Feasibility study of carbon black contaminated silica sand in the production of black blocks

K.Baskaran,
Senior Lecturer, Department of Civil Engineering, University of Moratuwa
(Email: baskaran@uom.lk)
K.Gopinath,
Graduate Research Student, Department of Civil Engineering, University of Moratuwa
(Email: atk.gopinath2006@gmail.com)

Abstract

Present study attempted to verify the feasibility of producing cement blocks by partially replacing fine aggregates with carbon black contaminated silica sand (CBCSS), which is a by-product of the tyre manufacturing process. In the present study performance tests such as compressive testing and flexural testing were conducted. In addition resistance against rain drops was measured and the quality of water, in case of inundation was also checked. As experimental investigations, eight individual black blocks were cast and tested for compressive strength and nine sample panels were made and tested for flexural and compressive strengths. In addition, pressurized drizzle test was conducted for individual blocks to study the erosion resistance characteristics against rain. Moreover, particularly in lower lands, during floods there is a room for these panels containing CBCSS being immersed under water for certain days. The present study accommodated the above through water quality test and the results were verified with drinking water specifications.

Compressive strength of individual black blocks was 4.74 N/mm^2, which is well above to that of the minimum requirement of 1.2 N/mm^2 as per the SLS 855: Part 1: 1989. These blocks, according to the Sri Lankan Standard, could be used for both load bearing walls for up to two storeys and in any non-load bearing walls. The flexural strength parallel to the bed joint was 0.113 N/mm^2, which is just below the recommended characteristic flexural strength of 0.2 N/mm^2 as per the BS 5628. The flexural strength perpendicular to the bed joint was 0.61 N/mm^2, which is higher than the recommended characteristic flexural strength of 0.4 N/mm^2 as per the BS 5628. The pressure drizzle test being done to the black blocks was shown smaller indentation after one hour to that of a normal brick at 50 kPa pressure, which revealed a fact that black blocks are rather resistive in terms of indentation to rain to that of normal bricks. Water, in which the black blocks were immersed for three days, satisfied the standard levels for drinkable water, recommended by the SLS 614-1983, which implies the fact that black blocks would not release any additional pollutants to the existing water/flood. Hence, it shall be concluded that the black blocks could be used in constructing masonry walls.

Keywords: carbon black contaminated silica sand, flexural strength, compressive strength, resistance to rain drops

1. Introduction

Tyre manufacturing is one of the leading export businesses in Sri Lanka. During the process of tyre manufacturing, a considerable amount of carbon black contaminated silica sand (CBCSS) is produced as a by product. However, CBCSS cannot be dumped in bare lands as it infertile the lands. Whereas reuse of CBCSS as a construction material shall be a viable option to consider. However prior to make use of this waste CBCSS as an ingredient in the production of cement blocks, it has to ensure that the structural criterions are met. While the present study attempted to verify the feasibility of producing cement blocks by partially replacing fine aggregates with carbon black contaminated silica sand (CBCSS).

In line with the present study, a considerable research effort has already been taken to develop economic alternative building materials with industry and other wastes. These waste materials were used to replace either the fine aggregate (filler material) or coarse aggregate (basic building material). The construction waste [1,2], glass wastes[3,4,5] polymers [6,7] and fly ash [8] have been studied in the past while the present study intended to focus on the behaviour of cement blocks by partially replacing the fine aggregates with carbon black contaminated silica sand.

2. Experimental investigation

2.1 Mixture proportions and production of black blocks

Mix proportion of 3:3:4:1 (black sand : sand : chips : cement) was selected to make the black blocks and water to cement ratio was selected as 1, both of which were based on the previous study conducted at University of Moratuwa [9] which is shown in Table 1. Before mixing the constituents, debris in the carbon black contaminated sand were removed. Then the constituents were thoroughly mixed and the mix was placed and compacted into the moulds in three layers. Each layer was compacted using a tamping rod. After preparing the black blocks, they were wetted on a regular basis for curing at least for seven days. Then, they were kept in stacks for 28 days to gain strength. Figure 1 shows the mixing, compacting and curing of black blocks.

