Evaluation of Mechanical Characteristics of Rice-Husk-Bricks

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ABSTRACT

Construction activities and materials extraction are major contributors to environmental pollution. To address this issue, the utilization of bio-based materials presents a promising sustainable alternative for the construction industry. Bio-based materials encompass a broad category of organic matter that can be either synthesized or naturally derived. One such noteworthy bio-based material is rice husk, which exhibits pozzolanic properties. Abundantly available as an agricultural waste product, rice husk holds potential as a viable substitute in construction processes. This study is dedicated to investigating the feasibility of replacing fine aggregates, traditionally comprised of sand, in cement blocks with untreated rice husk on a volumetric basis. In contrast to being used merely as an additive, this research delves into the possibility of substantially replacing sand with a higher proportion of rice husk, ranging from 20% to 80%, in the composition of cement blocks. The findings of this study reveal that up to 40% of the sand content in cement blocks can be effectively replaced with untreated rice husk while still meeting the requisite strength standards for non-load bearing blocks. Moreover, this study demonstrates an additional advantage in terms of weight reduction. Substituting sand with rice husk leads to a remarkable 30% reduction in the overall weight of the blocks. These results underscore the potential benefits of integrating rice husk into construction materials as an environmentally friendly and weight-efficient alternative.

KEYWORDS: *bio-based materials, rice husk, fine aggregate, SLS 855, BS EN 771*

1 INTRODUCTION

Construction sector holds a significant position in Sri Lanka's economy, being a major contributor. According to Karunaratne (2021), approximately 9% of the country's gross domestic product (GDP) in 2018 originated from construction-related activities. These activities, however, come with environmental implications. The production of construction materials and the upkeep of buildings collectively account for roughly 28% of the global carbon dioxide (CO2) emissions (Global Alliance for Buildings and Construction & United Nations Environment Programme, 2018). A report from the UK Green Building Council highlights an alarming yearly consumption of over 400 million tons of construction materials (The Environmental Impact of Construction - ProHort, 2020). Construction industry heavily relies on primary resources like sand, timber, and cement, which are mainly obtained through virgin sources. In Sri Lanka, the demand for sand in construction reaches around 40 million cubic meters, significantly surpassing the sustainable supply threshold of 10 million cubic meters. This scenario presents a complex challenge to the construction sector, as it not only strains legal and sustainable sand mining practices but also poses a potential threat to the environment.

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Figure 1 (a) Timbercrete block (Reproduced from timbercrete.com.au, 2023)

Figure 1(b) Hempcrete blocks (Reproduced from H.G Matthews Limited, 2023)

Preserving the environment and mitigating pollution are pivotal factors in ensuring the ongoing sustenance of life. Our commitment to the environment is essential for upholding the long-term viability of materials and resources. Given this context, there has been a growing emphasis on the utilization of bio-wastes as viable construction materials. Coir, hemp, and corn starch (Abdullah & Lee, 2017; Arnaud & Gourlay, 2012; Asasutjarit et al., 2007; Caruso et al., 2021; Chabannes et al., 2014; Geetha & Selvakumar, 2019; Hettiarachchi & Thamarajah, 2020; Jeyaraj & Tharmarajah, 2019) represent some commonly explored bio-wastes that offer potential alternatives to traditional construction materials. Across numerous developed nations, a tangible trend of using sawdust-based masonry blocks (timbercrete.com.au, 2023) and hemp-derived materials (H.G Matthews Limited, 2023) for both residential and commercial construction purposes (Figure 1a,b) can be observed.
Similarly, rice husks present a notable avenue for integration into masonry blocks, either partially or entirely substituting sand. Rice husks constitute the outer layer of the rice grain, separated during the cleansing process in rice mills. In 2017, Sri Lanka harvested approximately 5.15 million metric tons (MT) of paddy (Department of Census and Statistics, 2018), with rice husks accounting for around 20% of the paddy's weight (Singh, 2018). Regrettably, a significant portion of the annual 1 million MT of rice husks generated, becomes discarded waste in landfills. The potential of rice husks extends beyond waste, as they can be employed in incineration for heat and thermal energy generation, and even for electricity production due to their elevated calorific value (Zou & Yang, 2019).
Rice husks contain approximately 20% amorphous silica (Mansaray & Ghaly, 1997; Nair et al., 2008; Yogananda & Jagadish, 1988), with pozzolanic properties. This characteristic has led to numerous experimental investigations (Ganesan et al., 2008; Hossain et al., 2018; Makul, 2019; Rodríguez De Sensale, 2006; Saraswathy & Song, 2007; Tharshika et al., 2019) evaluating the potential of rice husk ash as an alternative binder, partially replacing cement. However, studies exploring the direct application of raw rice husk in civil engineering contexts remain scarce. A majority of these studies are confined to areas such as lightweight concrete and the creation of wall panels (Abdullah & Lee, 2017; Chabannes et al., 2014; Jauberthie et al., 2003; Liu et al., 2021; Obilade, 2014; Tamba et al., 2000). A preliminary exploration by Jeyaraj and Tharmarajah (2019) revealed that incorporating rice husk up to 23% of a masonry block's volume does not compromise its strength.

