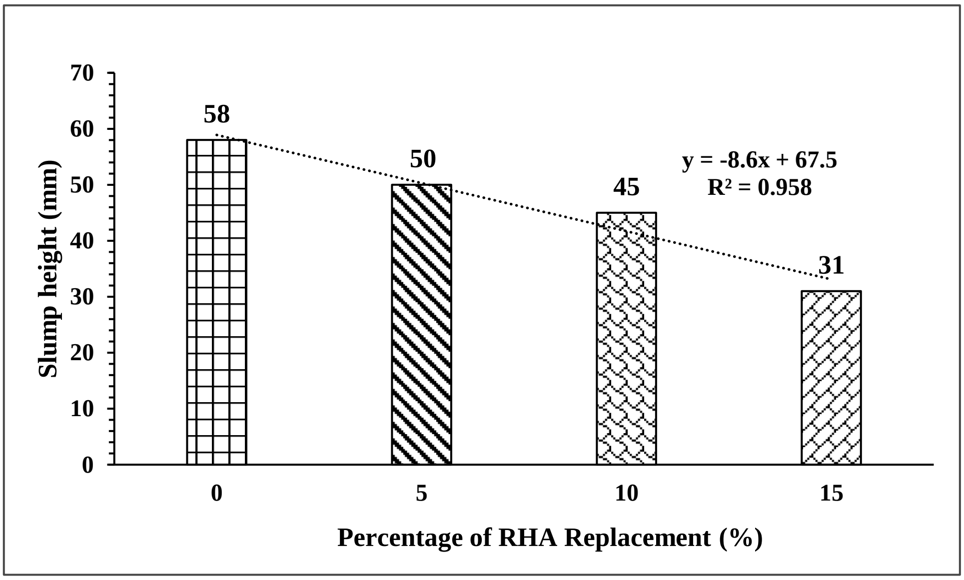


**Figure 6.** Relationship of RHA percentages to concrete mixes workability

3.2 Compressive Strength

Table 2 and Table 3 showed the density and compressive strength data for all samples (3 samples for each mix design,namely as A1, A2 and A3) for current study. It was note that the density of RHA is in the same range for all replacement of RHA where its can be regard as normal weight concrete (Newman & Owens, 2003).

**Table 2.** The density of concrete for different design mix

| Density (kg/m$^3$) | | | | |
|---|---|---|---|---|
| **RHA (%)** | **7 days** | **14 days** | **28 days** | **Average Density** |
| **0** | 2300 | 2300 | 2240 | 2280 |
| **5** | 2380 | 2340 | 2350 | 2357 |
| **10** | 2250 | 2310 | 2240 | 2267 |
| **15** | 2130 | 2130 | 2240 | 2167 |

**Table 3.** The compressive strength and density of concrete for different design mix

| **Compressive strength (N/mm$^2$)** | | | | |
|---|---|---|---|---|
| **RHA (%)** | **7 days** | | | **Average** |
| | **A1** | **A2** | **A3** | |
| **0** | 17.9 | 18.2 | 19.4 | **18.5** |
| **5** | 14.8 | 15.1 | 14.5 | **14.8** |
| **10** | 22.53 | 21.89 | 22.3 | **22.24** |
| **15** | 11.01 | 10.3 | 11.63 | **10.98** |
| **RHA (%)** | **14 days** | | | **Average** |
| | **A1** | **A2** | **A3** | |
| **0** | 28.3 | 27.5 | 28.5 | **28.1** |
| **5** | 19.1 | 18.9 | 20.5 | **19.5** |
| **10** | 31.74 | 30.1 | 29.9 | **30.58** |
| **15** | 13.76 | 13.3 | 12.81 | **13.29** |
| **RHA (%)** | **28 days** | | | **Average** |
| | **A1** | **A2** | **A3** | |
| **0** | 34.01 | 33.5 | 34.43 | **33.98** |
| **5** | 20.4 | 20.2 | 20.45 | **20.35** |
| **10** | 31.98 | 31.9 | 31.85 | **31.91** |
| **15** | 16.8 | 17.7 | 17.1 | **17.2** |

It can be observed that in each cases density decrease with incorporating RHA in concrete except for 5% replacement of RHA due to the change in specific gravity of both OPC and RHA (Anwar et al., 2000). Similarly, Akeke et al., (2013) data shows that the increasing of the replacement percentage for the RHA in concrete have slightly reduce the density value about 3 to 8% for 10 to 20%, replacement, but inconsistency of data did occur for the 25% replacement where it show some increment about 1 to 2 percent higher than 20%. However, there is no discussion why this situation occur for this previous study.

