VOL. 7, NO. 9, SEPTEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RECYCLING DEMOLITION WASTE SANDCRETE BLOCKS AS AGGREGATE IN CONCRETE

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ABSTRACT

Construction and demolition waste generated by the construction industry and which posed an environmental challenge can only be minimized by the reuse and recycling of the waste it generates. Therefore, this study seeks to utilize sandcrete blocks from demolition waste as an alternative material to fine aggregate in concrete. A concrete with compressive strength of $30N/mm^2$ at 28 days hydration period was designed for normal mixture as the control. The fine aggregate was replaced with crushed waste sandcrete block (CWSB) in various percentages in the steps of 10 starting from 10% to a maximum of 100%, while 0% represents the control. The properties of the concrete were evaluated at 7, 14 and 28 days curing periods. Results showed that replacing 50% of CWSB aggregate after 28 days curing attained the designed compressive strength as the conventional concrete (i.e., the control). Thus it is concluded that CWSB can be used as a supplementary aggregate material in concrete.

Keywords: sandcrete blocks, recycling, demolition waste, compressive strength, density, water-cement ratio.

1. INTRODUCTION

Aggregate as stated in ACI E1-07 [1] is granular material such as sand, gravel, crushed stone, blast-furnace slag, and lightweight aggregates that usually occupies approximately 60 to 75% of the volume of concrete. Aggregates can be processed from wastes that abound in the construction and other industries for use in mortar and concrete. The activities of renovation and demolition in the maintenance and modernization of buildings generate large amounts of solid waste and rubbles. Currently efforts are being intensified in the utilization of this waste in all areas of construction, mostly in civil and building construction, with the aim of achieving environmentally sustainable developments.

Construction and Demolition (C and D) wastes can be grouped into concrete, blocks, bricks, mortar, rods, wood and metals. The reuse of this waste will help to conserve limited resources, conserve energy, save cost and protect the environment. One avenue of its utilization is in the production of cement based component and as constituent in concrete. In the past 4 to 6 years, the amount of demolition waste generated in Akwa Ibom state, Nigeria, can be estimated to be in millions of tonnes per year. This is as a result of construction activities that are being embarked by various government agencies. The conversion of single carriage way to dual carriage ways, the renovation and re-building of township road network in all the 31 local government headquarters of the state, have caused thousands of buildings to be demolished and subsequently large volume of waste generation. The construction of 1000 housing units in each of the three senatorial districts; renovation and building of public schools, hospitals, and other public buildings have turn out immeasurable volume of construction waste. Unfortunately, these wastes are being disposed in a ravine, about 3Km, along Uyo - Ikot Ekpene road; instead of being crushed for use as aggregate in new concrete.

2. LITERATURE REVIEW

Waste generation from construction and demolition works has become a major challenge worldwide. For instance, Kumutha and Vijai [2] reported that a large quantity of construction waste is generated on yearly basis in India. Umm Kalsum *et al.*, [3] opined that demolition wastes from buildings or houses renovation are being illegally disposed off in most places. Several researches have been carried out on the utilization of C and D wastes in construction. Kenai and Debieb [4] examined the possibility of using crushed clay bricks as coarse and fine aggregate for a new concrete and found out that with the percentage of recycled aggregates limited to 25% and 50% for the coarse and fine aggregates respectively produce concrete with similar characteristics to those of natural aggregates concrete. A substitution of coarse aggregate with crushed fine clay brick up to 40% in concrete at 28 days curing had a higher mechanical strength compared to the natural aggregate concrete [3]. The applications of recycled aggregate as partial replacement of coarse aggregate in the range of 20 to 40% have been reported to be successful [5]. A study by Bairagi [6] concluded that up to 50% of natural aggregate could be replaced by recycled aggregate without seriously affecting the properties of the concrete, both in the fresh and hardened states. Umoh and Kamang [7] investigated the use of waste sandcrete blocks collected from block moulding yards, as partial replacement of fine aggregate in medium grade concrete of $20N/mm^2$, $25N/mm^2$ and $30N/mm^2$. The results indicated that the 28 days design strength was met with percentages replacement of 40%, 60%, and 50% for $20N/mm^2$, $25N/mm^2$ and $30N/mm^2$ respectively. In Nigeria, sandcrete blocks is widely used in the construction of walls over other types of walling units such as bricks, concrete, stone, timber, or metal. Sandcrete block is produced from intermixing of sand, cement and water, and the result paste moulded into various sizes of 125mm x 225mm x 450mm, 150mm x 225mm x 450mm and 225mm x 225mm x 450mm; and when sufficiently dried are laid with the use of mortar to form the wall which could be load bearing or non-load bearing. The quality of blocks produced is a function of the properties of the materials and the method of production employed [8]. Therefore, the fine aggregate constituent plays a role as the source of the material can influence the quality. In this study, the recycled sandcrete block from demolished buildings was used to establish its effect on the workability, compressive strength and density properties of concrete.

