Utilizing Rice Husk Ash And Coconut Shell As Partial Replacement Materials In Concrete

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ABSTRACT

The global demand for concrete, a predominant construction material, has risen significantly. Key components in concrete are cement and aggregate, are crucial, but their continual extraction poses a threat to the environment, leading to a potential ecological imbalance. Consequently, current trends in concrete technology focus on exploring sustainable alternatives to reduce dependence on natural resources and mitigate environmental degradation. This study aimed to produce concrete using rice husk ash and coconut shell as partial replacement materials for cement and coarse aggregate, respectively. The mix ratio is 1:2:4 (cement: fine aggregate: coarse aggregate) for grade 20. Rice husk ash replaced 10% and 20% of cement, while coconut shell replaced 5% and 10% of coarse aggregate by weight. Samples were tested for workability, water absorption, and compressive strength. According to the slump test, every sample exhibits collapse and a true slump meanwhile in water absorption showed less than 8% according to standard value. The control sample showed good compressive strength (>20 N/mm^2), while among the modified samples, the concrete mixture with 10% rice husk ash and 5% coconut shell achieved the highest compressive strength at 15 N/mm^2 after 28 days.

KEYWORDS

coconut shell; compressive strength; concrete; rice husk ash

1. INTRODUCTION

As one of the primary sectors of the national building industry, construction is crucial to a nation. According to (Star, 2023), Malaysia's construction industry is predicted to expand greatly as a result of increased government investment and private-public sector efforts. However, the materials utilised in building are going to depleted. The depletion of natural resources and raw materials can lead to environmental problems such habitat destruction, erosion, and the release of carbon dioxide (CO2). Coarse aggregate and cement are important components of the concrete mix, to increase the strength, durability, and workability. In the interim, cement are use as binding aggregates provide a balanced mix with appropriate qualities for building purposes.

Two major environmental effects of the concrete industry are global warming and ozone layer degradation (A.Omar, 2022). Malaysia ratified the Kyoto Protocol in 2002 and has taken initiatives to reduce its carbon emissions reported by (Mohd Noor Musa, 2024). Among his initiatives is the reduction of raw materials by partial replacement some materials. This helps to reduce the need for excessive use of these non-renewable materials, ensuring a sustainable and eco-friendly alternative to traditional building materials. Concrete is a basic building material comprising cement, fine and coarse aggregates, water, and additives. (Abbas, 2012) notes that minor cracks in concrete result from shrinkage, prompting the construction industry to explore new compositions with natural additives.

Plenty of investigations have carried out single and multiple replacements of components in concrete mix ingredients. Coconut shell and rice husk ash (RHA) were chosen based on research findings that highlight the material characteristics and benefits. (Kanojia & Jain, 2017) highlight the benefits of coconut shells is the high water and acid resistance, as well as reduced shrinkage, which improves workability and strength in concrete. Because of their superior thermal insulation qualities, they are an affordable and practical choice for partition and housing walls in high-performance applications. (Amin & Abdelsalam, 2019) research on rice husk ash (RHA), which is an effective super pozzolan containing 85-90% silica, shows a significant improvement in concrete durability. This is achieved by reducing air content and water permeability through the use of high ratios of RHA and fly ash. The related previous study also have been conducted but use the different percentage, particle size and repalcement purpose of coconut shell and rice husk ash in concrete.

This study aims to produce concrete using rice husk ash and coconut shell as partial replacements for cement and coarse aggregate, respectively. The research will assess the workability, water absorption, and compressive strength of the partial replacement material concrete, comparing these properties to standard values. Partially replacing concrete with rice husk ash and coconut shell is to enhance sustainability and performance by utilizing agricultural waste materials, reducing environmental impact, and potentially improving certain properties of concrete, such as durability and strength by comparing with control sample. This study not only provides insights into engineering and construction, but it also expands our understanding of agricultural waste potential use.

