Impact of Incorporating Rice Husk Ash (RHA) into Recycled Concrete Aggregates (RCA) on the Compressive and Flexural Strength of Concrete

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Abstract. This study aimed to assess the strength characteristics of concrete using Recycled Concrete Aggregates (RCA) as full replacement to coarse aggregates and Rice Husk Ash (RHA) as an admixture. The concrete samples were subjected to curing for 7, 14, and 28 days. Specifically, the study evaluated the workability of freshly mixed concrete and compared the compressive and flexural strength with RCA and RHA to normal concrete. Four different treatment mixtures were used with three replicates with varying ratio of RHA to cement: Treatment 1 (1 cement: ¾ RHA), Treatment 2 (1 cement: ½ RHA), Treatment 3 (1 cement: ¼ RHA). In all cases, RCA completely replaced natural coarse aggregates. The results indicated that the slump which measures the workability of the RCA concrete met the desired standard specifications. Additionally, the RCA concrete with the highest RHA content obtained the highest compressive and flexural strength on the 28th day test but did not exceed the control. Furthermore, the study revealed that the concrete specimens could handle maximum loads for flexure rather than compression load.

1 Introduction

Concrete is a universal construction material. However, the production of this material results to high gas emission which associated with production, transportation, use and the disposal. Basically, the entire life cycle of concrete contributes to high carbon footprint. Presently, there are various studies that promote the use of alternative materials such as recycled aggregates, natural fibers, recycled glass, fly ash, and many others. A recent study of Macmac et al. [1] utilized tire waste steel fiber in reinforced self -compacting concrete which found that tire waste steel fibers can be used to strengthen the self-compacting concrete. Another sustainable material that is eco – friendly is bamboo. This natural material has various purposes in utilizing the whole culm as structural material. Recently, Adier et al. [2] provided a review of the properties and various applications of bamboo in construction which generally promotes the use of sustainable environment friendly material rather than concrete. The common and low-cost material that is used as alternative for aggregates is recycled concrete. The strength of recycled waste concrete has been studied widely in many previous studies.

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Many have proved that it is lower than the normal [3]–[9]. However, there are few studies proved that it is comparable and near equal to the normal concrete provided with special treatments and methods to enhance its performance [10]–[13]**.** Rice husk ash (RHA) is an agricultural waste produced after the rice grains were milled. It contains approximately 83.7% silica that is capable to be used as replacement to cement in respective ratios. Previous studies used RHA as partial and full replacements to cement to produce a high-performance concrete. Salas et al. [14] used the highly reactive RHA and observed that 10% of a high reactive RHA is the optimum replacement level to ordinary cement which enhanced the compressive strength, flexural strength, and elastic modulus of concrete. However, using the RHA requires high water requirement. The RHA is a high porous material that affects the workability of concrete if the ratio increases. Wilson et al. [12] used the RHA as partial replacement to cement and observed that the compressive strength increased after 28 days of curing up to 20%. RHA has a great potential to be utilized as a viscosity modifying admixture. The RHA was found effective in improving the compressive strength of the self – compacting high performance concrete (SCHPC) especially at higher replacement percentage with later ages. The compressive strength of SCHPC reached 130 MPa after 56 days [15]**.** Recent studies found that incorporating RHA to concrete mixture will improved the strength capacity up to 25% [16]**.** Gull et al. [13] recommends the recycling of the wastes concrete in concrete production and suggested to further study the development and improvement of concrete wastes as a recycled aggregates for better performance and include the financial analysis. This paper supports the adaptation of recycled concrete aggregates in the production of concrete for construction. Recycling concrete waste from construction and demolition contributes to reducing pollution and waste disposal to landfill brought by RCA and RHA where sometimes a large concrete waste is brought by natural calamities, these wastes are a burden that creates large pollution. It will also lessen the high demands of the natural coarse aggregate resources in the production of concrete especially if there will be no mountain rocks to be blasted for aggregate resources and collecting from the riverside will be strictly prohibited. This study determined the compressive and flexural strength of RCA with RHA as admixture in 7, 14 and 28 days curing. In this experiment, the RCA fully replaced the coarse aggregates and observed the performance of concrete with a higher proportions of RHA admixtures. This experiment is limited only up to 28 days curing in which cannot fully predict the behavior of the RHA into the concrete strength, because literature indicates that RHA typically performs better in longer term.