3. MATERIALS AND METHODS

3.1 Materials

The cement used was ordinary Portland cement-UNICEM brand. Consistence of standard paste, initial and final setting time tests were conducted to assess conformance with NIS 447 [9]. Waste of sandcrete blocks were collected from building demolition sites. The blocks were manually crushed and sieved with 4.75mm size. Particles retained on the sieve were re-crushed and sieved again. Sample that passed 4.75mm and retained in 75um were used. Sieve analysis; silt content, specific gravity, bulk densities, water absorption and porosity tests were conducted on the crushed sample. The sample was soaked in water for 24 hours, removed and air dried in the laboratory for 48 hours to bring it to approximately saturated surface dry (SSD) condition before use. The natural sand used as fine aggregate was that of river-bed sand passing 4.75mm sieve and falls within zone 1 as shown in Table-1; while the coarse aggregate was quarried granite of nominal size 20mm. The water used for mixing was portable drinking water which was deemed fit for human consumption.

3.2 Methods

Three basic concrete were used: (1) Conventional concrete, that is, concrete containing cement, natural sand as fine aggregate and granite as coarse aggregate, (2) Concrete containing cement, crushed waste sandcrete blocks (CWSB) as fine aggregate and granite as coarse aggregate, and (3) Concrete containing cement, granite as coarse aggregate, combination of both CWSB and natural sand as fine aggregates. A mix design method published by the Department of Environment [10] was applied and a concrete of characteristics strength of 30N/mm^2 at the age of 28 days was designed. In the mix containing CWSB and natural sand, the percentage replacement of the natural sand with CWSB was done by weight and varied at intervals of 10% up to a maximum of 100%. The mixtures were maintained at medium workability level monitored using slump and compacting factor tests. A total of 99 concrete specimens of 150mm cube size were cast. The concrete constituents were manually mixed until a homogenous consistence was achieved before being cast. After casting they were properly covered with wet wooden bags to prevent flash set, and de-moulded after 24 hours. The specimens were immersed in water in a curing tank until their testing ages after 7, 14 and 28 days of hydration. Compressive strength tests were carried out using compression testing machine of capacity 2000KN.

4. RESULTS AND DISCUSSIONS

The results of the initial and final setting times of the cement were 102 minutes and 215 minutes respectively. These values were within the recommended setting times given by NIS 447 [9]. The sieve analysis on the crushed waste sandcrete block is presented in Table-1. The CWSB falls within grading limits for zone one fine aggregate and therefore suitable for use in concrete [11]. The physical properties such as specific gravity, silt content, bulk densities, water absorption and porosity values of the CWSB and the Natural sand are presented in Table-2. The specific gravity and the bulk densities of the CWSB is less than that of the natural aggregate; whereas, the silt content, water absorption and porosity were higher than that of the natural sand. The same phenomenon exists with the earlier finding [6]. The higher water absorption of 28.74% can be attributed to the mode of sandcrete blocks formation which according to Addleson [12] stated that the high porous nature of artificial aggregates is as a result of the fact that these materials have been formed from materials containing vast quantities of water in manufacture. Sandcrete blocks which are made by the addition of water during preparation before moulding is bound to have a high water absorption value.

Table-1. Sieve analysis of fine aggregates.

BS sieve (mm)	CWSB aggregate			Natural sand aggregate			BS 882 Limit for Zone 1
	Material retained		Cumulative % passing	Material retained		Cumulative % passing	
	(g)	(%)		(g)	(%)		
4.75	0	0	100	0	0	100	90-100
2.35	139	14.84	85.2	97.5	8.03	92.0	60-95
1.18	155	16.56	68.6	338.0	27.84	64.0	30-70
0.600	410	43.80	24.8	585.0	48.19	16.0	15-34
0.300	175	18.70	6.1	114.0	9.42	7.0	5-20
0.150	48	5.13	1.0	74.1	6.10	1.0	0-10
0.075	9	0.96	-	5.0	0.41	-	-

Table-2. Physical properties of fine aggregates.

