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Incorporation of Wood ash and waste glass powder in enhancing concrete block performance

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ABSTRACT

This study explores the feasibility of utilizing wood ash and waste glass powder as sustainable alternatives in the production of concrete blocks, aiming to address environmental concerns and enhance durability in construction. Cement blocks with varying percentages of wood ash (ranging from 10% to 25%) and a consistent 10% substitution of fine aggregates with waste glass powder were investigated. Six sample sets, including standard blocks, underwent testing for compressive strength, water absorption, and heat release at 7, 14, and 21 days of curing. Results demonstrate that a 15% wood ash replacement significantly improves compressive strength and reduces water absorption after 21 days. Furthermore, the combination of 15% wood ash with 10% glass powder replacement yields cement blocks with superior properties. The integration of wood ash with waste glass powder further enhances the performance of concrete blocks. By incorporating these materials into concrete block production, significant steps can be made towards reducing environmental impact and promoting sustainability within the construction industry.

Key Words: wood ash, waste glass powder, eco-friendly, concrete blocks, compressive strength

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INTRODUCTION

The concrete blocks are widely used around the world including Sri Lanka for the construction of wall and buildings. Due to the low affordability of cement, and its adverse environmental effects the greener technology innovation is urged to use in developing construction material. The usage of supplementary materials to balance the portion of cement blocks is a beneficial for the field of construction. Lightweight materials have gained attention for their ease of use (Gunasekara et al., 2011). There are some crucial physical parameters such as strength, durability and workability considered in the preparation of concrete blocks in accordance with Portland cement properties. Many other studies revealed in cement manufacturing as the supplementary materials. Wood ash, rice husk and coconut shells are partially replaced of the cement (Antiohos et al., 2014; Udoeyo et al., 2006). It has proved that wood ash can be used to replace cement material partially in concrete production and it provides self-compact in construction field (Elinwa and Mahmood, 2002; Elinwa *et al.* 2008; Abdullahi, 2006). Particulate matter in wood fly ash are very irregular shape and higher number of pores in the surface (Wang*et al.* 2008). Physicochemical and structural properties of wood ash can affect the pozzolanic and hydraulic reactivity. The materials such as silica fume and fly ash (Islam et al., 2011; Imbabi et al.,2012) are used to improve the strength and workability of concrete blocks (Detwiler et al., 1996). Similarly, waste glass powder, a solution for colored glass waste, improves material properties (Du, & Tan 2014, Taha and Nounu, 2009). Even though, glass powder has not achieved at the commercialization level (Rashed, 2014). Glass contains the chemical components as supplementary cement materials (Ryou et al., 2006; Nassarand Soroushian, 2012). This research explores wood ash and waste glass powder to create eco-friendly concrete block material, aiming to reduce environmental impact while maintaining quality construction.

METHODOLOGY

Preparation of concrete blocks

Concrete blocks were prepared according to ASTM C109/C109M standards using wooden molds and colored glass powder. Wood ash from household kitchen and waste colored glass were collected as main raw materials. The kitchen ash underwent sieving through an 850-micrometer sieve to ensure consistent particle size, while colored glass was crushed into a fine powder and sieved through a 1.18 mm sieve.

Table 1: Concrete preparation design

Sample	Cement (%)	Ash (%)	Sand (%)	Glass powder (%)
1 (Control)	100	0.00	100	0.00
2 (Control)	100	0.00	90	10
3	90	10	90	10
4	85	15	90	10

5	80	20	90	10
6	75	25	90	10

A total of six concrete samples were prepared, with the first two serving as control samples.A 1:6 cement-to-sand ratio is used traditionally for the preparation of concrete blocks. Sample 1 followed the preparation method, while control sample 2 included 10% waste glass powder replacing sand for the subsequent samples. Ash replacement for cement and glass powder replacement for sand were indicated in the Table 1 as the percentage. A constant 10% of sand was replaced with waste glass powder, while the percentage of wood ash replacement for cement varied from 10% to 25%. Materials were mixed, then water was added, and thorough mixing for 10 minutes ensured homogeneity. The mixture was poured into molds and allowed to set for an hour. After an initial 24-hour room temperature cure, blocks were submerged in water until testing at 7, 14, and 21 days. Compressive strength, water absorption, and heat release tests were conducted to assess mechanical properties and performance, with results compared to control samples to evaluate the effectiveness of wood ash and waste glass powder in enhancing sustainability and mechanical strength.