Table 1: Mix proportion of the black blocks

Black sand(g)	*Sand(g)*	*Chips(g)*	*Cement(g)*	*Water(g)*
1800	*1800*	*2400*	*600*	*600*

(a) *Mixing the constituents*

(b) Compaction by a tamping rod

(c) Curing of black blocks

Figure 1: production and curing of black blocks

2.1.1 The dimensional tolerances of the black blocks

Twenty black blocks samples were randomly selected from the stack and the dimensions were measured in accordance with Sri Lanka Standard [10]. Dimensional tolerance for black blocks were calculated and tabulated as shown in Table 2, in accordance with Sri Lanka Standard [11].

Table 2: Tolerances in blocks

Dimension	*Tolerances (mm)*	
Length	*+3*	*-5*
Width	*+3*	*-5*
Height	*+2*	*-2*

2.2 Compressive strength testing

Compressive strength of a concrete block wall depends on the strength of mortar used, shape and size of the block panel and procedure used for testing compressive strength etc. The characteristic compressive strength of the sample masonry panels were calculated as directed in the BS 5628: Part 1:1992 as shown below [12].

$$f_k = (F_m/A) \times (f_u \times f_m/1.2 \quad)$$

Where

F_m- mean of the minimum load carried by the two test panels

A - cross sectional area of each panel

f_u - Reduction factor for strength of mortar

f_m - Unit reduction factor for sample structural units

2.2.1 Compressive strength testing for Individual black blocks

Eight blocks were selected randomly from the sample and they were immersed under water for 24 hours [11].Then they were bedded with cement sand mortar at both top and bottom surfaces and again immersed under water for 24 hours until the testing being done. The load was gradually increased till the failure occurred, and the results are summarized in Table 3.

Table 3: Compressive strength of the black block samples

Sample	*Dimensions (mm)*			*Compressive Strength (N/mm^2)*
	Length	*Width*	*Height*	
1	*380*	*102*	*202*	*5.0*
2	*383*	*102*	*200*	*4.5*
3	*380*	*103*	*195*	*3.1*
4	*380*	*102*	*199*	*6.0*
5	*380*	*102*	*194*	*3.4*
6	*382*	*102*	*198*	*6.4*
7	*384*	*102*	*198*	*6.0*
8	*383*	*103*	*201*	*3.5*

From the Table 3, the average compressive strength of the individual black blocks is 4.74 N/mm^2.

2.2.2 Compressive strength testing for panels

Before making the panels, individual blocks were immersed under water for about 5 to 6 minutes and sample panels were built within one hour of the removal of blocks from water [12]. 10 to 15 individual blocks were used to make every sample panel. These sample panels were covered with polythene sheet for a period of three days continuously and then kept uncovered until the testing being done. The panels were tested after 28 days for compression. These sample panels were built up in such a way that 4 block courses height and 2.5 blocks long as shown in Figure 2. Three sample panels (C1, C2, and C3) were made and tested in compression using the universal testing machine one by one as shown in Figure 3 and the failure loads and the corresponding compressive strengths are tabulated in Table 4. Failure pattern observed during the compression testing is shown in Figure 4.

Figure 2: Sample panel used for compression testing

Figure 3: Application of compressive load

Table 4: Dimensions of the tested panels in compression

Panel no	*Length (mm)*	*Height (mm)*	*Thickness (mm)*	*Failure Load in kN*	*Area (mm^2)*	*Compressive Strength (N/mm^2)*
C1	*1180*	*750*	*100*	*296.3*	*118000*	*2.51*
C2	*1200*	*750*	*100*	*240.4*	*120000*	*2.00*
C3	*1195*	*750*	*100*	*245.3*	*119500*	*2.05*

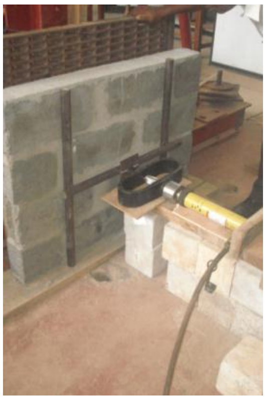
From the Table 4, the average compressive strength of the black block panel is 2.19 N/mm^2

