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STRUCTURAL PERFORMANCES OF SOLID MASONRY BLOCKS MADE USING CRUSHED COCONUT SHELL AGGREGATES

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Abstract: Coconut shells are produced in significant quantities in tropical countries including Sri Lanka. Utilization of coconut shell as building material will be an important step to improve sustainability. Objective of this study is to utilize Crushed Coconut Shell (CCS) in the manufacturing of masonry blocks as for the replacement of coarse aggregate (i.e., chips) and investigate strength properties of the manufactured blocks. Solid masonry blocks having the sizes of 360mm×100mm×170mm were cast with the mix proportion of 1:5 Cement:Sand. Coconut shells were crushed, sieved and added to the mixture in different proportions to determine its optimum percentage of utilization. The blocks were tested for 7, 14 and 28 day compressive strength. Compressive strength of crushed coconut shell based sand cement blocks with 20%, 25%, 30% (volume basis) of CCS have been examined, so as to investigate whether crushed coconut shell can be used as fully replacement of coarse aggregates and its optimum percentage. Water absorption capacity was investigated for this CCS based masonry blocks and was compared with a conventional cement sand block with coarse aggregate.
The optimum percentage of utilization of CCS was identified by considering maximum compressive strength that was obtained using laboratory experiments. It was found that the maximum compressive strength of CCS based cement sand block is achieved at 25% replacement level. The water absorption capacity was below 12%, which is the requirement of maximum percentage of water absorption in masonry blocks.
Keywords: Agricultural waste, compressive strength, water absorption.

1. Introduction

In tropical countries, although the coconut shell has different usage, considerable amount of them remains in the environment as waste. Thus coconut shells are considered as one of the most common agricultural waste in most of the tropical countries. In building construction, different types of bricks and blocks are used. Structural performances are the most important factors, when using these masonry blocks in constructing walls. However, due to the high cost of materials, the blocks available in the market have not shown proper structural performance. Therefore, it is very important to use innovative materials to reduce cost at least in masonry blocks. Also light-weight materials are becoming popular nowadays [1] because of its easy handling and low dead loads. Light-weight masonry blocks with sufficient compressive strength will be a major benefit in building construction. Sand cement blocks are

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extensively used because the cement block is beneficial in fast assembling of blocks into wall. These blocks are mainly constructed with cement, fine aggregate and coarse aggregate with a standard composition.

Coconut shells are hard and may have important characteristics which are suitable for replacement of the coarse aggregate in the masonry blocks. Considering properties of coconut shell, it can be used in construction industry for manufacturing masonry blocks. In addition, there is a trend to produce lightweight and economically profitable materials in building construction field. For example, lightweight concrete has become more popular due to its low weight. By using crushed coconut shell in masonry blocks, a lightweight masonry block can be made due to low density of coconut shell compared to the coarse aggregate. Objective of this study is to investigate the structural performances of the solid masonry blocks made using crushed coconut shells.

2. Methodology

2.1 Materials

Coconut shell was crushed manually to produce Crushed Coconut Shell (CCS) (Figure 1) and sieve analysis was carried out as presented in previous studies [2-4] so as to determine the particle size distribution. Particle size of CCS 12.5mm passing and 9.5mm retained were selected for the study. This was necessary because the maximum particle size of crushed coconut shell was restricted 12mm and around it. Crushed coconut shell was fully replaced for the coarse aggregates (chips) with different percentages.

Figure 1-Crushed coconut shells

The specific gravity and water absorption test were carried out to find the properties of crushed coconut shell and coarse aggregates. For specific gravity test, an exact weight of a cleaned aggregate sample of 2 to 3kg was measured with the wired container provided for 20mm sieve size aggregates. The sample with the container was suspended under the suspension hanger of the balance and the weight, when it was suspended in air was measured

(W2). Then water container was placed on the pad of the specific gravity frame and container was raised by using the handle of the pulley system until the sample completely sank in the water medium and then the balance reading was recorded. This is the buoyant weight of the sample. The above procedure was repeated for crushed coconut shells (W1).

To carry out water absorption test the sample was soaked in water for 24 hours. The soaked aggregates were taken out from the water and wiped. The sample was allowed to surface dry and the weight was measured (W4). The same sample was placed inside an oven under the 100°C of temperature and the weight after cooling in air was measured (W3).The above procedure was repeated for crushed coconut shells. Specific gravity and water absorption were determined using following equations.

