Journal of Agricultural Science and Engineering
Vol. 6, No. 4, 2021, pp. 43-47
http://www.aiscience.org/journal/jase
ISSN: 2381-6821 (Print); ISSN: 2381-6848 (Online)

The Effect of Wood Ash Blending on the Compressive Strength of Concrete Blocks

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Abstract

The increasing cost of concrete and its by-products such as concrete blocks has led to the increased efforts to find alternative bonding or cementing materials to Portland cement, at times even at partial replacement level. These include industrial by-products and agricultural wastes such as wood ash (WA). An experiment was conducted to determine the effect of the compressive strength of WA blended concrete blocks and the optimum proportion of the partial replacement by preparing a mix of 1:5 (cement: sand). The experiment had five treatments, which were the concrete block cement mix proportions of WA (0%, 10%, 15%, 20% and 25%) including the control (0%). The mix design was manipulated by blending the cement fraction with wood ash at proportions of 0%, 10%, 15%, 20% and 25%. A water/cement ratio of 0.5 was used throughout the experiment. The treatments were replicated three times and cured for 14 days. The wood ash was obtained from the slow burning of fire wood from wattle trees (*Acacia pycnantha*), which was carefully sieved. The results reflected that 15% wood ash in the mix was the optimum proportion of cement replacement as it had a higher (3.56 N/mm^2) compressive strength. This was significantly different from the 2.44 N/mm^2 achieved by the control (0% wood ash blended concrete blocks). It was then concluded that an increase in the curing period of the wood ash blended concrete blocks had a positive impact in their compressive strength, since there was an increase in compressive strength with an increase in the curing period.

Keywords

Wood Ash, Blending, Compressive Strength, Concrete Blocks

Received: November 25, 2020 / Accepted: December 8, 2020 / Published online: January 11, 2021

1. Introduction

Concrete is a composite material made up of aggregate bonded together by liquid cement which hardens over time [26, 27]. The major components of concrete are cement, water, and aggregates with aggregates taking about 50 to 60% of the total volume, depending on the mix proportion. The amount of concrete used worldwide has increased substantially over the years. However, concrete's use in the modern world is exceeded only by that of naturally occurring water before erecting any structure [24, 23, 8, 27]. This property can be affected by many factors including water to cement ratio, degree of compaction, aggregate size and shape to name a few.

In concrete, cement can be partially replaced by different supplementary cementitious materials [5]. However, in recent years pozzolonic materials, glass powder and silica fume are used in concrete as a partial cement replacement to improve its strength [7]. Cement is increasingly being chosen for use by most construction firms and developing homesteads as if there are no other alternatives to consider. The drive behind finding alternative binder or cement replacement materials is a response to the increasing costs and scarcity of cement that result from high cement demand that has led to the discovery

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of the unrealized abilities of using industrial by-products and agricultural wastes as cementitious materials such as wood ash.

Several studies have investigated the suitability of wood ash as a supplementary cementing material in the production of ordinary and self-compacting concretes. An optimum dosage of wood ash of 15% in the replacement of cement (by weight) for the production of concrete having a sufficiently high compressive strength for the casting of blocks [20]. An optimum replacement rate of 20% was identified and showed that the water requirement increased as the wood ash content increased [1]. On the other hand the mechanical strength (compression, tensile, and flexural) of concrete incorporating wood ash was characterised [3].

Wood ash concrete blocks have been widely used in many developing countries such as Sri Lanka over a considerable period of time [20]. Perhaps the use can be attributed to the abundance of the material in such environments. Wood ash (WA) is produced by the combustion of wood in domestic wood stoves or in industrial power generation plants [22]. Surprisingly, Eswatini which is also a developing country, has not yet engaged in the production or use of wood ash concrete blocks. A huge proportion of the population still consider wood ash as a waste product that deserves to be deposited on landfills. Ammong the new materials introduced to the market are light-weight materials like wood ash, which are becoming much popular because of their ease of handling and low loads. Since wood ash is an admixture, therefore a pozzolana [18], it is greatly rich in silica and alumina, which in itself has no cementitious value until it chemically, reacts with calcium hydroxide at ordinary temperatures in the presence of water to form compounds possessing cementitious properties [14].

Wood ash is the solid residual after incineration of wood [15]. It varies considerably in quality, therefore there is no doubt that wood ash from different sources or species may lead to variability in quality of the wood ash concrete blocks. Wood ash is continuously produced daily, and this ensures its eternal availability and utilization. The utilization of wood ash as a partial substitution for cement is one of the promising methods to increase the strength and thermal insulation for cement blocks [18]. The physical properties of wood ash, including a lower specific gravity than that of general Portland cement, make it a favourable cement replacement material. The specific gravity of wood ash and Portland cement is 2.0 and 3.14, respectively [6].

