J. Build. Mater. Struct. (2024) 11: 27-33 ***Original Article***
DOI : 10.34118/jbms.11i1.3046

Suitability of crushed sandcrete block (CSB) as a partial replacement for fine aggregate in concrete

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Received: 09-03-2023 **Accepted: 10-02-2024**

Abstract. The suitability of crushed Sandcrete block (CSB) for use as a partial replacement for fine aggregate in concrete was examined. The physical and mechanical properties of the crushed Sandcrete block and river sand were determined and compared. The specific gravity of the crushed Sandcrete block was found to be 2.58 while that for river sand was 2.66. The concrete with compressive strength of 25N/mm^2 at 28 days' hydration period was calculated for the normal mixture as the control. The percentage mix of the fine aggregate was substituted with CSB in different mix proportions of 0:1(0%), 1:3(25%), 1:2(33.3%), 1:1(50%), 2:1(66.7%), 3:1(75%) and 1:0(100%) of crushed Sandcrete block and river sand by weight as fine aggregate. The concrete cubes were cured, and compressive strength tests were carried out at 7, 14, and 28 days. It was observed that the 28-day density and compressive strength for concrete cubes with crushed Sandcrete block alone as fine aggregate (i.e. 100%) were found to be 2420kg/m^3 and 22N/mm^2 respectively compared to the 0:1(0%) proportion which was found to be 2485kg/m^3 and 26N/mm^2 respectively. It was observed that the density and compressive strength reduced with the increasing addition of CSB in all the proportions.

Keywords: Comprehensive strength, Crushed sandcrete blocks; River sand; Specific gravity

1. Introduction

In modern times the building manufacturing sector is realizing and still linking resources within its close environs in the exploration of suitable resources that can expedite the construction of civil engineering structures. Wates materials in the form of sandcretes blocks are often seen in the construction of new structures and demolition of old existing structures (Onjefu et al., 2019). The large wastes in the form of broken Sandcrete blocks in demolition sites and block industries posed environmental issues that can be reduced by recycling the waste. A lot of research has been undertaken in the area of waste recycling (Akor et al., 2021). Oftentimes, the use of recycled waste has proven to be more economical in construction. The findings of Onjefu et al., (2019) showed that Crushed Waste Sandcrete Block (CWSB) aggregate can be recycled as fine aggregate in concrete making and be able to efficiently be substituted with the conservative fine aggregate, sand, in concrete by 50% in average strength concrete of 30N/mm^2 target strength.

According to Neville (1993), crushed Sandcrete Block (CSB) is defined as a cohesion-less sandy material acquired artificially by the mechanical vibration of a Sandcrete block. It is made of constituent part using a diameter between 0.05mm to 5mm. Sandcrete block has the following physical characteristics which includes strength, durability, fire resistance, and thermal insulation (Neville, 1993). Also, the Sandcrete strength usually gives the general portrait of the value of the concrete (Osuji and Egbon, 2015). In the practice of engineering, the compressive strength of a

Sandcrete block depends mostly on the water-cement ratio and the amount of compaction (British Standard Institution, 1996). The compressive strength of Sandcrete is a degree of the resistance of the block to applied load. BS2028 gives the required mean strength as 3.45N/mm^2, and the least strength is 2.59N/mm^2 (Joaquín et al., 2020). Based on the requirement the block compressive strength must be at minimum 75% of the average value.

2. Experimental program

River Benue sharp sand and gravel were used in carrying out this work. The broken Sandcrete blocks were obtained from Hamzato Block Industry Limited, a Sandcrete block manufacturer in Benue state, Nigeria. The waste collected from the block manufacturer was crushed by carrying them in fibre bags to protect the sand grains. The right specification of Ordinary Portland cement (Joaquín et al., 2020; Nigerian Industrial Standard, 2004; BS, 1975) was used as the binding agent, and water used for mixing was from the public water supply. Sieve analysis and specific gravity test were shown on the aggregates. Concrete cubes 150 x 150 x 150 moulds using 0:1(0.0%), 1:3(25.0%), 1:2(33.3%), 1:1(50.0%), 2:1(66.6%), 3:1(75.0%), and 1:0 (100%) proportion of crushed Sandcrete block and river sand by weight as fine aggregate.