Physical properties of concrete block

Compression strength

The prepared concrete blocks were dried for 24 hours after taking out from the water bath. The concrete block's compressive strength was investigated using a compressive strength testing machine at different curing days of 7, 14 and 21 days for each blocks. The mean valuewas calculated.

Water absorption

Water absorption testing was conducted for six prepared blocks, including the control samples (1 and 2). The selected sample blocks were kept in oven for 24 hours at 103±2°C until their weight became constant, and their dry weights (w_1) were taken. Next, the same blocks were dipped in water bath for 24 hours, and their wet weights (w_2) were taken. The water absorption percentage of the block was calculated according to the below mentioned equation:

$$\text{Water Absorption } \% = \frac{(w_2 - w_1)}{w_1} \times 100 \quad (1)$$

Heat Release Test

The heat releasing test was conducted using an infrared (IR) thermometer. A sample block from each set was kept in an oven at 103±2°C for a duration of 24 hours. Within the first hour of removal from the oven, the surface temperature of the sample block was measured at 5-minute intervals using the IR thermometer. By plotting the surface temperature against time, the rate of heat release was computed.

RESULTS AND DISCUSSION

Compression strength

The compressive strengths of concrete blocks were evaluated at various curing times, as presented in Table 2. The data illustrates a notable increase in compressive strength values for all samples with the progression of curing time (Figure 1). After curing of 21 days, the highest compressive strength is achieved when utilizing 15% wood ash and replacement in the cement and 10 % of sand was replaced by waste glass powder, displayed notably higher compressive strength compared to Sample 1, indicating the positive influence of glass powder incorporation.

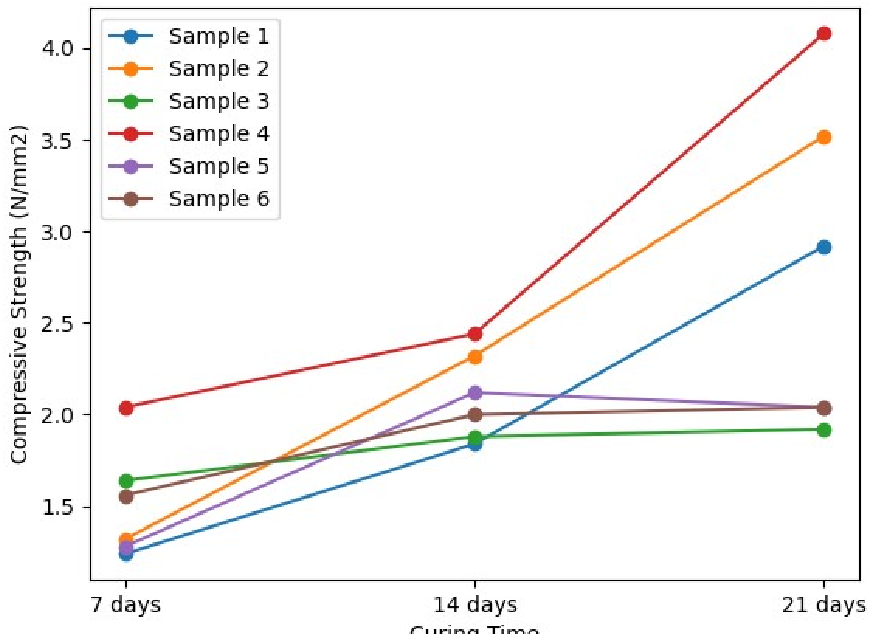

Figure 1: Compression Strength versus Curing Time

Glass incorporated into concrete can exhibit two distinct behaviors, the alkaline-silica reaction (ASR) and the pozzolanic reaction, each affecting concrete differently (Fengyan et al., 2006). ASR can lead to internal stresses, cracks, and structural damage, whereas the pozzolanicreaction, as observed in our study by replacing 10% of the sand with waste glass powder, enhances mechanical properties like compressive strength and durability.

For wood ash replacement, Sample 4, with a 15% ash replacement, demonstrated the most substantial rise in compressive strength compared to the control samples (Sample 1 and 2). This improvement was attributed to the pozzolanic reaction of wood ash, driven by its potassium, magnesium, and calcium content (Subramaniam et al., 2015).