Ordinarily, cement blocks used in construction contain a mixture of cement and sand at a 1:6 ratio to achieve requisite strength. Consequently, approximately 85% of the mixture's volume comprises sand. If rice husk were to replace sand entirely without compromising strength, a considerable quantity of sand used in masonry block manufacturing could be conserved.

This study focuses on utilizing untreated rice husk as a substitute for fine aggregate (sand) in the production of rice husk blocks, with cement serving as the binding agent. Sand was gradually replaced with rice husk at levels of 20%, 40%, 60%, and 80% by volume. The compressive strength of these diverse blocks was assessed and compared to gauge their performance.

2 EXPERIMENTAL INVESTIGATION

The primary constituents of the block encompass cement, sand, unprocessed rice husk sourced from rice mills, and water. Four distinct blends were subjected to testing, adopting mix ratios of 1:6 for cement to aggregate, while varying the proportions of rice husk to replace sand. The substitutions were made at rates of 20%, 60%, 70%, and 80% of rice husk based on the total volume of the fine aggregate (refer to Figure 2).

Figure 2: The composition of the block

2.1 Materials

2.1.1 Cement

Commercially available ordinary Portland cement was used for the study. Typical chemical composition of the cement is given in Table 1.

Table 1: Chemical composition of ordinary Portland cement

	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	Na2O	SO3	LOI	TiO2	Free CaO
Cement	19.70 %	5.18%	2.76%	65.13 %	0.69 %	0.99 %	0.17 %	2.85 %	1.51 %	-	1.31%

2.1.2 Rice husk

Rice Husk (RH) is the leafy outer covering of the seed, about 20-25% of the total weight. RH reflects a more spherical shape with a width between 1-4 mm and the maximum length is to be about 0.01m. Natural RH contains 75% organic compound and 25% of inorganic compound. Out of the organic compound percentage 45-60% Cellulose/Hemi-cellulose and 25-30% Lignin according to past literature. RH contains minor rate of open interior porosity. RH is considered by very minor pores under 0.1 μm and nearly no pores were detected for RH from 1μm to 30μm. Typical composition of the rice husk is given in Table 2.

Table 2: Composition of the rice husk

	Cellulose	Hemicelluloses	Lignin	Extractives	Silica ash
Rice Husk	25-35%	18-21%	26-31%	2-5%	15-25%

Cement blocks were prepared using cement block casting machine to the size 350 mm × 180 mm × 100 mm. After 24 hours, they were removed from the moulds and allowed for curing under wet conditions for 28 days. After curing, the blocks were tested for density and compressive strength as part of this preliminary investigation. Four different compositions were used for the experiments as shown in Table 3.

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Table 3: Ratio of cement: sand: rice husk by volume

Sample	Cement	Sand	Rice Husk
R1	1	4.8	1.2
R2	1	3.6	2.4
R3	1	2.4	3.6
R4	1	1.2	4.8

The content of the rice husk was increased while reducing the sand content by replacing sand with the rice husk. The water cement ratio was 0.3 for R1 samples and was increased to 0.5 as rice husk content increased. For each composition, 9 cellular-block samples were prepared and tested for 7-day, 14-day and 28-day strength.

