

PROPERTIES OF MASONRY PANEL AND BLOCKS MANUFACTURED WITH CRUSHED COCONUT SHELLS (CCS)

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Abstract

Coconut shell is often considered as solid waste though it has high strength, hardness and bond capacity. After using coconut fruit, outer shell is released to the environment as a waste material. Recently, several research studies have been carried out to investigate a possibility of utilize this waste as building material. The block manufactured using Crushed Coconut Shell (CCS) has shown acceptable structural properties and thermal performances at 28 days. Since the coconut shell is a biodegradable material it is important to investigate long term behaviour of CCS based masonry block. As masonry blocks are used as wall, an investigation on the behaviour of a wall panel is useful.

In this study, long term behaviour of CCS based block and panel were investigated. Compressive strength, water absorption and thermal performances of the individual block, which was manufactured twelve months ago, were determined. These solid masonry blocks having the size of 360 mm×100 mm×170 mm were cast with a mix proportion of 1:5 cement-sand by using local block manufacturing machine. Crushed coconut shell was used as replacement for coarse aggregates (chips) with 25 % (volume basis). Internal surface and external surface temperatures of the block were measured by using thermocouples. In addition, load-displacement curve of the wall panel subjected to vertical static loading was investigated. As a further development of the block, cost analysis was carried out.

From the experimental study, it was found that in long term also, the CCS based blocks exhibit the similar thermal performances as in the short term. Compressive strength and water absorption found in the current study were compared with the same properties at 28 days found in a previous study. Cost analysis study confirms that CCS based block is economical compared with the conventional block.

Keywords: Crushed coconut shell, Compressive strength, water absorption, load-displacement

1. Introduction

Coconut shells are freely available solid waste in Sri Lanka. Coconut shells are the protector of the main coconut fruit. After using the coconut fruit, outer shell is released to the environment as solid waste. The estimated total world production of 28,765 million coconuts, it can be calculated that over 4 million tons of shells are theoretically available (Brain et al, 1975).

Coconut shells are often considered as waste although they consist of significant properties such as high strength, bond capacity and hardness. In Sri Lanka, coconut shells are mostly produced by “copra” industry. There are few ways to utilize the coconut shell waste. Coconut shells are used as fuel for kilns. Other production of coconut shell is charcoal and also small amount of coconut shell is used by craftsman in making various ornaments such as flower vases, buttons and goblets. However, these utilize systems are not sufficient to reduce the wastage of coconut shells, which are released to the environment. A proper disposal method of coconut shell is required to reduce the environmental issues such as providing breeding places for mosquitoes and rats.

Building construction sector is rapidly developing nowadays. As a tropical country, both bricks and blocks are popular for construction work in Sri Lanka. Although block walls are popular as partitioning walls, a proper utilization can be done from these blocks as load bearing walls. In this case, structural properties of the blocks such as compressive strength, flexural strength and shear strength are the main considering factors. Though the conventional masonry blocks illustrate acceptable structural properties, the utility of blocks are limited due to its high manufacturing cost, poor thermal performances and high self weight. Therefore, innovative blocks with light weight and better thermal performances are sought in the field in order to reduce the weight of structures. All these blocks are manufactured by mixing cement, sand, and aggregate in standard mix proportions.

In order to utilize the waste and to add value to the waste materials, research studies on utilization of waste have been carried out (e.g. Subashi et al (2011)). Crushed coconut shell based blocks have made a value addition to the waste coconut shells. In previous studies Singhapura et al (2011a) have investigated the compressive strength and water absorption of the unit block. They have achieved 4.3 N/mm² compressive strength and 11.27% water absorption value for the mix proportion of 1:5 cement sand, 25% CCS (volume basis) and 0.5 water-cement ratio. As the minimum requirement of the compressive strength of block is 2.8 N/mm², the strength of CCS based block is within the acceptable limit. According to specifications (BS 5628-Part 1:2005), water absorption of an individual block of 12% is sufficient and the developed block has less water absorption than this level. However, the study was limited to investigation of short term performances. Since the coconut shell is a biodegradable material the long term performances of the block is a critical factor. These blocks are utilized for constructing walls and the behaviour of the wall panel subjected to loading also important. As in a tropical county, Sri Lankan buildings subjected to continues high temperature and severe weather conditions, especially during monsoon period. Although these blocks have exhibited better thermal performances than the conventional block in the short term condition, investigation on

long term thermal performances is necessary. Since this product is manufactured using waste materials, it was expected that the cost of block manufacturing would decrease and the product would be a cost effective masonry block.