The cubes were removed from the mould after a whole day and straightaway transferred into the water for curing at room temperature. Density and compressive strength tests were carried out at 7, 14, and 28 days. The percentage replacement of an aggregate of nine (9) cubes was formed and a total of sixty-three (63) cubes were made. Based on the results, logical conclusions were drawn, and appropriate recommendations were made.

3. Results and discussion

3.1 Specific gravity test

The specific gravity bottle having a volume of 1000 cm^3 was weighed and recorded. The bottle was filled half way with clean water weighed and recorded as W_2. About 100-150g of sample W_S was placed on the weigh balance and the result was noted, and water was added to the sample in the bottle then the combined weight was recorded as W_1. The above procedure was repeated twice and the mean value was taken to attain accuracy. The specific gravity was calculated using the formula in equation 1 and the results are presented in Table 1.

$$G_s = \frac{W_S}{W_S - (W_1 - W_2)}. \qquad \textit{Eq 1}$$

Table1. Specific gravity of sand and CSB

Sand				CSB		
Test No.	1	2	3	1	2	3
Vol of bottle cm3	1000	1000	1000	1000	1000	1000
Weight of bottle g	595	595	595	595	595	595
Weight of bottled +water+ soil W_1	1644	1643	1649	1701	1705	1704
Weight of bottled +water W_2	1551	1549	1655	1609	1620	1615
Weight of dry soil W_S	150	150	150	145	145	145
Submerged Weight W_1-W_2	93	94	94	92	85	89
GS	2.63	2.68	2.68	2.74	2.42	2.59
Mean G_S		2.66			2.58	

It can be seen that the CSB has a lower specific gravity than the sand. The lower values might be recognized for the higher fines in the CSB since the fines are smaller in size than sand elements.

3.2 Sieve analysis

The particle sizes were determine using the sieve analysis of different sizes of sieve with different aperture to obtain the particle-size grading of the aggregates as shown in Table 2 and the grading curve is shown in Fig, 1.

Table 2. Sieve Analysis showing percentage passing of CSB and sand

Sieve size	% Passing(CSB)	% Passing (sand)	BS 882 limit for zone 1
4.75mm	97.47	93.30	90- 100
2.36mm	80.52	74.01	60- 95
1.18mm	55.36	51.50	30- 70
600µm	28.11	26.05	15- 34
300µm	18.86	13.10	5 -20
150µm	8.00	5.03	0 -10
pan	0	0	0

3.3 Concrete mix

The objective of designing concrete mix is to find the most economical and suitable proportion of the constituents of the aggregate. According to the total weight approach, the concrete mix was created utilizing the properties of the materials. The batching of aggregate was done by weight using a 25-kilogram ELE Weighting machine. This was determined to produce concrete having the relevant quantities for the given mix. It was shown that more water was required to achieve the same workable consistency at a higher percentage replacement with CSB. This points toward the higher the percentage placement with CSB, the more porous the resulting concrete. The broader surface was put on the plate and held by legs after the slump test apparatus had been cleaned.