In addition, base on Figure 7, the mix with 5% RHA shows significantly lower compressive strength at all stages compared to the control mix, that might indicate that 5% RHA is insufficient to enhance concrete strength. However, this finding contradict with the fact that 5% RHA have increasing of density compare to the 0%, 10% and 15% replacement as discussed before, where the increasing in the compressive strength should be measured in this case. Meanwhile, the control mix (0% RHA) exhibits a typical strength development pattern, with compressive strength steadily increasing over time to reach 33.98 N/mm² after 28 days, aligning with the expected design strength of 30 N/mm². On the other hand, the 10% RHA mix demonstrates the highest compressive strength at 7 days (22.24 N/mm²) and maintains superior strength to the control mix at 14 days (30.58 N/mm²), although it is slightly lower than the control at 28 days (31.91 N/mm²). The strength increment for 10% RHA measured about 8 to 16 % from the value of the control sample (0% RHA replacement).

It can be seen that the value of compressive strength for 5 to 10% RHA replacement is not quite consistent with the finding from the previous studies. Botchway et al., (2020) and Neeraja et al., (2021) findings show that, the 5% RHA have an optimum value for the percentage replacement compared to control concrete for low percentage replacement from 5 to 15% while further increase in RHA resulted in decreased compressive strength. However, some studies by Siddika et al., (2015) and Akeke et al., (2013) on the other hand, shows that the replacement of 10% cement by RHA did provide an optimum and considerable with respect to compressive strength of concrete for 10 to 25% replacement range. As observed, the concrete sample for each % RHA replacement batch was done at different stages (different day and time), and the type of ingredients, the procedure during the mix design, or the curing method might influence the performance of RHA in concrete. This inconsistency of the current findings also has similarities to the study by Rasoul et al. (2017), where the majority of the RHA blended samples have lower compressive strength than the control OPC mortar for 7 days, but with inconsistent data for replacement 5% to 30%, while all samples with 30% replacement are weaker than the control mix. The reason why this behaviour found in the past study still have no clear discussion.

However, Miller et al., (2019) through their comprehensive literature reviews show that the combustion conditions, pre-combustion treatments and post-combustion treatments applied in ash preparation have a possibility to influence the compressive strength obtained in RHA-concrete. Besides, batching decision such as water-to-binder ratio, moist-curing period and ash properties (such as grinding level and fineness of ash size) are among the additional condition factor that need to be consider for use of RHA as a partial cement replacement. Therefore, it was suggested that, the possible variation of type of ingredients, the process used during the mix design, or the curing method condition may be contributing factors that can influence the performance of RHA in concrete and result in the inconsistency of the sample data, as the concrete sample for each % RHA replacement batch was completed at different stages (different day and time) for the current study. To properly understand, additional study and analysis should be done to figure out why these findings are inconsistent.