2. Objectives

Objectives of this study are

- To investigate the long term performances of the CCS based blocks
- To investigate behaviour of the wall panel manufactured with CCS based blocks
- To investigate the cost effectiveness of the product

3. Methodology

To investigate long term performances, the blocks, which were manufactured by previous researches (Singhapura et al, 2011b), were used. CCS based masonry blocks were collected from the stack of blocks. The age of these blocks is approximately 1 year. The mix proportion of 1:5 (cement sand , 25% CCS (volume basis) and 0.5 water cement ratio for CCS based block and 1:5 (cement sand blocks with 25% chips (volume basis)) and 0.5 water cement ratio for conventional block have been used in the previous study. The same mix proportion of block was used in the current study for investigation of behaviour of wall panel. To investigate the load-displacement of wall panel, both CCS based blocks and the conventional blocks were manufactured.

3.1 Block Manufacturing

All the blocks were manufactured using a local block manufacturing machine (Figure 1). The size of the blocks is 360mm x 100mm x170mm. In this study, saturated surface dried CCS was used in order to have a proper bonding between cement sand mixtures. The steel mould attached to the block manufacturing machine was filled with the mixture by three layers and each layer was compacted. First, the steel mould was filled with the mixture to full height of the mould and the vibro-compaction was applied to the mould for 10 seconds. For further compaction, remaining height of the mould was filled with mortar and the vibro-compaction was applied for another 10 seconds. Finally, the remaining height of the mould was filled with mortar and the top surface was manually compressed by using a lever system.



Figure 1 – Local block manufacturing machine

3.2 Wall Panel Casting and Testing

Two wall panels with the bond pattern shown in Figure 2 were cast using CCS based blocks and conventional blocks. Size of wall panel was 1100mm x 530mm. Thickness of the wall was 100mm, which is equivalent to the thickness of single block.

Mortar of 25mm thick was spread on the baseboard. Some amount of 1:5 cement sand mortar was picked by using trowel and trowel point was placed on the base board. The trowel was rotated by 180° and laid the mortar below the wall panel. The verticality of the masonry panel was checked using a plumb bob. Three courses of block layers were placed (Figures 2 and 3).

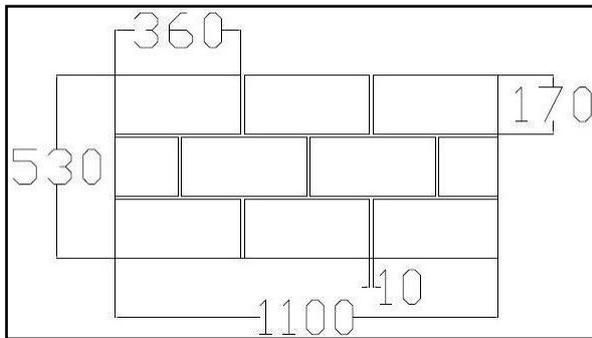


Figure 2 – Bond pattern of the wall panel



Figure 3– Casting the masonry wall panel

Wall panels were tested after 28 days of the casting. Compressive strength and vertical displacement of the wall panel were measured while applying vertical load. Vertical displacement was measured since the lateral displacement is comparatively small compared to vertical displacement in a vertically loading case. The test was carried out using dynamic actuator, hydraulic system, and control system (Figure 4). The actuator was placed at the centre of the wall and load was statically applied. The vertical displacement was recorded using displacement transducer connected to data logger as shown in Figure 4.



Figure 4 –Testing of wall panel

3.3 Compressive Strength

The compressive strength of CCS based blocks and the conventional block was investigated by using concrete crushing machine available in the same laboratory. Average compressive strength was determined by averaging at least two corresponding strength values. In this process, exceptionally high and exceptionally low strength values were neglected. The average compressive strength values were compared with the 28 day compressive strength of the blocks, which has been published in the previous study (Singhapura et al, 2011b).

3.4 Water absorption

CCS based blocks used in this test also were at two different ages: 28 days and one year. Conventional blocks in the same ages were also tested for water absorption. Water absorption of the blocks was determined as the method described in previous studies (Singhapura et al, 2011b). First, the blocks were immersed in water for 24 hours and their weights were measured after drying the surfaces of blocks. Then the same blocks were kept in an oven at 105⁰C for 24 hours and their dry weights were measured. The ratio of the reduction of the weight into the dry weight is defined as the water absorption of the blocks. The calculated water absorption values were compared with the water absorption values published in the previous study (Singhapura et al, 2011b).