The extensive surface area of wood ash particles facilitated a more extensive pozzolanic reaction, resulting in additional calcium silica hydrate gel formation. This not only improved the binding within the concrete matrix but also contributed to enhanced compressive strength, emphasizing wood ash as a sustainable cement replacement. Moreover, wood ash's presence positively influenced the concrete's pH, further enhancing its pozzolanic activity and, consequently, chemical resistance and durability. It's important to note that the compressive strength results after 21 days varied with different ash replacement percentages, suggesting an optimal replacement level to balance the benefits of the pozzolanic reaction (Fengyan et al., 2006).

Water Absorption Test

The water absorption capability of concrete blocks in 7, 14 and 21 days are given in Table 2. The results indicated that the water absorption ability of all blocks except sample 6 are much less compared to control blocks after the curing period of 21 days. The lowest absorption ability was found to be in sample 4.

Table 2: Water absorption percentage over different curing time

Sample	Water Absorption Percentage (%)		
	7 Days	**14 Days**	**21 Days**
1 (Control)	9.36	7.68	8.32
2	7.1	6.07	7.29
3	6.45	6.49	6.17
4	7.42	6.16	6.1
5	6.11	7.35	7.24
6	7.91	9.5	9.18

Heat Release Test

The findings regarding the heat release rate with varying percentages of included materials at different curing days are presented in Figure 2. Notably, on the 21stday of curing, sample 3, 4, 5, and 6 exhibited lower heat release rates when compared to the control samples. Among these, sample 5 demonstrates the lowest heat release rate after 21 days, while sample 4 displays the second lowest heat release rate during the same period.

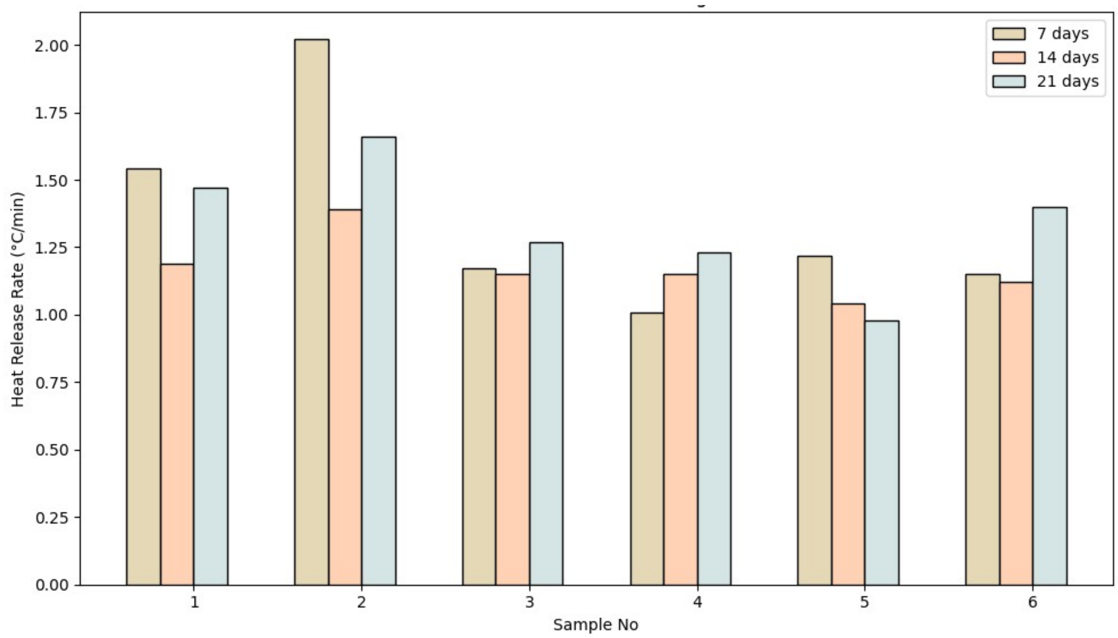

Figure 2: Heat release rate of samples over curing time

Concrete's water absorption characteristics significantly impact its durability(Ithuralde, 1992). In comparison to the control samples, all concrete samples containing wood ash demonstrated relatively lower heat release rates, contributing to enhanced thermal comfort in various settings

Comparison of wood ash and glass powder incorporated concrete

Wood ash (WA) and glass powder (GP) incorporated in concrete blocks is a commercially beneficial in the construction industry. It is used as filler which enhances cement properties and increase the economic benefits of concrete.