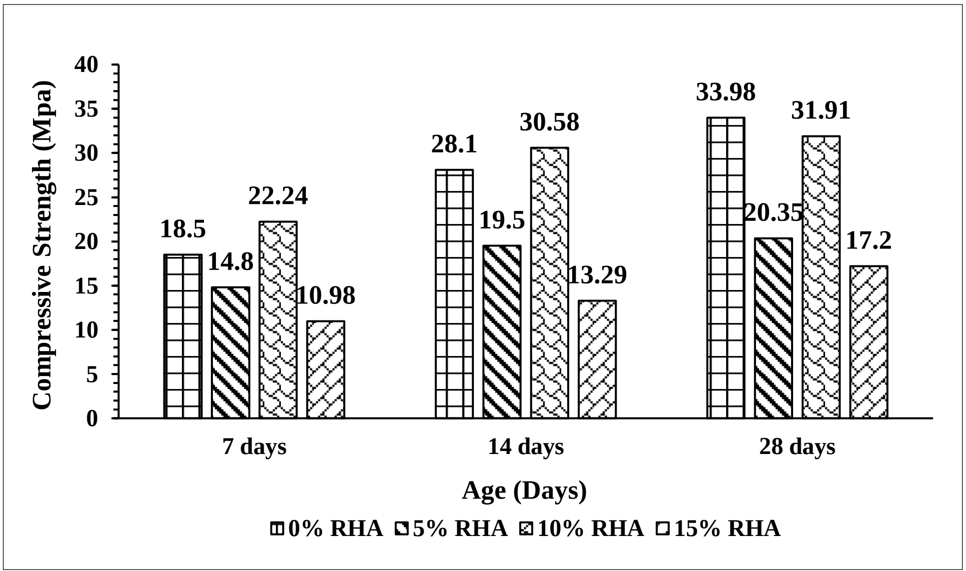


**Figure 7.** Compressive strength of concrete mixture at 7, 14 and 28 days

On the other hand, the 15% RHA mix exhibits the lowest compressive strength at all stages, with 10.98 N/mm² at 7 days, 13.29 N/mm² at 14 days, and 17.2 N/mm² at 28 days. The percentage different found to be significant while compared with the control samples (0%), which are 40.65% , 52.70% and 49.65% at 7, 14 and 28 days, respectively. The possible reason why the 15% shows such slow strength growth might attributed to preparation errors that occurred in this current study, specifically raising the burning temperature to 700°C to accommodate a large crucible, which possibly reduced the quality of the silica in RHA. Studies by Isberto (2019) and Daulay (2021) confirm that the optimal temperature for producing reactive RHA is around 600°C where for the current study, it is done for all % RHA replacement except for 15% RHA replacement. The results also in line with Xu (2012) which showed that silica remained essentially amorphous for the samples at 500 and 600°C but the crystalline formation start to present at temperature 700°C. It can be seen that the temperature and duration of combustion are crucial factors that greatly influence whether silica in RHA stays amorphous or crystallizes. With such crystalline conditions, the study also recommended that more post-processing should be performed, such as grinding the RHA to a very fine particle size to achieve reactivity and facilitate pozzolanic reactions. Given that the substantial amorphous percentages of silicate are necessary for the ash to be reactive, the increase to 700°C for the current study apparently might changed part of the amorphous silica into less reactive crystalline forms, and besides, no additional grinding has been done for the RHA, which in turn led to a decrease in pozzolanic activity and compressive strength. Therefore, to maximize concrete strength during RHA preparation, rigorous temperature control is essential.

By conclusion, base on the current finding, it can be suggests that 10% RHA replacement have an potential optimizes strength development, as supported by Hussin (2018) and Nursyamsi & Aruan (2021), who emphasized the beneficial pozzolanic reaction and improved microstructure due to RHA. However, for future references and research, the potential mistakes or contributing variables for the 5% and 15% of RHA replacement on their strength development should be addressed and taken into consideration.

### 3.3 Pulse Velocity

Table 4 and Figure 8, shows the result from the UPV test. By observation, the mixtures of concrete that contained different proportions of RHA demonstrated some variations in quality after 7 and 28 days of curing. The control mixture, which contained 0% RHA, exhibited consistent pulse velocities of 3220 m/s at 7 days and 3250 m/s at 28 days, both falling within the "medium" quality range. The value of mixture with 10% RHA consistently demonstrated the highest pulse velocities of 3330 m/s at 7 days and 3350 m/sec at 28 days while compare with control and other % RHA replacement, maintaining a "medium" quality similar to the control mixture. In overall, the gradual increase in pulse velocity over time for all samples suggests a progressive homogenization of the concrete. The density data for both 0% and 10% have show some comparable value where the different found is only about 0.5%, thus indicate the reason why this sample could have same “medium” quality range. The obtain results of pulse velocity also comparable with the finding of Anwar (2000) where the situation might be contributed by the physical properties of rice husk that is smooth and contains adequately high silica that can close the pores of the concrete which lead to quality improve in concrete specimens (Nursyamsi & Aruan, 2021).