Similarly, the density of the bricks was obtained by measuring the weight and volume of the brick on three samples of each composition.

3 RESULTS

3.1 Compressive strength

Figure 3 illustrates the compressive strength of the masonry blocks throughout the 7-day, 14-day, and 28-day curing periods. Notably, a linear upsurge in strength is observed in blocks containing 20% added rice husk. However, a distinct strength gain profile is evident in blocks incorporating 40%, 60%, and 80% rice husk fibers. Up to the 14-day mark, the rate of strength gain remains comparable across all four compositions, with a subsequent decline in this rate observed beyond the 14-day curing period. Despite uniform cement content across all compositions, the deceleration in strength gain can be attributed to various factors linked to rice husk and the availability of water for the hydration process.

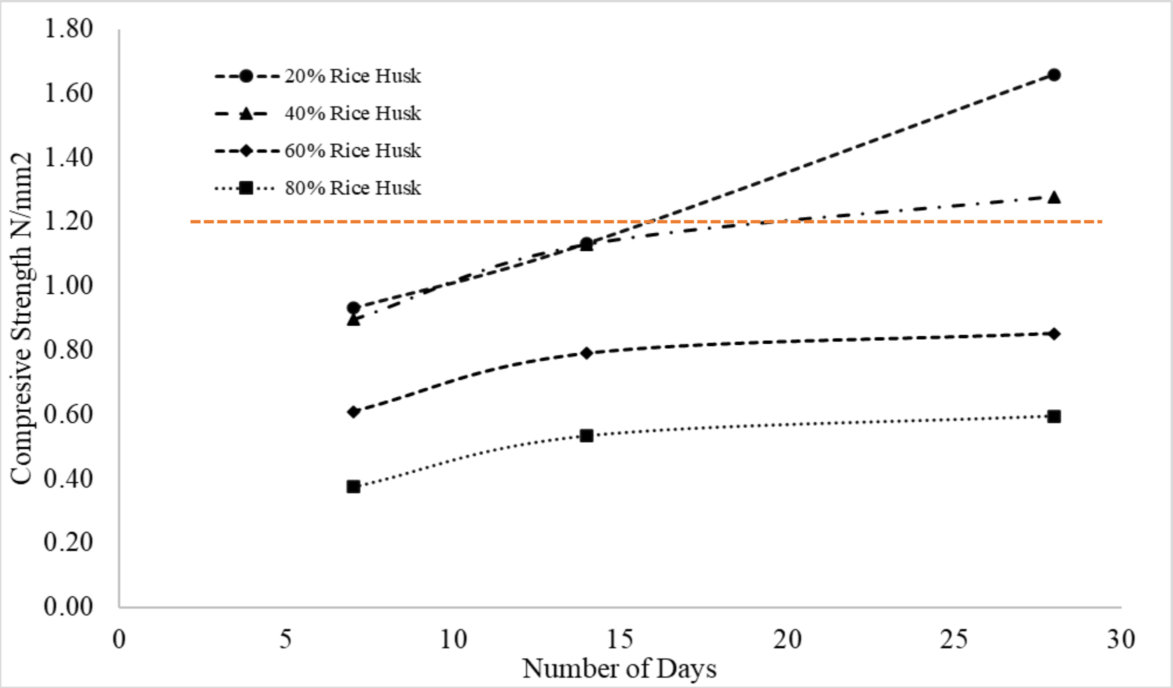

Figure 3: Strength increment with the number of days of curing

Among the tested compositions, the blocks with 40% rice-husk demonstrate sufficient strength as per SLS 855 (SLS 855, 1989). SLS 855 recommends a minimum of 1.2 N/mm^2 for masonry blocks. Although other blocks with higher rice-husk content do not demonstrate sufficient strength after 28 days, there is a possibility for enhancement of strength with longer curing periods. This requires further investigation.