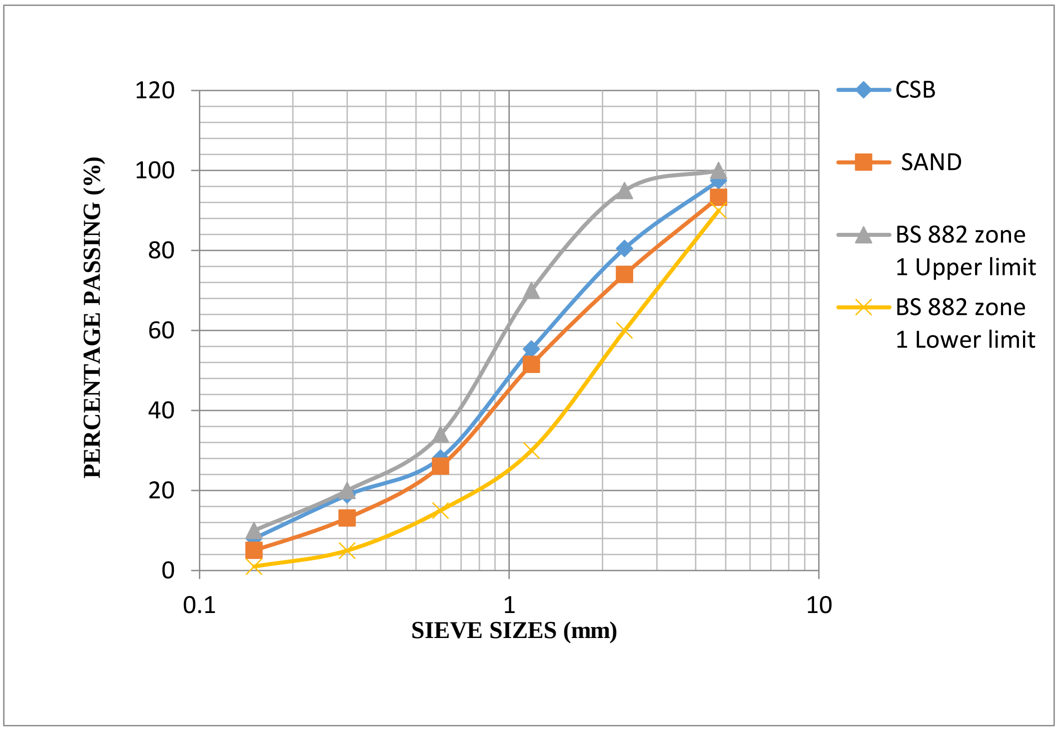

Fig 1. Particle Size Distribution Curve

The concrete mix was filled in the apparatus in four layers, each layer tamped 25 times with a 600mm metal rod of 16mm diameter and finished with a float. The device was carefully raised and set down on the plate close to the concrete. The droop is the disparity in height. Fig. 2 showed that when the CSB content increased, the tested cubes' compressive strength decreased. This might be explained by the CSB aggregates' increased fine content and greater w/c ratio. Figure 3 displays the varied cube densities created by varying sand substitution percentages using CSB aggregates. The density of the concrete was found to decrease with increasing CSB replacement. As a result, the CSB aggregate is said to be lighter than sand.

Table 3: Laboratory results of W/C, Slump test, Density and Compressive Strength

			7 Days		14 Days		28 Days	
Ratio	W/C Ratio	Slump (mm)	Density Kg/m^3	Strength N/mm^2	Density Kg/m3	Strength N/mm^2	Density Kg/m^3	Strength N/mm^2
0:1(0.0%)	0.55	65	2444	19	2471	24	2485	26
1:3(25%)	0.57	72	2427	18	2470	24	2480	25
1:2(33.3%)	0.59	79	2419	18	2457	23	2479	25
1:1(50%)	0.62	86	2418	18	2443	22	2458	24
2:1(66.7%)	0.64	92	2410	18	2430	22	2444	23
3:1(75%)	0.67	98	2405	17	2417	20	2434	22
1:0(100%)	0.69	105	2400	16	2415	19	2420	22

Because the CSB aggregates lose their compaction as the bonded and cemented hydrate disintegrates during crushing, as seen in Fig. 4, the increase in fines is likely caused by crushed cement hydrate. In accordance with BS1620, the cubes were subjected to compressive strength tests using a 1560 kg capacity ELE electrohydraulic pump-powered testing equipment. Each cube was weighed before being inserted between two metal plates in the testing apparatus. Load was applied to each sample until failure occurred, and the load at failure was recorded. The compressive strength of the cubes was calculated as the loads at failure divided by the effective cube areas, measured in square millimeters. Table 3 below provides a summary of the results as they were discovered in the laboratory.