2. METHODOLOGY

The concrete consists of Ordinary Portland Cement (OPC), fine aggregate less than 9.55 mm and coarse aggregates is generally between 4.75 mm and 20 mm. The partial replacement material size are particles ranging in size from 5 to 10 μm of rice husk ash and sharp fracture of coconut shell with the size 10 mm to 20 mm. The concrete mix ratio is 1:2:4 with a grade of M20. In the study, the cement is partially replaced with 10% and 20% rice husk ash and coarse aggregate is replaced with 5% and 10% coconut shell. A control sample with 0% replacement is used as a reference, and three samples are developed for each replacement ratio throughout testing. The samples preparation is shown in Table 1.

Ther workability (MS 26-1-2), water absorption (MS30) and compressive strength (EN 12390-3) tests were conducted at Chuan Seng Industries Sdn Bhd as shown in Figure 1 and Figure 2. The slump test is crucial for assessing the workability of fresh mixed concrete, ensuring uniformity and strength. It helps identify variations in the mix's homogeneity, which is essential for correct placement and compacting and indirectly reveals the water content. The durability of concrete is determined by its porosity, which is influenced by its ability to absorb water. A water absorption test is conducted to assess the concrete's permeability, ensuring a low rate of absorption, indicating its high quality and resistance to degrading elements. Compressive strength standards are crucial for quality control in concrete. as they ensure the mix meets the intended weights under compressive loads, ensuring durability and long-term performance.

Table 1. Sample preparation

Sample	**Ratio 1**	**: 2**	**: 3**	**Rice Husk Ash (kg)**	**Coconut Shell (kg)**	**Total Sample**
	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)			
Control Sample	12.08	24.16	48.31	0	0	9
A	10.87	24.16	45.90	1.21 (10%)	2.42 (5%)	9
B	9.66	24.16	45.90	2.42 (20%)	2.42 (5%)	9
C	10.87	24.16	43.48	1.21 (10%)	4.84 (10%)	9
D	9.66	24.16	43.48	2.42 (20%)	4.84 (10%)	9

Figure 1. Concrete mixture

(a) (b) (c)

Figure 2. a) Slump test b) Water absorption test c) Compressive strength

3. RESULTS AND DISCUSSION

3.1 Slump Test (MS 26-1-2)

Referring to Table 2, the slump test results indicate that the control sample obtained the slump value of 120mm. Sample A shows a slump of 130mm, sample B records 65mm, sample C is 30mm, and sample D is 27mm. Control Sample and sample A demonstrated high workability and suitable for slab and beam construction. Sample B had medium workability and can utilize as slab, huge construction mass and deck of bridge. Meanwhile sample C and sample D showed low workability, marked by its true slump but can apply as pavement of highway. Figure 3 shows the sample A obtained the highest slump value among all samples, indicating a collapse slump. This is ideal for constructing beams, reinforced walls, and building columns that not normally suitable for vibration this can be proven by (Weerasekara, 2019). On the other hand, samples B, C, and D exhibit a true slump, making them suitable for road pavement and slab construction due to the limited water content that accelerates concrete hardening.

Table 2. Slump test

Sample	Control Sample	A	B	C	D
Slump					

Slump Value	120 mm	130 mm	65 mm	30 mm	27 mm
Type of Slump	Collapse	Collapse	True Slump	True Slump	True Slump
Workability	High	High	Medium	Low	Low
Application (Source: Jabatan Kerja Raya Rembau)	Column, Wall		Slab, R.C. Work, Huge Mass Construction, Deck of Bridge,	Pavement, Huge Mass Construction	