2 Materials and Methods

The recycled concrete aggregates used were gathered from the removed road pavement in the project of DPWH 3rd Engineering District of Palawan in Zigzag Road, Puerto Princesa City. The road was constructed in 2009 but removed in 2016 due to the traffic accident issues. The rice husk was gathered from the rice mill in Barangay Mabini, Aborlan, Palawan. The rice mill is operating over 20 years and produce rice husks at an average of 20 cubic meters every day. The rice husk from the rice mill was rinsed with clean water and sun dried for one day before being burned. The rice husk was burned openly till it converted to ash. After burning, the ashes were allowed to cool before being pulverized with hammer mills and mallets. The fineness of the rice husk ash was improved by grinding. According to the literature review, the fineness of rice husk ash must be equivalent to or more than that of cement to increase its performance. Afterwards, it was collected into an open rectangular container for air dry in a room temperature together with the RCA. The natural aggregates were taken in Montible, Puerto Princesa City because the natural aggregates were gathered in the area. Type 1 Portland Cement was used in concrete mixture with 0.56 water – cement ratio. The specific gravity of materials was determined in the laboratory by the ratio of its

mass and volume. ASTM C33-01 (Standard Specification for Concrete Aggregate) was used to evaluate the concrete aggregates.

Abrasion loss test was performed on the RCA to evaluate the hardness of the RCA. The test was done under Grading B standard specifications of Department of Public Works and Highways (DPWH) test for abrasion loss with 40% maximum allowable loss by mass. There were 11 bolts used and 500 revolutions.

There were three treatments with three replications that were fabricated. Treatment 1 is for every 1 parts of cement, ¾ of RHA were added; Treatment 2 was 1 part of cement is to ½ of RHA; and Treatment 3 was 1 part of cement is to ¼ RHA. The double mixing method was used in this study to enhance the properties and performance of concrete mixture. The recycled coarse aggregates were prewetted and air dried before mixing. In double mixing method, the cement and sand were mixed in concrete mixer with first water application, then RCA was added to the mixture with the second part of water application, and finally the rice husk ash was added to the mixture with the final part of water. The mixture was mixed thoroughly until the color of concrete became neutral. Extra water was added as compensation to the property of the recycled concrete aggregates and RHA that has high water absorption. The concrete mixtures for compressive strength test were casted into cylindrical moulder in 6 inches in diameter and 12 inches long and the concrete for the flexural strength test were casted to the rectangular moulder with 6 inches wide by 6 inches thick by 21 inches long. The internal surface of moulders were thoroughly cleaned and applied a light coat of clean oil. The concrete specimens were allowed being hardened for 24 hours and it were removed from the forms after 24 hours and placed it to the curing tank for their respective days of curing. Tests for the compressive and flexural strength were done in accordance with ASTM C39 and ASTM C293-02, respectively. Curing was done after removing the concrete samples from the moulds. The concrete samples were soaked into a water tank for curing. The specimens for compressive and flexural strength test were cured and tested in three stages such as: 7, 14, and 28 days. The specimens were tested under UTM with 1500 kN capacity for compression and 300 kN for flexure. The ultimate speed of 2 m/s of the UTM was used. The specimen was loaded continuously up to its breaking capacity.

3 Results

The recycled concrete aggregates from the removed pavement undergo abrasion test to establish the benchmark for determining the percentage loss in hardness of the corresponding removed pavement. Figure 1 shows that the RCA has a 10.72% loss from the original strength of aggregates with standard deviation of 0.36 compared to natural aggregates with standard deviation of 0.16.