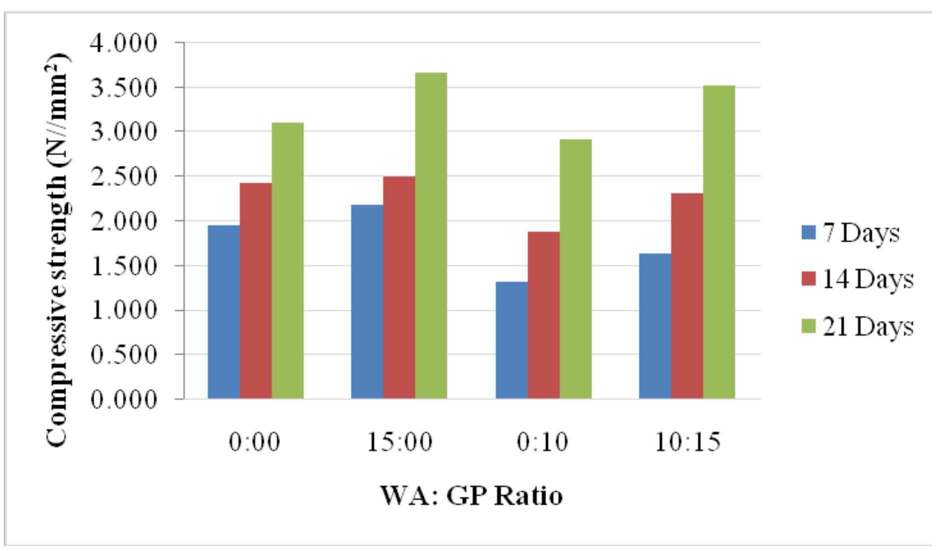

Figure 3: Compressive strength of samples over curing time

Table 3 presents the compressive strengths of cement with the partial replacement of waste glass powder and wood ash after 21 days of curing. According to the statistical analysis (Turkey HSD, $p < 0.05$) there was no significant different in compressive strengths between the samples with 15% wood ash addition and those with a 10:15 ratio of glass powder to wood ash addition. These compositions exhibited high results, ranging from 3.58 to 3.69 N/mm2, compared to the control cement. These values meet the minimum requirement of 2.8 N/mm2 specified in BS 6073: Part 2: 1981. Previous studies have also demonstrated similar trends, where cement with 10% glass powder showed the highest compressive strength (Rashed, 2014), while contrasting findings indicated that 20% addition of glass powder yielded higher compressive strength at 90 days (Sadiqul Islam et al., 2017).

Table 3: Comparison of physical properties of 21 Days cured concrete

Concrete	Strength/ (N/mm$^{2)}$	Water absorption	Heat releasing rate
WA:GP	**21 Days**	**21 Days**	**21 Days**
00:00	3.073 ±0.052^{b}	8.365 ± 0.058^{d}	0.978 ± 0.011^{a}
15:00	3.689±0.056^{a}	9.662 ± 0.074^{c}	0.953 ± 0.011^{a}
00:10	2.923±0.005^{c}	7.293± 0.007^{b}	1.663±0.005^{b}
10:15	3.587±0.057^{a}	6.152± 0.052^{a}	0.977± 0.005^{a}

Means that do not share a letter are significantly different.

The concrete with a 15:10 ratio of wood ash to glass powder exhibited lower permeability, attributed to the effective filling of pores by both ash and glass powder. This feature is desirable as it minimizes concrete deterioration. Regarding heat release properties, significant differences were only observed in concrete incorporating 10% glass powder ($P < 0.05$). Concrete containing 15% wood ash and a 15:10 ratio of wood ash to glass powder displayed a similar and gradual heat release pattern. This characteristic is crucial for maintaining thermal comfort.

CONCLUSION

The inclusion of waste glass powder and wood ash in concrete block preparation has yielded favourable outcomes on mechanical properties. Specifically, the combination of 15% wood ash and 10% glass powder replacement has led to cement blocks exhibiting increased compressive strength and reduced water absorption capacity following 21 days of curing. Moreover, the incorporation of wood ash alongside glass waste powder has contributed to moderating the rate of heat release, despite the inherent tendency of glass material to release heat rapidly. Collectively, these findings underscore the potential of both waste glass powder and wood ash as sustainable alternatives for enhancing the properties of cement-based materials in various construction applications.

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