**Table 4.** Ultrasonic Pulse Velocity (UPV) result

| Percentage replacement of cement by RHA (%) | Pulse velocity (m/s) at 7 days | Concrete quality grading at 7 days | Pulse velocity (m/s) at 28 days | Concrete quality at 28 days |
|---|---|---|---|---|
| 0 | 3220 | medium | 3250 | medium |
| 5 | 2160 | doubtful | 2180 | doubtful |
| 10 | 3330 | medium | 3350 | medium |
| 15 | 2250 | doubtful | 2270 | doubtful |

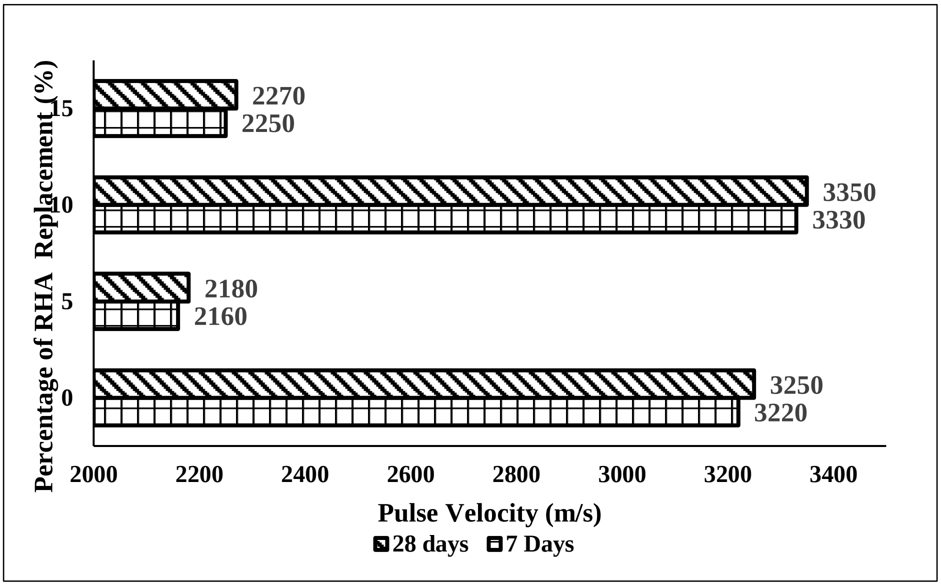


**Figure 8.** Pulse velocity value for different percentage of RHA.

The combination with 5% RHA, on the other hand, showed the lowest pulse velocities at 7 and 28 days, respectively, at 2160 m/s and 2180 m/s, suggesting "doubtful" quality and possible structural problems. The low figure could be the consequence of a problem with the strength development for 5% RHA replacements, which could be caused by a number of previously mentioned causes. The 15% RHA mixture showed similar behavior, with somewhat greater pulse velocities than the 5% RHA mixture (2250 m/s at 7 days and 2270 m/s at 28 days), although it was still classified as "doubtful" quality. This was probably caused by variances in the RHA's incorrect preparation, like shifting the burning temperature from 600 to 700 degrees Celsius, which raised porosity and decreased quality.

On the other hand, Figure 9 shows the correlation between compressive strength and pulse velocity for the averages of 8 concrete specimens (for each concrete mixes) at age 7 and 28 days only. The use of ultrasonic pulse velocity in this study is mainly to distinguish concrete mixture design and show the predictive relationship between compressive strength and UPV value. The relationship between the destructive test (compressive test) data and non-destructive data (UPV test) could provide necessary data for the strength and safety of concrete materials if properly developed. For all concrete specimens, it can be seen that the relationship between these two parameter is quite low where the proposed regression model is $R^2=0.5279$. From the correlation data, the development of strength is not significantly being predicted by using this current model. From Table 5, it was observed that the actual and predicted strength (calculated by using the predicted equation, $y=0.0101x-6.5442$) of concrete cubes for 10% replacement are not the same and has percentage variation more than ±10%, which can be considered higher than early study (Benaicha et al., 2015).