Properties	CWSB	Natural sand
Specific gravity	2.40	2.63
Silt content (%)	5.22	0.12
Loose bulk density (kg/m^3)	1490	1567
Compacted bulk density (kg/m^3)	1564	1833
Water absorption (%)	28.74	5.42
Porosity (%)	11.22	2.84

4.1 Workability

4.1.1 Slump and compacting factor

Table-3 shows the slump and compacting factor values for all the mixes. It was observed that the slump and the compacting factor values increased in the same direction, that is, increase in the value of the slump caused a corresponding increase in the value of the compacting factor. The values of slump fall within the range of 30-60mm as stipulated [10] for medium workability level. However, the slump of the concrete without CWSB was less than that of concrete mixtures incorporating CWSB. The relation between slump and the CWSB content on one hand, and Compacting factor with CWSB content on the other show strong positive linear relationship (Figures-1 and 2).

Table-3. Slump and compacting factor values.

CWSB content (%)	Slump (mm)	Compacting factor
0	42	0.87
10	43	0.87
20	46	0.88
30	48	0.88
40	48	0.88
50	50	0.89
60	54	0.88
70	55	0.89
80	56	0.89
90	54	0.90
100	58	0.90

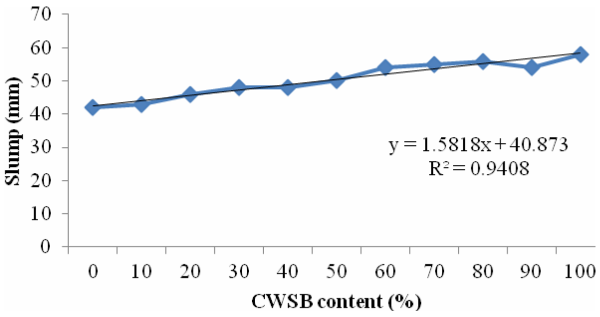

Figure-1. Variation between slump and CWSB content.

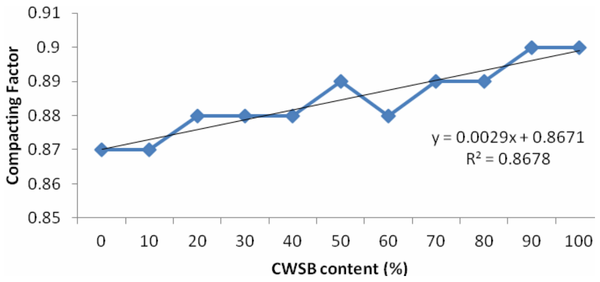

Figure-2. Variation between compacting factors with CWSB content.

4.2 Water-cement ratio

In order to maintain the same workability range with mixes containing CWSB aggregate a higher water content was required. This had been the reason for the gradual increased in the value of water-cement ratio as the percentage of the CWSB aggregate increases (Table-4). This higher water demand in mixture incorporating CWSB aggregate is as a result of high silt content and absorptive capacity of CWSB aggregate used. The relation between water/cement ratio and percentage of CWSB content as shown in Figure-3 indicated a high correlation value R of 99.75%.

Table-4. Water- cement ratio for various cwsb content.

CWSB content (%)	Actual water/cement ratio
0	0.48
10	0.50
20	0.52
30	0.54
40	0.56
50	0.58
60	0.60
70	0.62
80	0.65
90	0.65
100	0.68

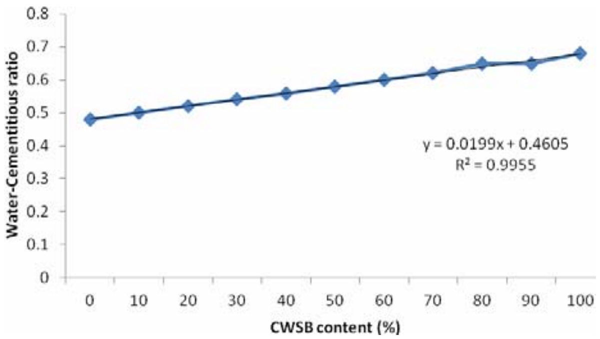

Figure-3. Variation between water/cement ratio and CWSB content.