Bulk density = W3×*density of water*/ (W2-W1)---------- (1)

Specific gravity of aggregates = W3/ (W2-W1) ---------- (2)

The percentage of water absorption =100× (W4-W3)/ W3----------(3)

2.2 Manufacturing of blocks

Crushed coconut shell was selected in saturated surface dry condition because CCS has considerable amount of water absorption. The crushed coconut shell was kept in water in 24 hours and exposed till excess water evaporated and it achieved a saturated surface dry condition of CCS. Solid masonry block having the size of 360mm×100mm×170mm were cast with mix proportions of 1:5 cement-sand by using local block manufacturing machine. The water-cement ratio was controlled to 0.5.

Initially, 25% of CCS was used instead of coarse aggregate to investigate whether the CCS could be used in manufacturing of masonry blocks. Then characteristics of CCS based sand cement blocks having three different CCS contents (20%, 25% and 30%) have been examined so as to investigate optimum percentage of CCS replacement for the coarse aggregates. Control blocks were cast relevant to above replacement levels using coarse aggregates (Figure 2)

Figure 2-Sand cement blocks

2.3 Compressive strength

The compressive strength was investigated with the laboratory experiment by using concrete crushing machine. Three samples for each replacement level of CCS were tested at the age of 7, 14 and 28 day. The average compressive strength was determined by averaging the corresponding compressive strength values. The strength characteristics of CCS based sand cement blocks were compared with strength characteristics of control block: the 25% of the coarse aggregate (chips) content of cement sand block.

2.4 Water absorption test

Water absorption test was carried out to identify and specify the water absorption properties of CCS based sand cement block. The block manufactured with each CCS percentages were used to test the water absorption. Three samples for each percentages of CCS based sand cement blocks and 25% of coarse aggregate based control blocks were used for water absorption test. First the control blocks and CCS based sand cement blocks were immersed in water for a time period of 24 hours and the wet weight were measured. Then the same blocks were kept in an oven at a temperature of 100-105° C, for a time period of 24 hours and the dry weight of the blocks were measured. Water absorption of individual sample blocks was determined as in the water absorption test for crushed coconut shell and the average values were computed.

3. Results

3.1 Specific gravity and water absorption tests

The results of specific gravity and water absorption for coarse aggregates (chips) and crushed coconut shell are shown in Table 1. It can be seen that the water absorption of chips is less than that of the Crushed coconut shells. However, the specific gravity of chips is larger than that of the Crushed Coconut Shells.

Table 1-Specific gravity and water absorption ratio

Properties	Coarse aggregates (Chips)	Crushed coconut shell
Specific gravity	2.620	1.335
Water absorption	1.2%	29.11%

3.2 Sieve analysis test

The particle size distribution curve for crushed coconut shell is shown in Figure 3. About 40% of particles are in the range of 9.5 mm to 12.5 mm.

3.3 Compressive strength

The average compressive strength of 7, 14 and 28 day of crushed coconut shell based masonry blocks with different CCS content is shown in Table 2.

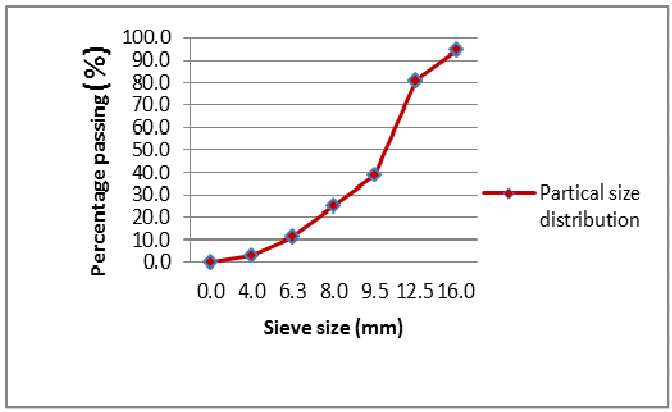

Figure 3-Particle size distribution of crushed coconut shell

Table 2-The Average Compressive Strength with Time for CCS Percentages

Time (Days)	Average compressive strength with CCS (N/mm^2)		
	20%	25%	30%
7	3.410	2.731	2.457
14	3.614	4.097	2.700
28	3.784	4.330	2.963

The optimum compressive strength was obtained at 25% CCS replacement level and it complies with the minimum standard value of 2.8 N/mm^2 according to Specifications for cement blocks Part1- requirements, Sri Lanka standards 855:part1:1989. [5]. Although compressive strength of CCS based masonry blocks have lower value when considering the compressive strength results of control samples they have fulfilled the minimum requirement value of 2.8 N/mm^2.