3.5 Thermal Performances

To investigate long term and short term thermal performances, one block at each age was used. In the present study, CCS based block was manufactured to investigate the short term thermal performances. Previously manufactured CCS based block was used to investigate the long term thermal performance.

Long term thermal performances of the CCS based blocks was also investigated using the method presented in a previous study (Singhapura et al, 2011a). The method of measuring thermal performance is briefly presented in this section. A 5mm diameter hole was drilled to the middle depth of the block in the centre of the 360 mm x 100mm surface. Thermo couple (Type K) was inserted into the hole and made sure the tip of the thermo couple touched with the internal surface of the block. Thermo couple reading was considered as the internal temperature of the block. External surface temperature was also measured by continuously touching the thermo couple at the centre of the 360mm x 170mm surface as shown in Figure 5. Both of these thermo couples were attached to a digital thermometer and the temperature readings were recorded for a period from 10:00 a.m to 2:00 p.m, as a pilot study. The reading was taken on a day of July, when the weather condition was cloudy and sunny.

In order to achieve the same conditions as in a wall, four surfaces (i.e., two surfaces with 360 mm x 170 mm, two surfaces with 100 mm x 170 mm) of the block were covered using a heat insulator as shown in Figure 6.



Figure 5- Measuring the temperature



Figure 6 – Cover the blocks using insulators

3.6 Cost Analysis

Cost analysis was carried and compared with each block type. It was assumed that the cost of labour and cost of other facility requirements are same for both conventional block and CCS based block. Therefore, these cost components were not considered in this analysis.

The material quantities and their cost were considered. The prices of the material were selected based on the local market price. The price of a 50 kg cement bag was considered as Rs 855.00. With transport one hundred cubic feet of sand costs Rs 6000, although the transport cost is significantly varied. One hundred cubic feet of chips costs Rs 10000.00.

Quantity of the material was determined according to mix proportions. Amount of cement was quantified weight basis and the amount of sand and chips were quantified volume basis. With these prices and material quantities, the material cost of one block was determined and compared with the material cost of a conventional block. No cost was considered for coconut shells since they are freely available.

4. Results and Discussion

4.1 Wall Panel

The load-displacement curve of the wall panel cast with CCS based blocks is shown in Figure 7

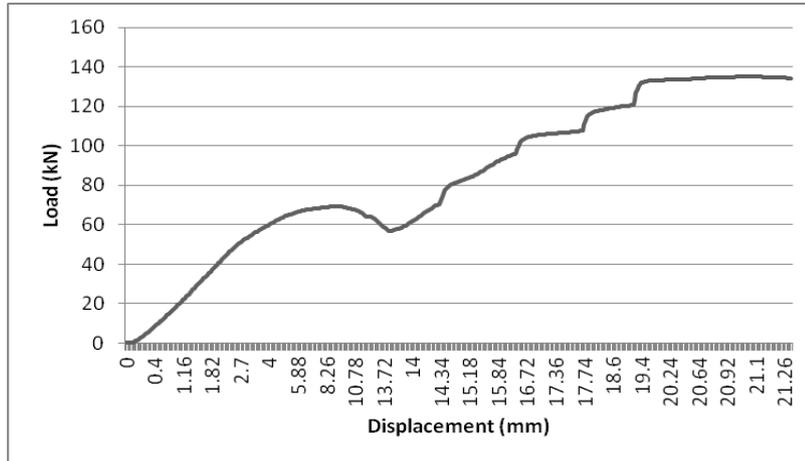


Figure 7 –Load displacement curve for CCS based block wall

The wall panel cast with CCS based blocks tended to overturn backward at the vertical load of 130kN. This may probably due to less thickness of the wall panel (i.e., 100 mm). No crack was appeared in the wall up to 130kN loading. Since the loaded area was 100mm x 1100mm the compression strength for 130kN is 1.81N/mm^2 .

According to Figure 7, it can be seen that the vertical displacement of the wall gradually increases with the load. While carrying out the test, a steel plate was placed at the top surface of the wall in order to uniformly distribute the applied load. Although in the current study, the wall was loaded up to 130kN, in previous studies, it has been observed that compression force needed for brick masonry wall is around 200kN. This implies that failure load for block masonry wall might be higher than 200kN. Although the maximum capacity of the apparatus is 200kN a load greater than 130kN could not be applied due to high slenderness of the wall.

4.2 Compressive Strength

Individual and average compressive strengths of the CCS based blocks at the age of 1 year are tabulated in Table 1.