The reason for this low relationship might be significantly due the low development of strength and inconsistency of data measurement for the 5% RHA replacement as well as the error encountered during the specimens preparation for 15% RHA cement replacement. Meanwhile, the lack of numbers of concrete specimens' data might also contributed to poor data distribution. For better assurance on concrete strength result, the combined test can be done in the future to make the result more satisfactory while also taking account the concrete mixing parameters and possible cause and factors of errors. Even though the fundamental objective of the data correlation between the concrete's quality and compressive strength could not be met by the current study, it did show that, with the correct design and measurement, the UPV test can be used to qualitatively compare the quality of the concrete and strength development of blended concrete RHA.

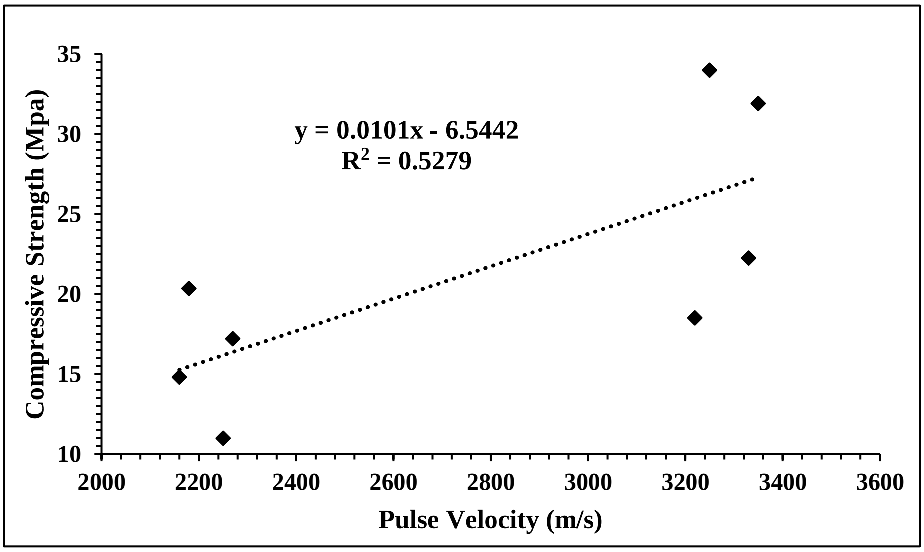


**Figure 9.** Correlation between compressive strength and pulse velocity at age of 7 and 28 days

**Table 5.** Result of pulse velocity and compressive test of concrete specimens at 7 days.

| Samples | Pulse Velocity | Actual Compressive Strength (N/mm$^2$) | Predicted Compressive Strength (N/mm$^2$) | Percentage Variation (%) |
|---|---|---|---|---|
| A | 3330 | 22.24 | 27.09 | 21.81 |
| B | 3350 | 31.91 | 27.29 | -14.48 |

## 4. Conclusion

The main conclusions of the study on the performance of concrete mixtures that use rice husk ash (RHA) in place of cement substitution are presented in this section. The workability tests showed a steady decrease in slump values as the percentage of RHA increased, indicating that the absorptive qualities of RHA particles were responsible for decreased fluidity and increased water need. It has been found that adding 10% RHA to normal concrete (M30) production improves the development of compressive strength and results in a slight rise in strength when compared to the control mix sample (0%). The 5% RHA and 15% RHA replacement, which demonstrated a delayed and low growth of strength, must be considered when evaluating the validity of the findings because they are found to be inconsistent with earlier research. The type of ingredients, the procedure used for the mix concrete design and batching, the curing method, and the combustion process (temperature variation) could all be contributing variables for the error to be occurred. It is important to draw reference to and note these uncertain elements for future reference. In addition, the current study demonstrated that, with the right design and measurement, the UPV test can be used to qualitatively compare the quality of the concrete and strength development of blended concrete RHA, even though it was unable to meet the fundamental objective of the data correlation between the concrete's quality and compressive strength. More comprehensive research is needed to maximize the potential used of RHA content in order to improve the workability, assess long-term performance, and guarantee sustainable construction methods. By integrating RHA into concrete mix designs, these findings will be promoting the development of standards, guidelines, and useful advice that will encourage the use of high-performance, ecologically friendly building materials.

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**Declaration of Conflicting Interests**

All authors declare that they have no conflicts of interest.

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