Figure 4: Failure patterns due to compressive load

2.3 Flexural strength of block panels

The flexural strength is a predominant parameter when designing masonry units if bending is critical. Flexural strength testings were done to the sample panels in two orthogonal directions. When the failure surface is parallel to the bed joints, the sample panels were built up in such a way that panels were of 1.5 blocks long and 5 block courses high as shown in Figure 5(a). When the failure surface was perpendicular to the bed joints, sample panels were arranged in such a way that the panels were of 2.5 blocks long and 4 block courses high as shown in Figure 5(b) [12]. After 28 days from casting, panels were tested for flexural strength, by applying uniformly distributed loads. Panel no F1, F2, F3, F4, F5 and F6 were used for testing flexural testing. Sample wall panels were tested under four point loading in two orthogonal directions. Outer bearings were placed 50mm away from the edges of the sample panels and spacing of inner bearings were varied to have equal shear spans. Then the flexural stress was applied at a rate of 0 to 0.4N/(mm^2/min) by using a hydraulic jack as shown in Figure 5. The failure pattern during the flexural testing is shown in Figure 6.

(a) Flexural testing panel arrangement 1



(b) Flexural testing panel arrangement 2

Figure 5: Flexural testing panel arrangements

Figure 6: Failure pattern of the panel after flexural testing

Table 5: Flexural strength of block panels

Panel no	*Failure plane*	*Failure load(N)*	*Flexural strength (N/mm^2)*
F1	*Parallel to bed joints*	*1036*	*0.12*
F2	*Parallel to bed joints*	*1036*	*0.12*
F3	*Parallel to bed joints*	*864*	*0.10*
F4	*Perpendicular to bed joints*	*3453*	*0.45*
F5	*Perpendicular to bed joints*	*4143*	*0.55*
F6	*Perpendicular to bed joints*	*6043*	*0.83*

From the Table 5, average flexural strength parallel to bed joint was 0.113 N/mm^2 whereas the average flexural strength perpendicular to the bed joint was 0.61 N/mm^2.

2.4 Pressure drizzle test

During the rain, coupled with heavy wind, erosion may occur in the wall panels. Driving rain water is due to the combine action of the rain and wind force. The amount of rain water that may hit vertical surface may be much larger to that of on horizontal surface [13]. This erosion is mainly due to lack of quality control in manufacturing masonry units. Mainly erosion will occur in bricks due to improper burning and in block walls due to the improper mixing of raw materials.

The accelerated erosion test could be used to determine relative erosion resistance of blocks. Three specimens were subjected to continuous jet of water spray for 60 minutes or until water has completely penetrated the specimens. Performance, in terms of erosion rate (mm/hrs), could be determined on the basis of pitting depth or time taken to completely penetrate the specimens.

The apparatus, shown in Figure 7 was used for this test, includes a stand-mounted 50mm spray nozzle, water pump, pipes and valves, pressure gauge, water tank, filtration screen to remove particulate matter, mounting for specimen, shield and gasket. This test has been selected to simulate the heavy rain conditions expected in tropical weather conditions. The standard erosion test apparatus has been modified to suit the Sri Lankan condition and fabricated at the Department of Civil Engineering, University of Moratuwa. Figure 7(a) shows the apparatus assembled. This apparatus can spray a water jet at the pressure of 50kPa through a nozzle of 40mm diameter circle. After 60 minutes, depth of each pit due to water spray was measured to the nearest millimetre, by inserting flat-ended rod. The maximum depth is taken as the rate of erosion, D (mm/hrs) for the specimen. The durability is measured in terms of erosion rate (mm/hrs) evaluated on the basis of pitting depth or time taken to completely penetrate the eroded specimens.

(a)Pressure drizzle apparatus

(b) Jet of water spray was applied to the black block sample

Figure 7: Pressure drizzle testing setup

Observed erosion depth variations with time for three samples of black blocks and clay bricks samples are given in Tables 6 and 7 respectively.