Concrete or cement blocks are generally divided into two types; load-bearing concrete blocks and non-load-bearing concrete blocks. As a result, masonry units have different degrees of strength. In order for concrete blocks to be fit for use in construction, they need to meet the standard compressive strength requirements. Standard Specifications of compressive strength for Load-Bearing Concrete Masonry Units (ASTM C90) is the most frequently referenced standard [10]. This Standard Specification reveals that 1900 pounds per square inch (13.11 N/mm^2) is the recommended standard. The standard limit of compressive strength requirement for all concrete blocks for most construction is said to be lower than the aforementioned. The majority of acceptable concrete blocks fall in the range of 2.8 - 30 N/mm^2 [11].

Concrete is the most competent construction material that is commonly used in structural works, and development around the world [29]. Concrete is the most commonly used building material in the construction industry in Eswatini [20]. The generally accepted concrete construction practice is evaluated to be unsustainable because it uses huge amounts of water-adsorbent sand and cement. As a result, there is an escalation of power and energy demand in the cement industry operations. This escalation intensifies the need of strategies that will lower the amount of cement used without compromising the compressive strength of concrete products. The benefits of concrete blocks should therefore drive their use as masonry units during construction. Besides structural strength and aesthetic appeal, masonry blocks provide the added benefits of fire protection, structural durability, sound control, energy efficiency and cost effectiveness [2].

In Eswatini most of the concrete blocks used for building are moulded in block yards using concrete mixes designed using river sand and the rather costly Portland cement as the bonding agent [20]. The demand for concrete blocks in the ever increasing construction industry in the country is high, yet the bonding agent is expensive. As a result, efforts to reduce the cement without compromising the compressive strength of the concrete blocks could be welcomed in the building industry, hence this study. The objectives of the study were (a) to investigate the compressive strength of load bearing concrete blocks blended with wood ash and (b) to determine the water absorption proportion of the wood ash blended concrete blocks.

2. Methodology

The methodology utilized in the study comprised the following.

2.1. Research Design

The study was an experiment with five treatments (T), including the control and three replications. The treatments were; T_1 control; 0% wood ash: + local mix. i.e. 1 cement: 6 sand, T_2; 10% wood ash + 90% cement:sand, T_3; 15% wood ash + 85% cement: sand, T_4; 20% wood ash + 80% cement: sand, T_5; 25% wood ash + 75% cement: sand.

2.2. Fabrication of Blocks

Prior to concrete mixing, wood ash was sieved through a 75 mm sieve to get rid of the course unburned carbon that was present in the ash. A 90 microns sieve was then used to further get rid of smaller particles of unburned carbon. The sand was also sieved using a 10 mm test sieve to ensure uniformity of its aggregates and removal of twigs. The cement and sand mixture used was 1:5 as this is the standard used in the country. The blocks were manufactured by mixing wood ash as a partial replacement for cement in the proportions of 10%, 15%, 20% and 25%. The mixing of the aggregates took place on a clean concrete slab to avoid incorporation of debris or foreign material, which might have interfered with the results. The curing periods for each treatment were 7 days, 14 days and 21 days.

2.3. Measurements and Data Analysis

2.3.1. Compressive Strength Load Testing

The ProIkon Cube Press load testing machine was used to determine the compressive strength of wood ash blended concrete blocks. Equation 1 was used to calculate the compressive strength of the wood ash blended concrete blocks [21]. The analysis utilized student t-test at 95% confidence intervals.

$$\sigma_c = F/A \quad (1)$$

Where: σ_c - Compressive strength (N/mm^2)

F - Failure load (N)

A - Area of bed face (mm^2)

2.3.2. Water Absorption

The absorption of water was conducted for all the block sets including the control (T_1). Sample block sets assumed to be representative of the unit population were tested for water absorption. The sample blocks were oven dried for 24 hours at a temperature of 100 -105°C until the mass was constant and the dry weights (W_1) were measured. The same blocks were immersed in water for 24 hours and the wet weights (W_2) were measured. The proportion of water absorption of the wood ash blended concrete blocks was determined using equation 2.

$$\text{Water Absorption} = \frac{W_2 - W_1}{W_1} \text{ X } 100\% \quad (2)$$

Where: W_1-Oven dry weight.

W_2-Wet weight.

3. Results and Discussion

3.1. Compressive Strength

The results in Figure 1 reflected that the mean compressive strength of all the sample blocks generally decreased with an increase in the proportion of wood ash blending. The optimum mean compressive strength (3.56 N/mm^2) of the wood ash blended concrete blocks was achieved with 15% wood ash. The mean compressive strength for T_1, T_2, T_3, T_4 and T_5 was 2.44 N/mm^2, 2.23 N/mm^2 and 2.51 N/mm^2, 2.48 N/mm^2 and 1.20 N/mm^2 after 14 days of curing, respectively. The mean compressive strengths reflected a trend of a decline in mean compressive strength as the proportion of wood ash increased. The decrease of compressive strength with an increase in the proportion of ash in concrete has been documented by a number of researchers [29]; [19].