4.3 Compressive strength

The compressive strengths up to 28 days hydration for various percentages of natural sand replacement with crushed waste sandcrete blocks are presented in Figures 4, 5 and 6. In Figures 4 and 5, it shows that the compressive strength continually increased with curing age but decreases with increased in the content of CWSB replacement of natural sand. Whereas, in Figure-6 only conventional concrete (i.e., 0% CWSB content) attained 62% of the design strength at 7-day hydration, and 10%, 20% and 30% CWSB could attain 50% and above of the same design strength. It means that concrete with CWSB as fine aggregate cannot compare favourably with early strength development of conventional concrete which should attain up to 60% of the 28-day design strength at 7-day [13]. Similar result was obtained by Zakaria and Cabrera [14] who reported that the relatively lower strength at early curing age for bricks and artificial aggregate concrete was attributed to the higher water absorption values of these aggregates. At 14-day hydration, it was observed that mixes containing up to 30% CWSB attained above 60% of the design strength at 14-day hydration; while mixes containing 10% to 50% CWSB made over 100% of the targeted strength at 28-day hydration as expected. This low strength exhibited by mixtures containing CWSB can be attributed to the high pores content and water absorption capacity of the CWSB, which resulted in low bonding between it and the cement paste. This finding is in conformity with Neville [15] which stated that the porosity of aggregate, its permeability and absorption influence the bond between it and the cement paste and consequently the low strength of the concrete.

However, the compressive strength values obtained for CWSB replacement of natural sand of up to 50% compare favourably with the conventional concrete, and also meet the targeted design strength of 30N/mm^2 at the standard age of 28 days. Therefore, 50% CWSB content could be taken as the optimum replacement level in the production of medium grade concrete. The same phenomenon exists with similar investigation on the use of waste sandcrete block and crushed brick (waste) as fine aggregate which established that a replacement level of 50% is adequate to produce concrete of similar characteristics to natural aggregate concrete [4, 7].

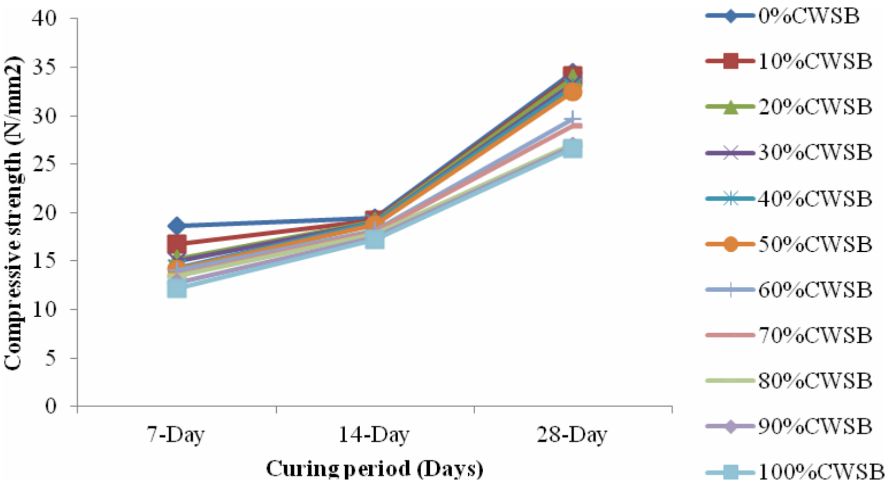

Figure-4. Variation of compressive strength with hydration period for varying percentage of CWSB content.