3.4 Water absorption

The average water absorption of blocks manufactured with different replacement level is shown in Table 3.Water absorption decreases with percentage of crushed coconut shell. However, all CCS percentages which were considered for the study have acceptable value of 12% for masonry blocks according to BS 5628: Part 1: 2005 [6]. The water absorption is also maximum at 25% CCS replacement level. However, there was no significant difference with

20% CCS replacement level. With the increasing of CCS percentage the water absorption decreases.

Table 3-Water Absorption of different percentages of CCS based masonry blocks

Percentage of CCS	Average Water absorption (%)
20%	11.11
25%	11.27
30%	9.23

4. Discussion

During the manufacturing process the crushed coconut shells in Saturated Surface Dry (SSD) condition was used. It seems that the compressive strength increased due to the proper bonding with the evaporation of the water. By allowing it to dry in normal air condition, after soaking the crushed coconut shells in water for 24 hours the saturated surface dry condition was obtained. When the dry crushed coconut shells mixed with cement sand mix, due to the low weight of the crushed coconut shells they were gathered around the topmost surface of the mixture so this mixing in SSD condition permits proper mixing of the compounds.

4.1 Structural performances

Compressive strength of the masonry blocks developed with 25% of Crushed Coconut Shell (CCS) was slightly lower than the masonry block with the coarse aggregate material (i.e., Chips), which was used as a control sample in the study. According to the specifications for cement blocks part-1 requirements (Sri Lanka standards 855:part1:1989), the minimum compressive strength should be greater than 2.8 N/mm^2. Compressive strength of the Crushed Coconut Shell base masonry blocks is greater than the specified value of 2.8 N/mm^2, implying that the coarse aggregate can be replaced with the crushed coconut shells with appreciable strength characteristics. At the age of 7, 14 and 28 days the masonry blocks gained compressive strength than the value specified in the standards [5].

The percentages of 20%, 25%, and 30% of masonry blocks were casted for crushed coconut shell based and chip based. According to the data collected with the samples it seemed that 25% of percentage showed the optimum value for the average compressive strength.

4.2 Water Absorption

After weighing of the masonry blocks, the water absorption test was carried out for the masonry blocks. The optimum value was observed for the masonry blocks with 25% percentage of crushed coconut shells. This value is much closer to the value in previous

literature as 12% implying that water absorption capacity of the developed block was satisfied the required value. But comparing the water absorption of crushed coconut shell the CCS based masonry blocks have lower value (Tables 1 and 3). This significant reduction in water absorption of CCS based masonry blocks compared to CCS may be due to use of saturated surface dry condition of CCS when manufacturing of sand cement blocks. There was a decrease in the water absorption with increasing the percentages of CCS in masonry blocks (Table 3), although this was not expected. It seemed that CCS did not absorb more water from the water medium, because the crushed coconut shells were used in saturated condition and water absorbed mainly by the mortar in the masonry block.

During initial days, water reduction of the masonry block was not significant and it might be caused due to the SSD condition that had been used. This was not engaged for the strength gaining of the block and after 7 days strength was gained by the hydration of the cement. The water cement ratio of 0.5 was used and maximum particle size was 12.5 mm that was obtained by sieve analysis. It was essential that maximum particle size should be 12.5mm due to two reasons. In a previous study a satisfactory level of compressive strength was gained for concrete by adding CCS with the maximum particle size of 12 mm [1]. Also the CCS was replacing for coarse aggregates (chips). The particle size of chips is around 12mm. Therefore maximum particle size of CCS was selected as 12.5 mm in the current study.

5. Conclusions

It was found that the maximum compressive strength of CCS based cement sand block is achieved at 25% replacement level of coarse aggregates. The water absorption capacity was below the 12%, which is the requirement of maximum percentage of water absorption in masonry blocks.Blocks which are light weight, implying that they can be used for the partition walls of high rise buildings. Further research will be conducted on the durability of this organic material, and elimination of flat particles.

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