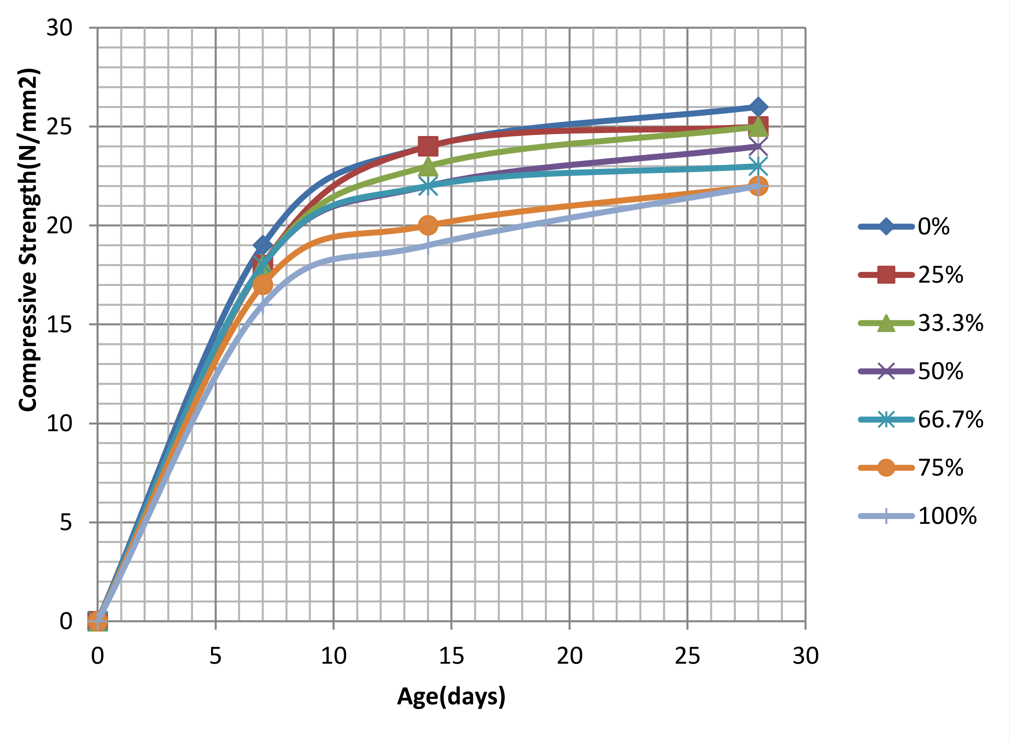

Fig 2. Compressive strength versus age curve

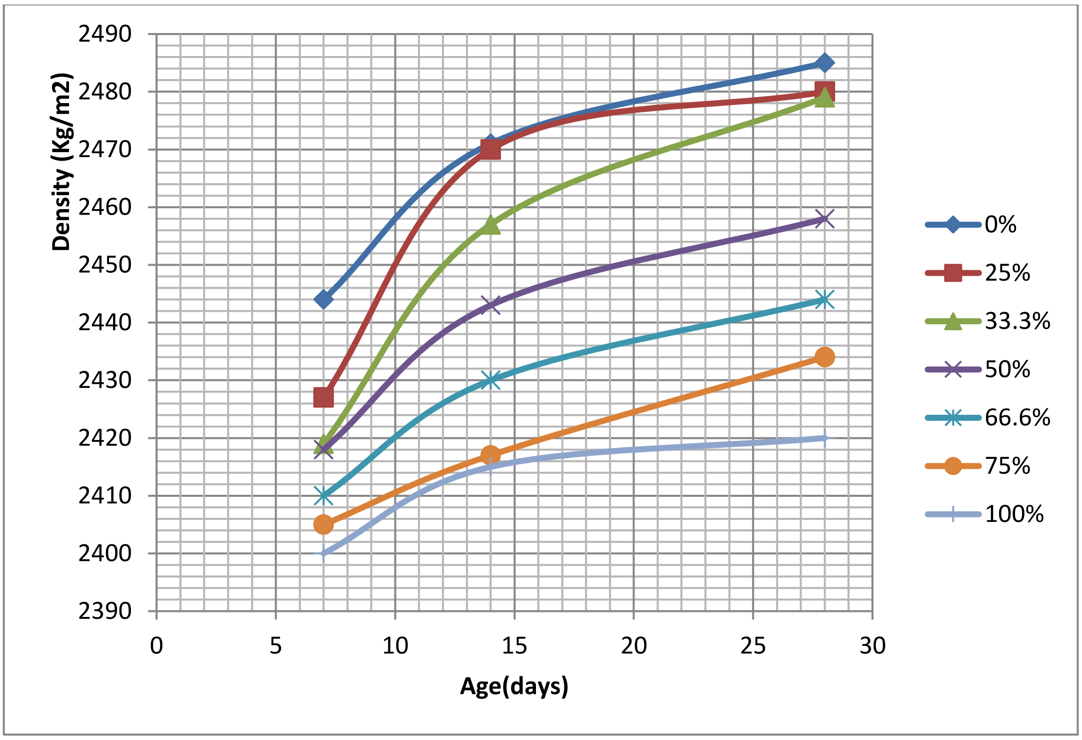

Fig 3. Density versus Age curve

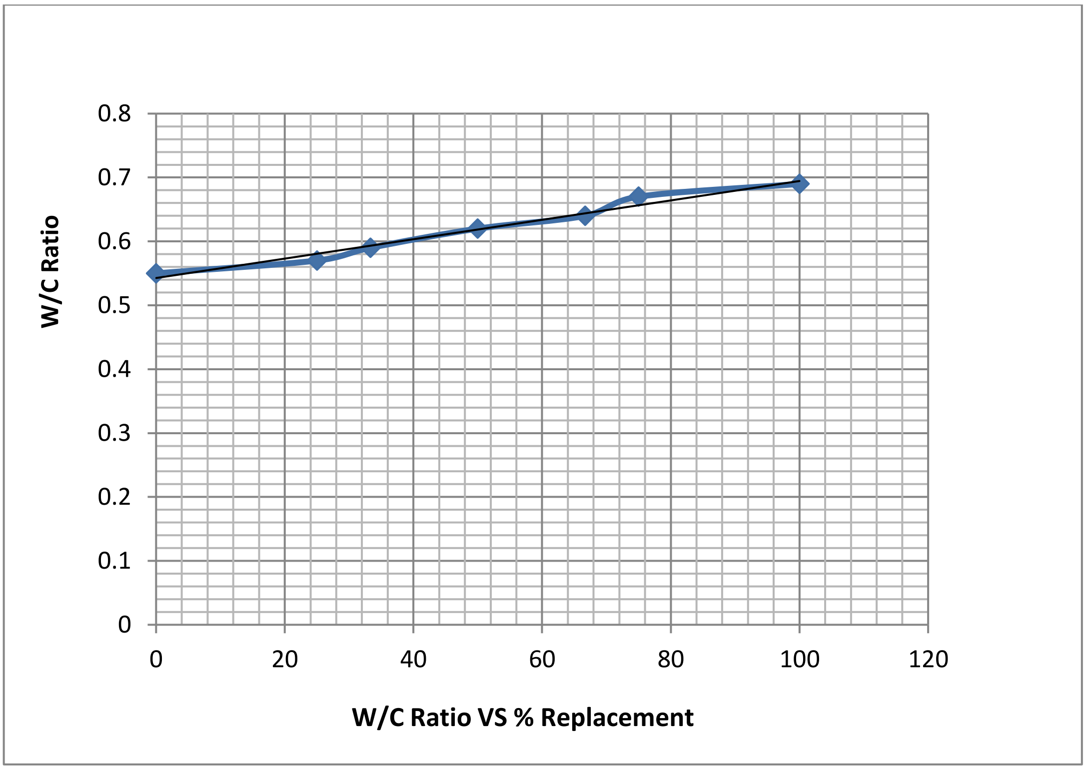

Fig 4. Percentage Replacement with CSB (%)

3.4 Compressive strength patterns

Linear regression models were developed and provided a means of predicting the dependent variable (compressive strength of concrete) given the proportions of the independent variables (% CSB replacement, w/c ratio, and slump). The multiple linear regression methods were incorporated using statistical software for data science (STATA). The generated models to predict the concrete compressive strength containing CSB are summarized in Table 4. The results show very highly significant models. It is seen that all the models are statically significant and perhaps represent predictable trends. The regression models so developed were evaluated for their significance using the coefficient of determination, R^2, standard error of the estimates and T-test.