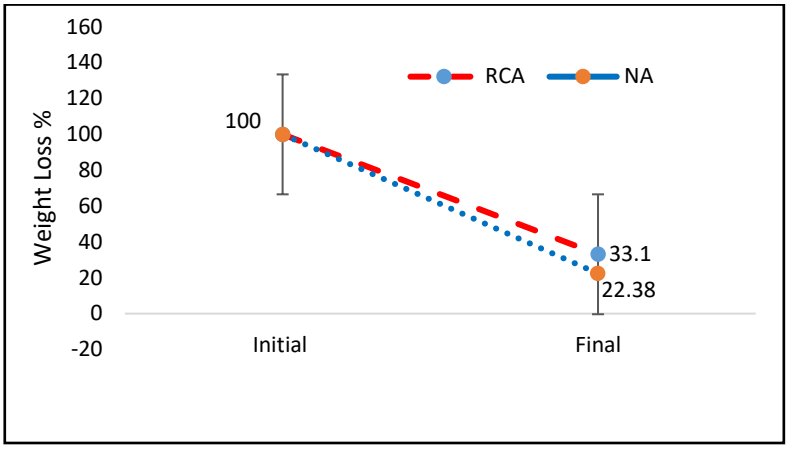

Fig. 1. Result of the Abrasion Loss Test of RCA and NA samples.

The specified slump consistency range for Portland Cement concrete pavements, according to the Department of Public Works and Highways (DPWH) is 40-75mm (equivalent to 1 ½ to 3 inches) without vibration. The findings indicated that the concrete mixture incorporating both Recycled Concrete Aggregates (RCA) and Rice Husk Ash (RHA) exhibits satisfactory workability, aligning with the specified criteria presented in Table 1 with Coefficient of Variance (COVs) of 2.20, 3.36, 4.76, and 5.62 for Control, Treatment 1, Treatment 2, and Treatment 3, respectively.

Table 1. Result of slump test conducted for all treatment mixtures.

Mixture	Slump*(mm)	Slump**(mm)	COV (%)	Specifications (Non vibrated)	Remarks
Control	63.50	59.00	2.20	40 - 75 mm	S
Treatment 1	80.00	50.80	3.36	40 - 75 mm	S
Treatment 2	85.60	44.45	4.76	40 - 75 mm	S
Treatment 3	79.30	48.26	5.62	40 - 75 mm	S

slump* First trial slump

slump** Second slump
Note: S =Satisfactory

Figure 2 is the comparison of the peak load obtained on compressive strength test of every treatment with respect to 28 days test along with the time elapsed to its breaking point. The COVs for load capacity and time elapsed are 6.92 and 20.82, respectively. The result also shows that the peak load obtained by each treatment is not dependent on the time elapsed capacity. It can be concluded that concrete can rupture in a shorter time but obtained the highest load.

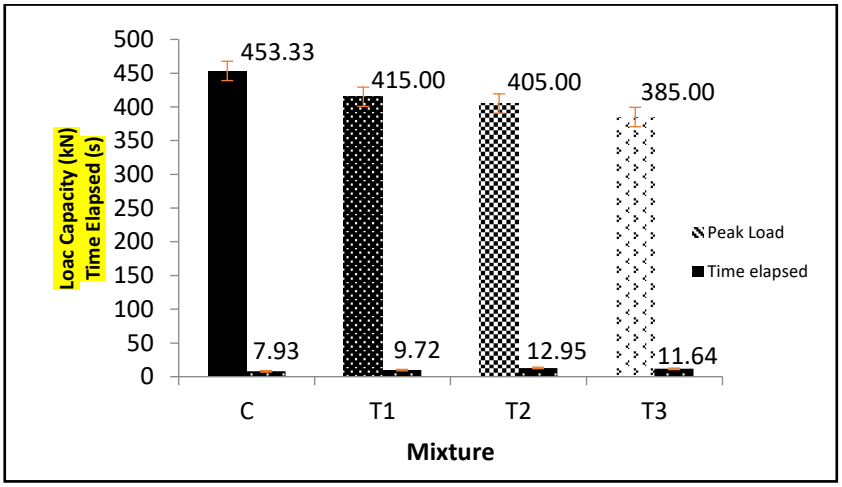

Fig. 2. Result of Load Capacity and Time Elapsed of cylindrical specimens on the 28th Day.