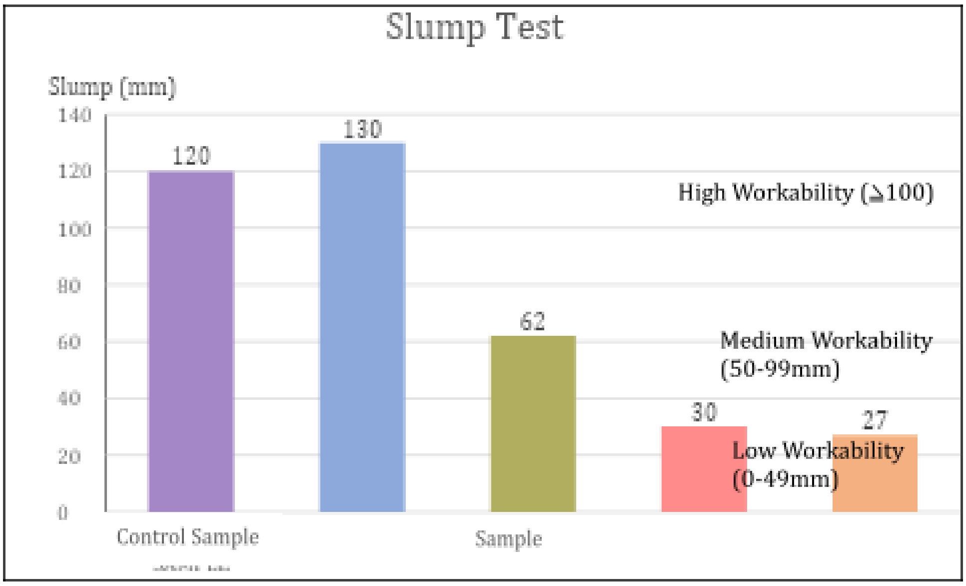

Figure 3. Slump test of samples

3.2 Water Absorption Test (MS 30)

Referring to Table 3 and Figure 4 the control sample has achieved highest result in water absorption test which is 2.6%, following by sample A is 1.9%, sample B is 0.56%, sample C is 0.5%, and sample D is 0.2% after 28 days of curing. All samples show low water absorption (less than 8%). The control sample and sample A have high absorption due to low partial replacement material compared to sample B, sample C and sample D based on rice husk ash and coconut shell ratios. RHA and coconut shell in concrete can balance water absorption by generating a denser matrix and reducing porosity. Coconut shell aggregates3 have a high water absorption capacity due to their porous structure, which increases total water absorption. In between, the concrete matrix's pores are filled with RHA, a high pozzolanic reactivity that increases durability and reduces water absorption and permeability. According to (Ghewa et al., 2020) research, the application of pozzolanic materials such as rice husk ash in concrete decreases its water absorption capacity. Furthermore, he found that higher pozzolanic content can further reduce water absorption values. This is demonstrated in Sample D form other samples, which contains 20% rice husk ash and 10% coconut shell. The impact of rice husk ash on water absorption is evident, showing better absorption than the control sample.

Table 3. Water absorption test

Sample	Water Absorption (%) $\frac{W2-W1}{W2}$ x 100		
	7 Days	14 Days	28 Days
Control Sample	3.55	2.70	2.66
A	1.10	1.17	1.96
B	0.33	0.47	0.56
C	5.59	1.8	0.5
D	0.9	0.1	0.2