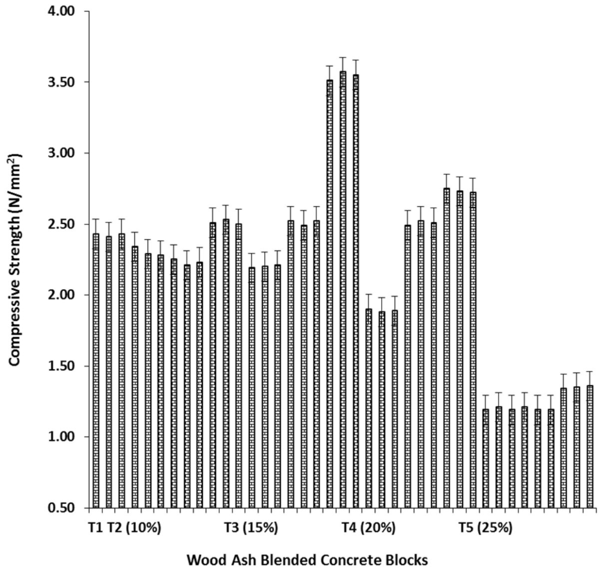

Figure 1. Compressive strength of wood ash blended concrete blocks after 21 days of curing.

The mean compressive strengths slightly or marginally increased after 21 days of curing to be 3.14 N/mm^2, 2.51 N/mm^2, 3.56 N/mm^2, 2.73 N/mm^2 and 2.73 N/mm^2, respectively (Figure 2). It is worth noting that even though there was a significant difference between the mean compressive strengths of the wood ash blended concrete blocks between treatments, it was not significantly different between the compressive strengths of blocks within treatments.

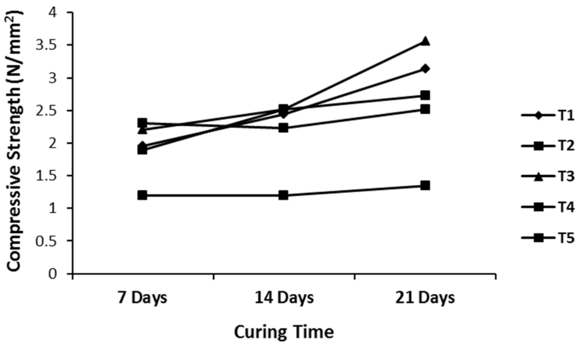

Figure 2. Compressive strength of wood ash blended concrete blocks with aging.

The high compressive strength of 3.56 N/mm^2 achieved at 15% wood ash blending could be attributed to the pozzolanic reaction of wood ash [19]. It is worthy of note that according to [13] the pH value increases with the hydratuion of cement. Whereas, the presence of potassium, magnesium and calcium in the wood ash increases, the pH value of hydrated cement mixture enhance the pozzolanic activity, encouraging the formation of hydrous silica, a compound that reacts with Ca^{2+} ions and produce insoluble compounds, which are secondary cementations products. The large surface area associated with the wood ash particles could also have an effect in enhancing the compressive strength of the wood blended concrete blocks as reported by [22].

3.2. Water Absorption

The water absorption by the wood ash blended concrete blocks was as reflected in Figure 3. The results indicated that the percentage water absorption of all the sampled wood ash blended concrete blocks, except T_5 was lower than the control (T_1) after 21 days of curing.

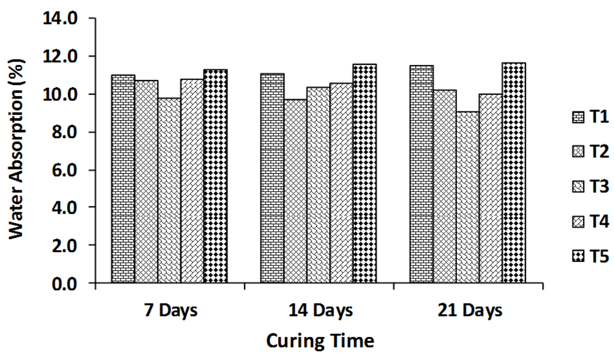

Figure 3. Water absorption over 21 days of curing.

The water absorption trend was inversely proportional to that of the compressive strength i.e. it got lower as the compressive strength and curing period increased except for T_5. It was 11.0%, 10.7%, 10.8% and 1.3% for T_1, T_2, T_3, T_4 and T_5 after 7 days of curing, respectively, while it was 11.1%, 9.7%, 10.4%, 10.6% and 11.6%, respectively after 14 days of curing. The trend was similar after 21 days. It is worth noting that the results reflected that there was an increase in water absorption with an increase in wood ash percentage or blending. This trend was consistent with the conclusions of [9]; [4]. This trend was also similar with the water absorption and curing time over 21 days.

4. Conclusions

Wood ash has the potential to partially replace cement in the concrete block manufacturing industry. This could be attributed to the results, which reflected that the optimum proportion that can replace cement was 15% resulting in concrete blocks with high compressive strength of 3.56 N/mm^2. There was a slight increase in compressive strength of all the wood ash blended concrete blocks with an increase in the curing period.

The proportion of water absorption by all the sampled wood ash blended concrete blocks except for T_5 (25% wood ash) was slightly lower than the control (T_1) after 21 days of curing. The water absorption of T_1, T_2, T_3, T_4 and T_5 after 7 days of curing was, 11.0%, 10.7%, 10.8% and 11.3%, respectively. This trend was similar after 21 days of curing.

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