Figure 3 is the comparison of the peak load obtained in the flexural strength test of every treatment on the 28th day test. The COVs for the load capacity and time elapsed are 1.92 and 1.49, respectively. The result indicates that the trend of peak load is increasing as the proportion of RHA is increasing, the time elapsed is partially reciprocated the pattern of the peak load. However, it cannot directly remark since Treatment 1 and 2 obtained the same duration. It is recommended to perform a longer stage of testing to expand the trend for better conclusion.

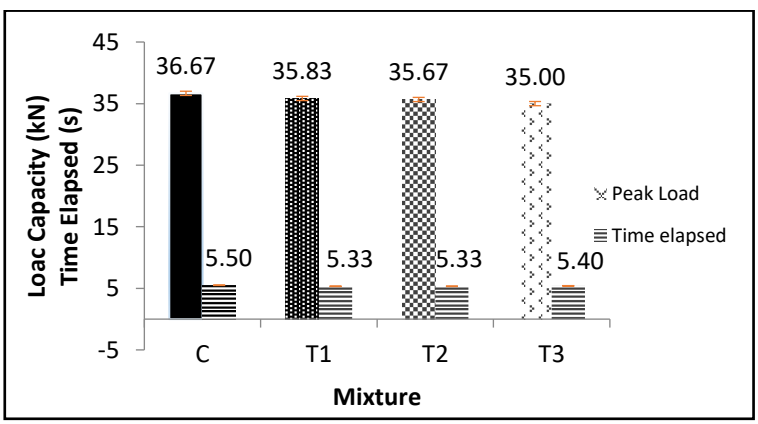

Fig. 3. Result of Load Capacity and Time Elapsed of beam specimens on the 28th Day.

The summary of the compressive and flexural strength test result is presented in Table 2. Both compressive and flexural strength for 7th and 14th day have high coefficient of variance of 13.43% and 14.68%, and 14.22% and 19.41%, respectively. However, compressive and flexural strength of 28th day have low coefficient of variance of 5.09% and 1.89%, respectively. The result indicated that there is no significant difference among the three treatments on the 7th, 14th and 28th day for compressive strength. The flexural strength test result for both 7th and 14th day has no significant difference for all treatments, while the 28th day result is significantly different. The compressive strength for both 7th and 14th day test were not correlated with the percentage of RHA admixture as shown in Figure 4. However, the 28th day test result shows correlation on the percentage of admixture by which it increases

as the percentage increases. The result also indicates that the longer the age of concrete increases the compressive strength which coincides to the study of Wilson et al. [12]. The double mixing method and the high fineness of rice husk ash enhanced the performance of the concrete treatments as suggested by the study of Otsuki et al. [10] and Xu et al. [17]. It is recommended to add more in between proportions and longer stage of curing and test to fully understand the trend and behavior of the concrete strength. The differentiation of flexural strength is presented in Figure 5. Additionally, it is advisable to prolong the duration of the test to cover a more extensive phase. This extension will facilitate a broader comparison and validation of the strength behavior involving a greater range of proportions.

Table 2. Summary of the compressive and flexural strength of different treatments in 3 curing stages.

	Compressive Strength (MPa)			Flexural Strength (MPa)		
	7 days	14 days	28 days	7 days	14 days	28 days
Control	12.40	13.40	23.73	2.85	3.82	4.63
Treatment 1	15.47	16.33	22.67	2.17	2.65	4.53
Treatment 2	11.47	12.77	21.87	2.10	2.58	4.48
Treatment 3	14.23	17.27	21.07	2.43	2.83	4.43
COV	13.43%	14.68%	5.09%	14.22%	19.41%	1.89%

Note: Means with the same letter are not significantly different at 5% level.