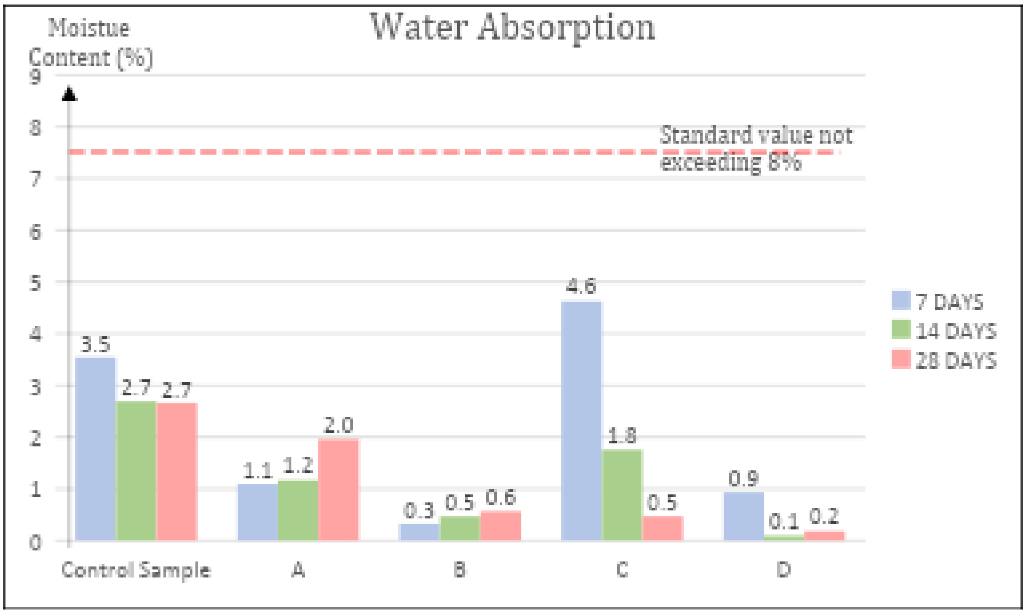

Figure 4. Water absorption test of samples

3.3 Compressive Strength (EN 12390-3)

Table 4 presents data of compressive strength test, indicating that the control sample achieved the highest compressive strength among all samples which is more thank the value according to (Viera Valencia & Garcia Giraldo, 2019). The control sample's compressive strength increases from 7 to 28 days, without any partial replacement material. Figure 5 and Figure 6 indicate that on the 7 days and 14 days, none of the samples, except the control, met the Jabatan Kerja raya Specification compressive strength standards of 14 N/mm^2 and 18 N/mm^2. By the 28th day as shown in Figure 7, sample A achieved a compressive strength of 15 N/mm^2, highest among the modified samples, while the control sample remained above the standard at 20 N/mm^2. This suggests that a smaller percentage of replacement materials results in higher compressive strength.

However, samples A, B, C, and D, with partial replacement materials, failed to meet the standard values at 7, 14, and 28 days due to the impact of increased replacement materials on compressive strength as shown in Figure 8. While rice husk ash reduces water absorption, it does not enhance compressive strength. Coconut shell, as a partial replacement for coarse aggregate, lowers concrete density but doesn't increase compressive strength with increased replacement percentages due to porous and irregular nature of coconut shells. Sample A, with 10% rice husk ash and 5% coconut shell, demonstrates higher compressive strength than other replacement mixture samples at day-28, it suitable for lean concrete and non-structural work, even below grade 20.

Table 4. Compressive strength

Sample	Compressive Strength (N/mm^2)		
	7 Days	14 Days	28 Days
Control Sample	17	20	24
A	10	13	15
B	6	8	10
C	8	11	12
D	8	8	13