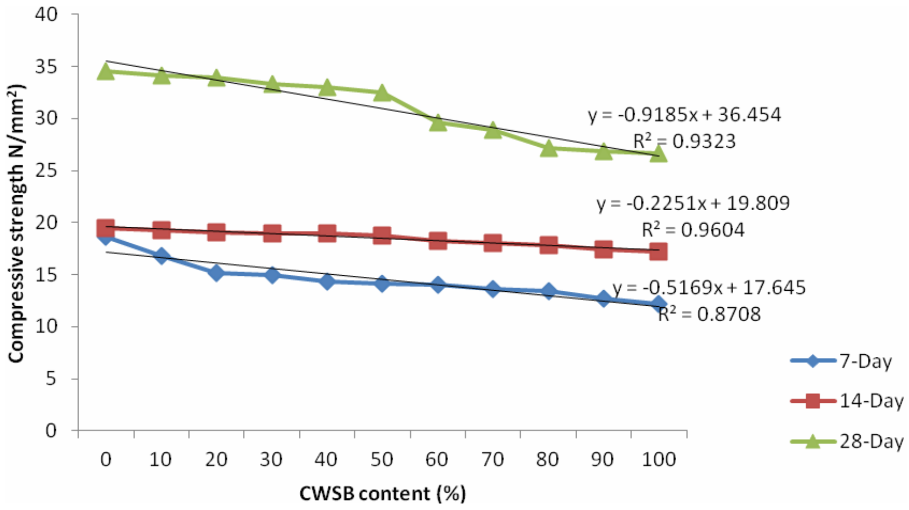

Figure-5. Variation of compressive strength with percentage CWSB content at 7, 14 and 28 days hydration period.

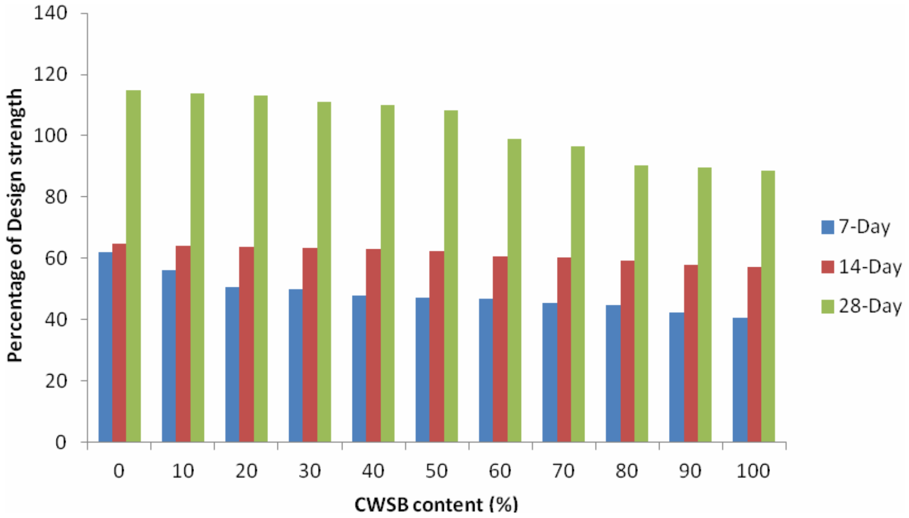

Figure-6. Variation of CWSB content to percentage attainment of design strength.

4.4 Relationship between water - cement ratio and compressive strength

It was observed in Figure-7 that with a higher Water-cement ratio, the compressive strength was lower and vice versa. This relationship between the compressive strength and the water - cement ratio, which is said to inversely proportional, is as a result of a full compaction done on the concrete during casting. Neville [15] stated that the strength of concrete at a given age and cured at a prescribed temperature depends primarily on the water - cement ratio and the degree of compaction. He further observed that for a fully compacted concrete the strength is inversely proportional to the water - cement ratio. This relationship was obeyed with the use of the CWSB as aggregate in concrete. It is envisaged that with water - cement ratio in the range of 0.4 to 0.58, the strength development of concrete containing CWSB will be comparable with that of conventional concrete of the same design strength.

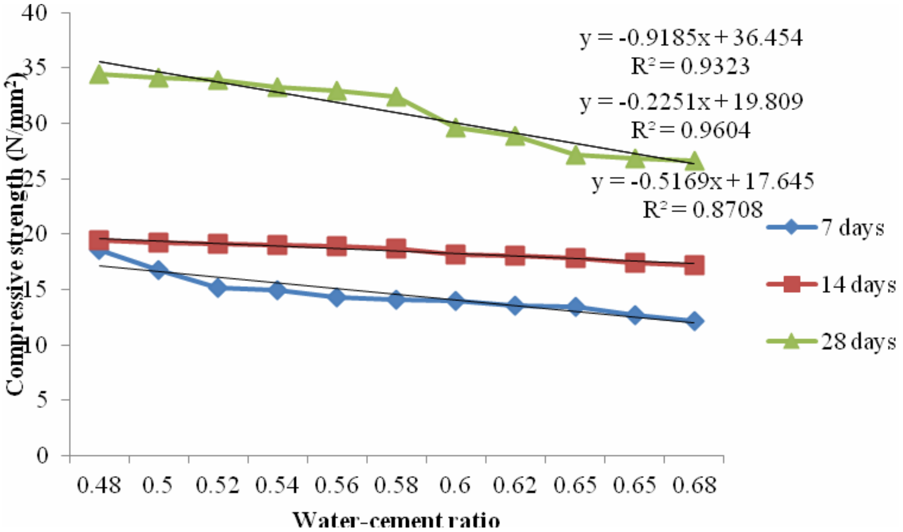

Figure-7. Variation of compressive strength and water - cement ratio.