Table 4: Linear regression models

model	days	Equations	R^2	Adjusted R^2
1	7	$Y = 22.27393 - 0.0702338X_1 – 32.34895X_2 + 0.2223371X_3$	0.8640	0.7281
2	14	$Y = 61.90176 + 0.0105538X_1 - 88.0118X_2 + 0.1642964X_3$	0.9645	0.9289
3	28	$Y =49.04478 – 0.0171403X_1 – 59.86917X_2 + 0.1489433X_3$	0.9753	0.9507

The regression analysis result for the concrete compressive strength at 7 days was derived from the different variables computed such as % CSB replacement, w/c ratio, and slump.

$$Y = 22.27393 - 0.0702338X_1 – 32.34895X_2 + 0.2223371X_3 \quad \text{Eq. 2}$$

In the above equation, y is the expected or predicted compressive strength. X_1, X_2 and X_3 are % CSB replacement, w/c ratio, slump with a coefficient of -0.0702338, -32.34895and +0.2223371 as their corresponding coefficient of determination respectively, the value 22.27393 is the constant term. The Square of correlation coefficient R^2 is 0.8640 and this implies that 86.4% of the changes in compressive strength are caused by the CSB while the remaining 13.6% are due to other factors.

Also taken into consideration was the concrete's compressive strength after 14 days. The same variables used in the model were entered to generate an equation of the form.

$$Y = 61.90176 + 0.0105538X_1 - 88.0118X_2 + 0.1642964X_3 \quad \text{Eq.3}$$

The above equation shows the relationship between y (compressive strength) and X_1, X_2 and X_3 are % CSB replacement, w/c ratio, slump with coefficients of + 0.0105538, - 88.0118 and +0.1642964 as their corresponding coefficient of determination respectively. The value 61.90176 is the constant term. The square of correlation coefficient R is 0.9645 and this implies that 96.45% of the changes in compressive strength are caused by the CSB while the remaining 3.55% are due to other factors.

The coefficient of determination was used to assess the significance of the equation (regression model), which was created using the compressive strength of concrete for a 28-day curing period.

$$Y = 49.04478 – 0.0171403X_1 – 59.86917X_2 + 0.1489433X_3 \quad \text{Eq.4}$$

The above equation shows also the relationship of y (compressive strength and X_1, X_2 and X_3 are % CSB replacement, w/c ratio, slump with the coefficient of – 0.0171403, –59.86917 and +0.1489433 respectively. The value 49.04478 is the constant term. It is also seen that the square of correlation coefficient R^2 is 0.9753 and this implies that 97.53% of the changes in compressive strength are caused by the CSB while the remaining 2.47% are due to other factors.

4. Conclusions

It can be concluded that the crushed Sandcrete block is the most significant variable in the three equations and its shows that the compressive strength from each of the equation increase in significance as the age of curing increase. Also, it was noted that the R^2 increased in every case from 7 to 28 days of curing. As a result, the model can be used to forecast the compressive strength of concrete. The above information implies that CSB can be utilized as a partial substitute for river sand in ordinary construction projects, particularly in locations where river sand is scarce and leftover Sandcrete blocks are easily accessible. As a result of their negligible rate of decay, these shattered Sandcrete bricks will pose less of a hazard to our environment. Machines should be fabricated to crush these broken Sandcrete blocks in large quantities. From this study, the following conclusion can be drawn:

- CSB met the aggregate requirement for zone 1 grading limit (Bledzki and Gassan, 1999) of fine aggregate and is, therefore, suitable for use as a partial replacement for river sand in concrete.
- CSB can be used to create concrete with lesser weight, which results in lower dead loads when building with concrete.
- The strength of CSB-sand concrete decreases with increasing amounts of crushed Sandcrete block.
- The workability of CSB-sand concrete decreases as the CSB content increases.
- Model developed for the prediction of the expected compressive strength of concrete was suitable and worthwhile.

Further studies are recommended to determine the performance of CSB concrete in an aggressive environment. Conclusions should state clearly the main findings of the case report and give a clear explanation of their importance and relevance.

5. References

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