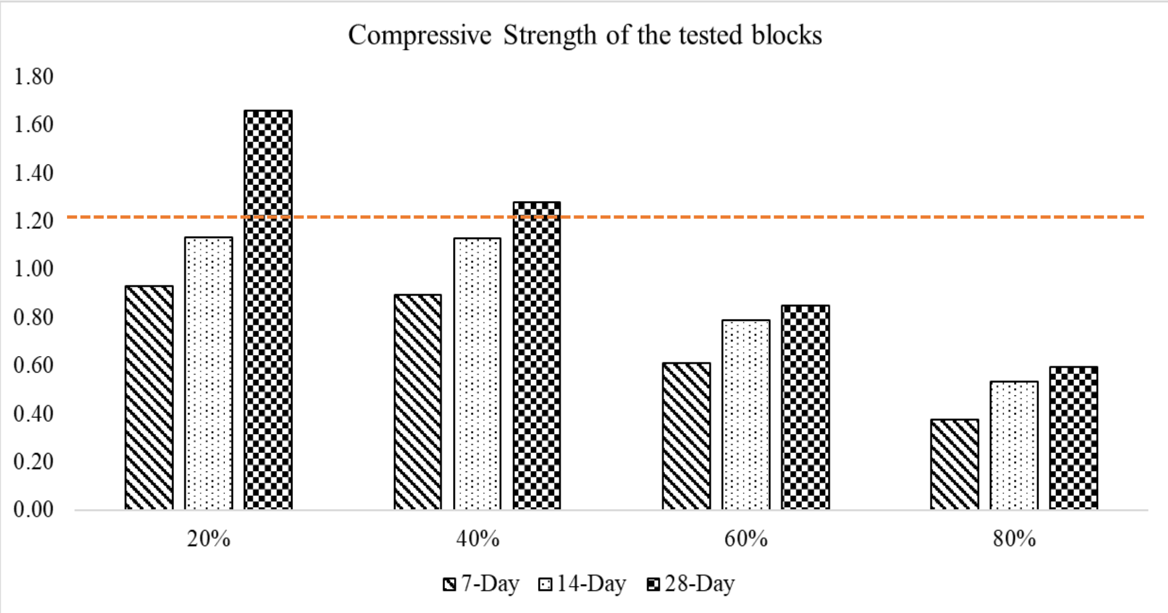

Figure 4: Compressive strength of all the tested blocks

3.2 Density

The wet density of the test blocks was measured by calculating the weight of the specimens. The change in density with time is shown in Figure 5. It can be seen from Figure 5 that the density of all the specimens were lesser than the average density of 2100 kg/m^3 recorded for commercially available cement blocks.