Table 1: Long term compressive strength of the CCS based blocks

Compressive Strength (N/mm ²)	
Individual Compressive Strength	Average Compressive Strength
4.901	4.947
4.604	
5.337	

Long term compressive strength of the block was found as 4.947N/mm². This average compressive strength of the blocks is above the acceptable limit that is 2.8N/mm². (BS 5628-Part 1:2005). Figure 8 shows the comparison of the long term and short term performances (i.e., average compressive strength) of the blocks.

Average compressive strength of the block has increased with time. The strength gain process of the block is rapid at the early stage of manufacturing. After 28 days, the strength increases in a low rate.

This study was carried out for investigating long term performances since the waste material that has been used for block is a biodegradable material. From the above results it shows that the coconut shell particles have not deteriorated when they were mixed with cement- sand mixture. In a previous study Gunasekaran et al (2012) has also observed a similar behaviour in coconut shell at long term, although the study was carried for CCS based concrete, where a proper compaction is generally applied.

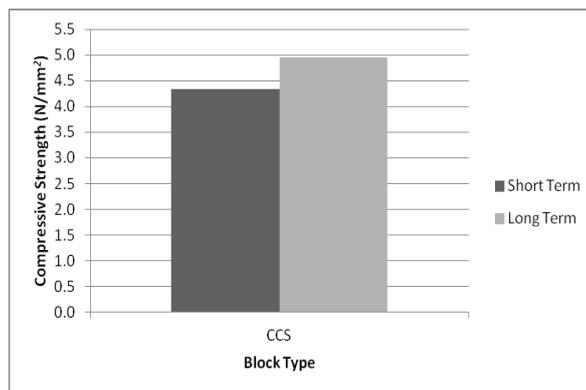


Figure 8–Comparison of the long term and short term compressive strength of blocks

4.3 Water Absorption

Average value of long term water absorption of the CCS based block is presented in Figure 9. It has been found that the long term water absorption was 13.513%. This value is slightly higher than the recommended water absorption of the masonry block (i.e. 12% BS 5628-Part 1:2005).

Average value of long term water absorption was determined and compared with the 28 days average water absorption values found in the previous study (Singhapura et al (2011b)). Figure 9 shows the comparison of the water absorption properties of the blocks at 28 days and 1 year.

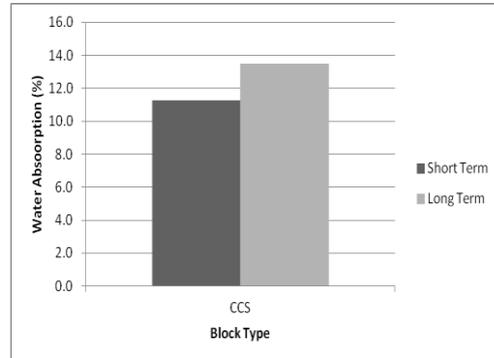


Figure 9 –Comparison of the long term and short term water absorption of blocks

From Figure 9, it can be seen that the water absorption of the block has increased with time. Since the block has increased its strength with time, moisture inside the block has probably been utilized for strength gaining process. As a result, the CCS particles have lost their saturate condition. As dry CCS remains as it is in the cement sand mixture, CCS absorbed more water in long term than that for short term condition.

4.4 Thermal Performances

Long term and short term external and internal temperature variation of the CCS blocks are presented in Figures 10 and 11, respectively.

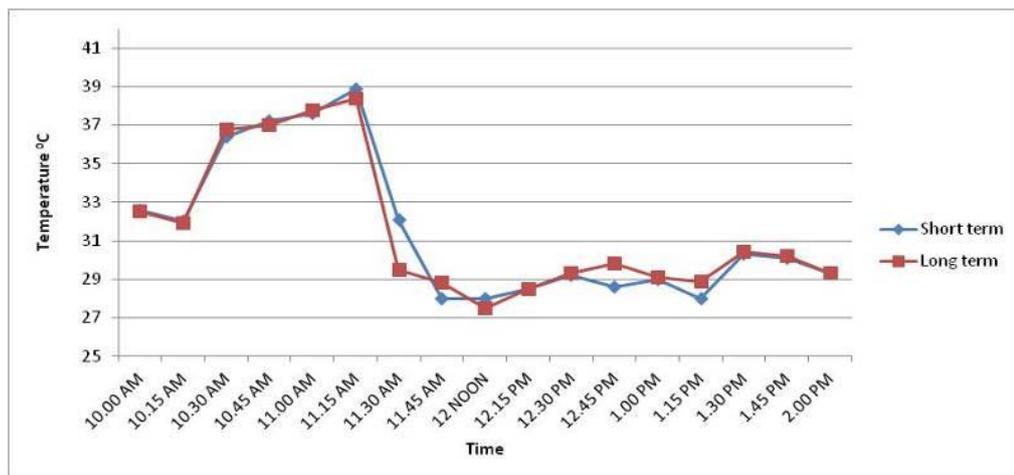


Figure 10 – External temperature variation of the short term and long term CCS based blocks