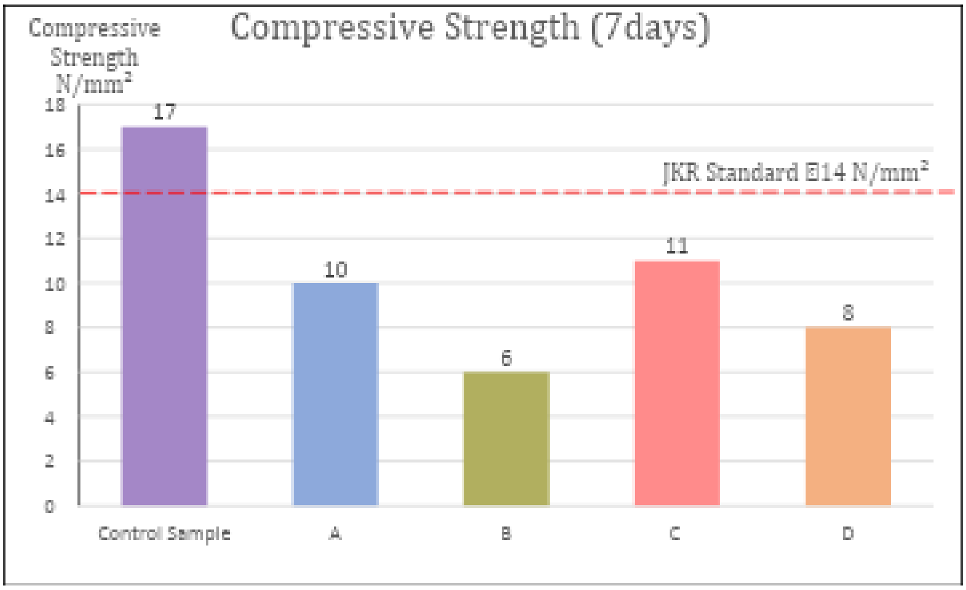

Figure 5. Compressive strength of samples at 7 days

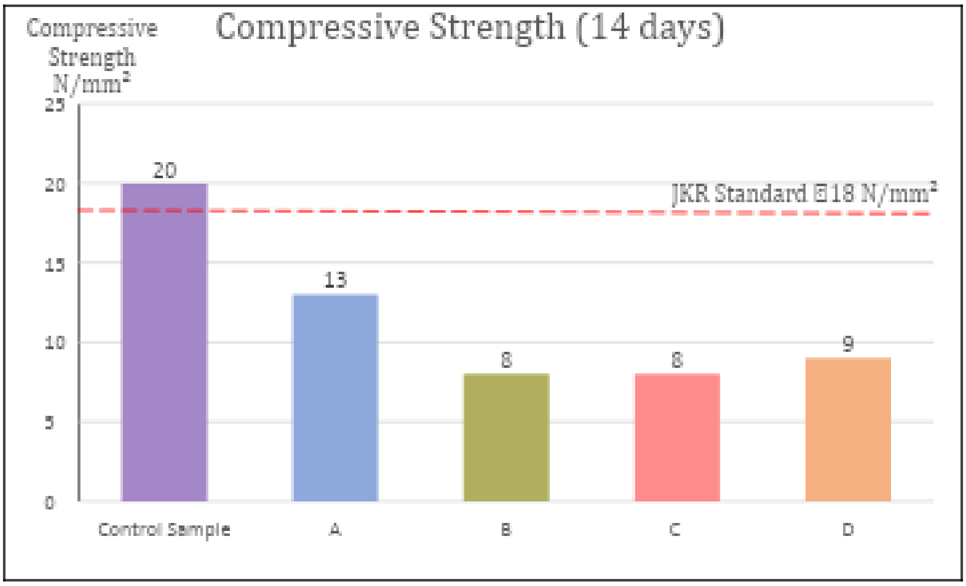

Figure 6. Compressive strength of samples at 14 days

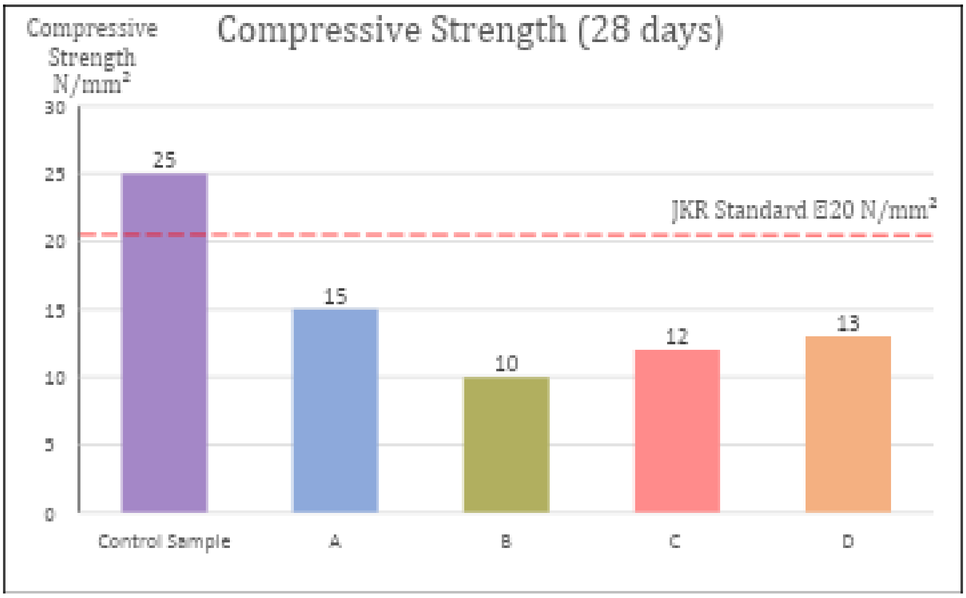

Figure 7. Compressive strength of samples at 28 days

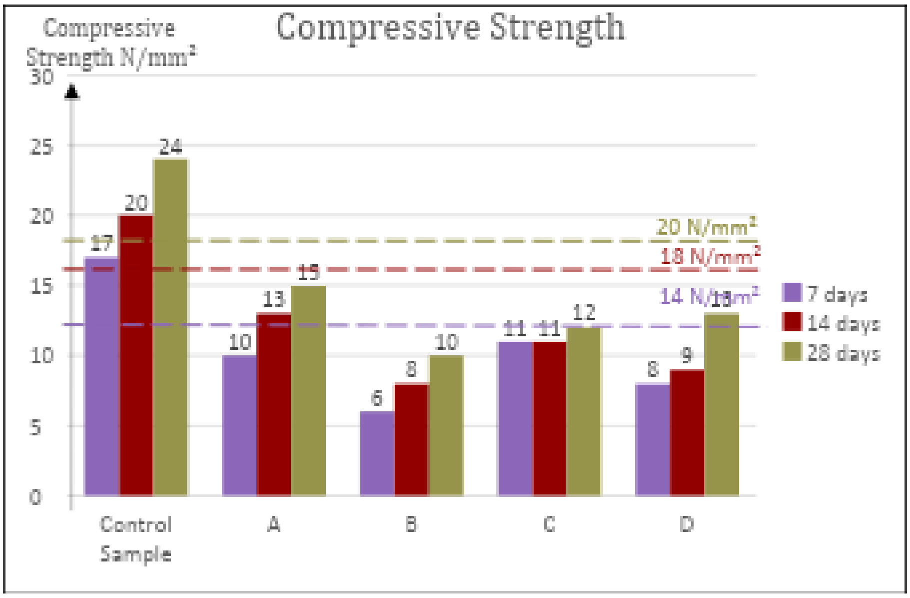

Figure 8. Comparison of samples' compressive strength

4. CONCLUSION

From this study, the replacement of 10% of rice husk ash in cement and 5% of coconut shell in coarse aggregate of sample A shows good workability among all the others sample. Concrete workability, quantified by concrete slump, is an important property of a concrete mixture. Concrete slump is generally known to affect the consistency, flowability, pumpability, compactibility, and harshness of a concrete mix. Hence, an accurate prediction of this property is a practical need of construction engineers (Pham2, 2016). In addition, we saw that our control sample and sample A concrete slump is collapse. This type of concrete is best used for leancon purposes and casting slabs that have a low load. Meanwhile for our sample B, C and D is a true slump concrete. Since this research is using G20 concrete, this type of concrete constantly used in pre-cast panels like scupper drain concrete cover and etc. However, in this research, we can see that sample D have the lowest water absorption compared to the other samples. As the compressive strength decreases with the presence of water in the pores, a better understanding of the material behavior at high water content range is critical to ensure safety (Antonin Fabbri1, 2019). In the compressive strength test shown above, control sample and sample A has the most highest concrete strength. However, only control sample has achieved the concrete strength of 20N/mm^2. Sample A almost achieved concrete strength of 20N/mm^2 which is 15N/mm^2. This concrete can also be use to make a low load slabs with small area. 10% of rice husk ash and 5% of coconut shell as partial replacement material in concrete can be use in construction industry to cut the financial cost and also will help to save the environment excessive waste disposal issue. Rice husk and coconut shell are produced in large quantities that need to be burned in an open air to disposed it. Due to high quantities of silica in the rice husk and high activated carbon in the coconut shell, it will cause some disposal problems in order to dispose it (Mardiha Mokhtar*, 2022).

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