Table 6: Erosion depth in black block samples

Time duration (minutes)	*Maximum erosion depth(mm)*		
	Sample 1	*Sample 2*	*Sample 3*
15	*0.0*	*0.1*	*0.0*
30	*0.0*	*0.2*	*0.1*
45	*0.0*	*0.4*	*0.3*
60	*0.1*	*0.4*	*0.5*
Average erosion in an hour			*0.33 mm*

Table 7: Erosion depth in clay brick samples

Time duration (minutes)	*Maximum erosion depth(mm)*		
	Sample 1	*Sample 2*	*Sample 3*
15	*0.0*	*0.0*	*0.1*
30	*0.2*	*0.1*	*0.1*
45	*0.4*	*0.3*	*0.3*
60	*0.6*	*0.4*	*0.4*
Average erosion in an hour			*0.46 mm*

From the Tables 6 and 7, black blocks were shown smaller indentation after one hour than normal bricks at 50 kPa pressure.

2.5 Tests on water Quality

During the rainy seasons, particularly in lower lands, black block wall panels are likely to be submerged under flood. Whereas it is important to study whether these black blocks immersed under water for certain days, contaminate the water body. Thus a series of tests were conducted for the water quality parameters such as pH, chloride (Cl^-) (mg/l), fluoride (F^-) (mg/l), total alkalinity and total hardness as $CaCO_3$ (mg/l), sulphate (SO_4^{2-}) (mg/l). Figure 8 shows the test setup being used to conduct these series of water quality tests. The level of concentrations of the above water quality parameters were measured under laboratory conditions after immersing the black blocks under water for three days and compared against the Sri Lankan Drinking Water Standard SLS 614-1983 [14]. The observations on water quality parameters against the Sri Lankan Standard are tabulated in Table 8.

Figure 8: Water quality testing setup

Table 8: Concentration level of water quality parameters against the SLS 614-1983

Parameter	Method	Results		Drinking Water Standards (SLS 614-1983)	
		Sample 1	Sample 2	Highest Desirable Level	Maximum Permissible Level
pH at 28 °C	*APHA*	*8.3*	*7.8*	*7.0 - 8.5*	*6.5 - 9.5*
Chloride(mg/l)	*Colorimetric*	*< 0.05*	*<0.05*	*200*	*1200*
Fluoride(mg/l)	*Colorimetric*	*<0.05*	*<0.05*	*-*	*1.5*
$CaCO_3$ *(mg/l)*	*Colorimetric*	*217*	*47*	*Total hardness 250*	*600*
				Total alkalinity 200	*400*
Sulphate(mg/l)	*Colorimetric*	*28*	*51*	*200*	*400*

It was observed from the series of water quality test results shown in Table 8 that, the water in which the black blocks immersed for three days were well below the levels specified as highest desirable level in the SLS 614-1983.

3. Conclusions

The measured average compressive strength of individual black blocks is 4.74 N/mm^{2}while the value specified as the minimum requirement is 1.2 N/mm^2 as per the SLS 855: Part 1: 1989 [11]. These blocks could be used as load bearing walls for up to two storeys and in any non-load bearing walls according to the Sri Lankan Standard [11].

The measured average flexural strength parallel to the bed joint was 0.113 N/mm^2 while the BS 5628 recommended the characteristic flexural strength of 0.2 N/mm^2. Whereas the measured flexural strength perpendicular to the bed joint was 0.61 N/mm^2 while the BS 5628 recommended characteristic flexural strength is 0.4 N/mm^2. Thus panels tested in flexure for bending perpendicular to the bed joints showed adequate capacity in flexure [12].

The pressure drizzle test being done to the black blocks was shown smaller indentation after one hour to that of a normal brick at 50 kPa pressure, which revealed a fact that black blocks are rather resistive in terms of indentation to rain than normal bricks.

Water, in which the black blocks were immersed for three days, satisfied the standard levels for drinkable water recommended by the SLS 614-1983, which implies the fact that black blocks will not cause any additional pollutants to the existing water/flood. Hence, it shall be concluded that the black blocks could be used to construct masonry walls.

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