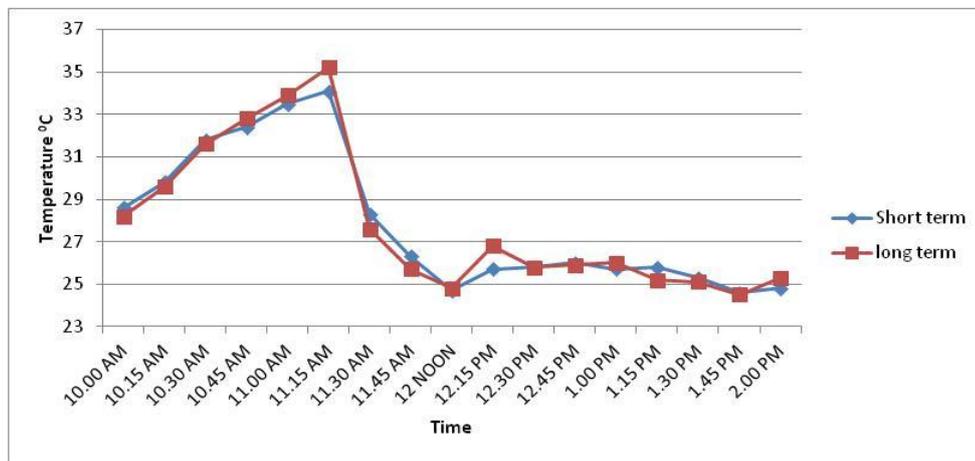


Figure 11 – Internal temperature variation of the short term and long term CCS based blocks

From Figures 10 and 11, it can be seen that the thermal performances of the blocks for short term and long term are similar. In order to investigate the thermal performances, only a pilot study has been carried out. The blocks were exposed to direct sunlight only for 4 hours. The maximum temperature was observed at 11.00 am, although this is not common in a typical sunny day in Sri Lanka. The maximum temperature was observed at the early half of the day, possibly because the weather was cloudy after 12 noon.

According to the pilot study, the CCS based blocks exhibit the similar thermal performances in the short term and long term. It has been reported that CCS based blocks showed better thermal performances compared with the conventional blocks (Singhapura (2011a)). Therefore, it can be expected that the CCS based blocks will show better thermal performances in long term also, although the current study was limited to the investigation of temperature variation only for 4 hours.

4.5 Cost Analysis

Material cost of the CCS based block and conventional block are shown in Table 2.

Table 2 – Material cost of blocks

<i>Cost (Rs)</i>		<i>Saving (Rs)</i>
<i>CCS Block</i>	<i>Conventional Block</i>	
26.74	32.14	5.40

From Table 2, it can be seen that the money saving from the developed block is Rs 5.40. According to cost analysis results, Rs 5.40 saving could be achieved from one block compared to conventional block. This implies that CCS based block is a cost effective product, while having greater strengths. In addition, utilization of waste will be a solution for burning problems in solid waste management sector so as to reduce the waste in the environment.

Further studies can be done by adding the initial cost for crushing the coconut shells. Though it adds an additional cost to the product, the cost effectiveness of the product can still be achieved since coconut shell is a waste material.

5. Conclusions

Coconut shell is a waste material freely available in the environment. In previous studies, CCS based masonry blocks has been manufactured and observed appreciable structural properties of the individual block for short term. In this study, long term performances of individual blocks and behaviour of wall panel cast with CCS based blocks were investigated.

For the wall panel, the vertical displacement increases with the increase of load, up to 130kN. The long term compressive strength of blocks increases with time. At the age of one year, the average compressive strength of the block was found as 4.947 N/mm². Water absorption also slightly increases from 11.27 % to 13.513% with the period of approximately 1year. Long term thermal performances of the blocks are similar to the short term performances, implying that the blocks manufactured with CCS has better thermal performances. This will help to reduce the running cost of masonry buildings; no energy is necessary to provide thermal comfort to the occupants in building. From the cost analysis study, it was found that the CCS based block is a cost effective product: Rs 5.40 saving of material cost from a block.

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