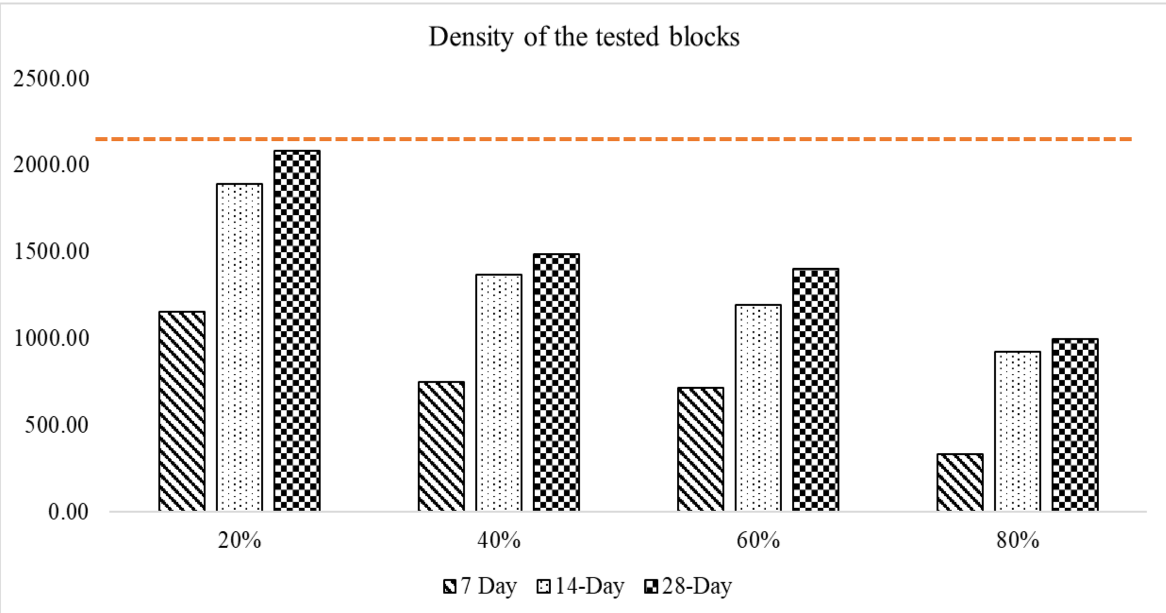

Figure 5: Density of the masonry blocks

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It can also be seen that the density of the blocks increased with the number of days of curing. However, the change in density between 14-day and 28-day was lesser in all the samples. Compared to the control value of 2100 kg/m^3 the blocks with 40% rice husk have 30% lesser density while satisfying the strength required for masonry blocks.

4 DISCUSSION

Lightweight cement blocks are commonly manufactured using autoclaved aerated concrete (AAC) technology. Existing literature reveals that AAC blocks exhibit compressive strengths ranging from 2.3 N/mm^2 to 7.0 N/mm^2 across diverse compositions, while densities span from 425 kg/m^3 to 700 kg/m^3 (Pachideh & Gholhaki, 2019; Yang & Lee, 2015). Commercial lightweight cement blocks available in the market showcase compressive strengths surpassing 2.5 N/mm^2, with dry densities ranging between 700 kg/m^3 and 800 kg/m^3 (Tokyo Cement Group, 2022). The production of AAC blocks involves intricate procedures and specialized equipment to achieve such lightness. Interestingly, the inclusion of rice husk indirectly amplifies block porosity, resulting in density reduction.

Various design codes prescribe distinct strength criteria for masonry blocks. The Australian code (AS/NZ 4455, 2008) stipulates a minimum of 3.0 N/mm^2 for solid or vertically cored non-load bearing units. Correspondingly, the Eurocode (BS EN 771, 2016) mandates a minimum strength of 1.5 N/mm^2 for load bearing AAC blocks or other lightweight variants. Sri Lanka's standards (SLS 855, 1989) advocate for 1.2 N/mm^2 in non-load bearing cement blocks. A comparative analysis of these code requisites reveals that units replacing 20% of sand with rice husk meet the strength specifications of both SLS 855 and BS EN 771 recommendations. Both 20% and 40% rice husk-added units satisfy the SLS requirement for non-load bearing masonry blocks.

When contrasted with conventional commercially available cement blocks, both 20% rice husk-added and 40% rice husk-added units exhibit lower density, attributable to the incorporation of rice husk. On a broader scale, it becomes apparent that substituting sand with rice husk in masonry units at a volume of 40% of the total sand demonstrates potential as a feasible option.

5 CONCLUSION

This study focused on evaluating compressive strength and wet density of cement blocks produced using cement, fine aggregate and rice husk. Rice husk replaced the sand on volumetric basis up-to 80% to evaluate the compressive strength and wet density. The following conclusions were obtained from the study.

1. Both 20% and 40% rice-husk added cement blocks demonstrated a similar strength up-to 14 days. However, the strength of 40% sand replaced with rice-husk specimen achieved a lower strength than 20% rice-husk added specimen at 28-day.
2. Compressive strength of 20% and 40% rice husk added samples satisfy the SLS 855 strength requirement for non-load bearing cement blocks. It can be noticed that 20% rice-husk added samples satisfy both BS EN 771:4 and SLS 855 requirements.
3. It can be seen from Figure 5 that the wet density decreases with the increase of rice husk percentage. The densities increased with the number of days of curing. This can be attributed to the addition of raw rice husk and its absorption of water.
4. The study indicates the possibility of using rice-husk to replace sand in cement blocks up-to 40% of the volume. Further studies can be carried out to enhance the strength and durability characteristics.

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