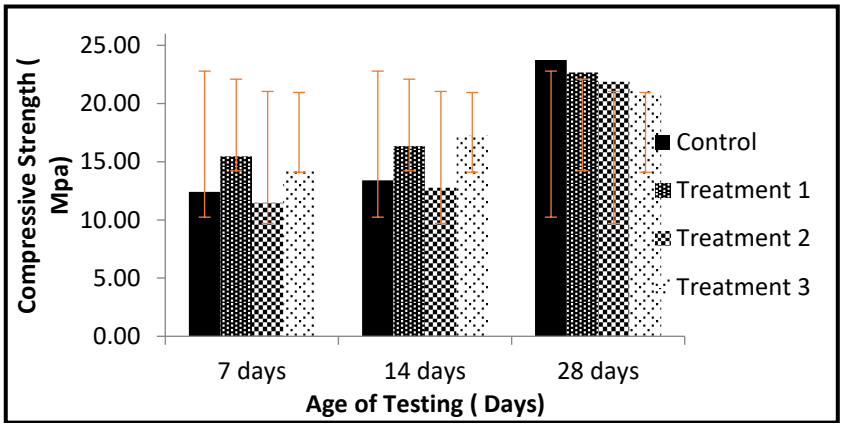

Fig. 4. Result of compressive strength of different treatments in 7, 14, and 28 days test.

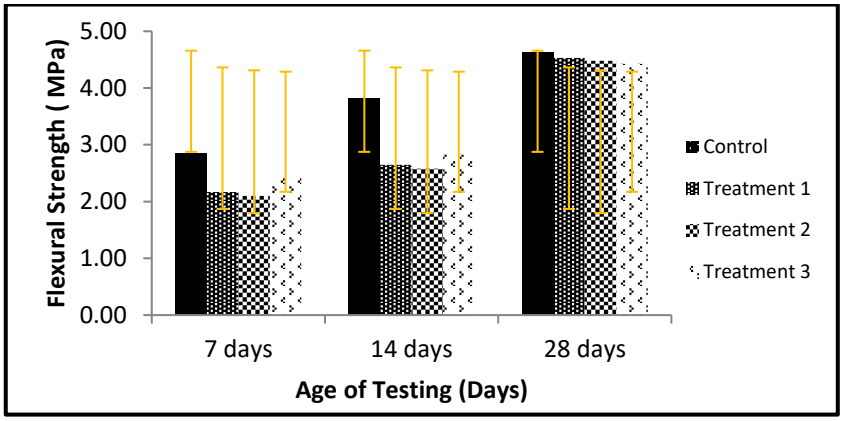

Fig. 5. Result of flexural strength of different treatments in 7, 14, and 28 days test.

4 Conclusion

The construction and demolition of concrete is progressively increasing nowadays causing it to have huge concrete waste. This study was conducted to contribute to the management of concrete waste, economic production of concrete and preservation of natural resources. The double mixing method to the mixtures of RCA with RHA admixture improved the workability of fresh concrete in which the RCA with RHA concrete slumps are very satisfactory. Treatment 1 is the most comparable mixture of RCA with RHA in both compressive and flexural strength. It was observed that concrete that has the highest ratio of rice husk ash admixture has the highest compressive and flexural strength on the 28th day. The result also indicates that the longer the age of concrete increases the compressive strength of the RCA with RHA concrete. For flexure, the treatment condition is significant because the increase in the ratio of RHA shortened the time capacity of the concrete specimen. This implies that for beam specimens that use RCA and RHA is strongly need of reinforcement. However, further studies may be conducted for wide variations of admixture and longer stage of curing because literature stated that it has better performance in longer age of curing.

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