4.5 Density

The density of the hardened concrete was tested. Table-5 shows the average values and the percentage of variations for each mixture in comparison with the conventional concrete (that is, 0% CWSB - denoted as 'A'). The findings indicated that the density decreases as the percentage of CWSB content increases, and that the density of sample 'A' exhibits the highest values while concrete containing CWSB have less values. This value agreed with Topcu and Guncan [16] which report that the density of concrete made with recycled concrete aggregate is less than that of the normal concrete. The low density can be related to the high porosity of the CWSB which contributes to the overall porosity of the concrete; this assertion is also reported by Neville and Brooks [17] which stated that density of concrete is a function of aggregate pore space.

Table-5. Density of CWSB concrete for different curing ages.

Specimen	**CWSB content** (%)	**Density** (Kg/m^3)		
		7 days	**14 days**	**28 days**
A	0	2548 (0.00)	2550 (0.00)	2578 (0.00)
B	10	2546 (-0.08)	2548 (-0.08)	2578 (0.00)
C	20	2545 (-0.12)	2578 (-0.08)	2577 (-0.04)
D	30	2545 (-0.12)	2546 (-0.16)	2572 (-0.23)
E	40	2544 (-0.16)	2542 (-0.31)	2564 (-0.54)
F	50	2543 (-0.20)	2530 (-0.78)	2541 (-1.44)
G	60	2542 (-0.24)	2532 (-0.71)	2514 (-2.48)
H	70	2540 (-0.31)	2459 (-3.57)	2502 (-2.95)
I	80	2538 (-0.39)	2459 (-3.57)	2489 (-3.45)
J	90	2534 (-0.55)	2459 (-3.57)	2474 (-4.03)
K	100	2530 (-0.71)	2444 (-4.16)	2459 (-4.62)

In bracket (X density - 'A' density) x 100/ 'A' density, with X representing any of the 10 samples ('B' to 'K') type of concrete.

4.6 Relationship between density and compressive strength

In Figures 8, 9 and 10 the compressive strength of the concrete was found to increase as the density increases for the curing ages of 7, 14 and 28 days hydration periods. A strong linear relationship of R values in the range 0.934 to 0.965 was exhibited.

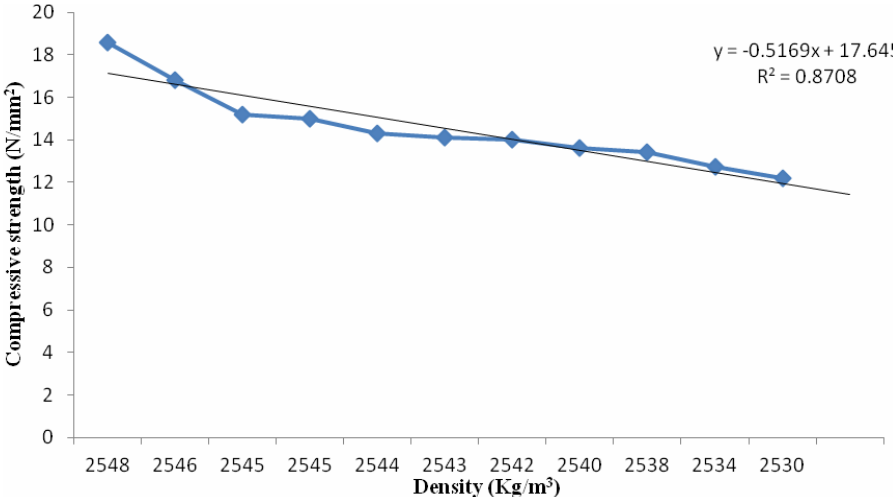

Figure-8. Variation of compressive strength with density at 7 days hydration period.

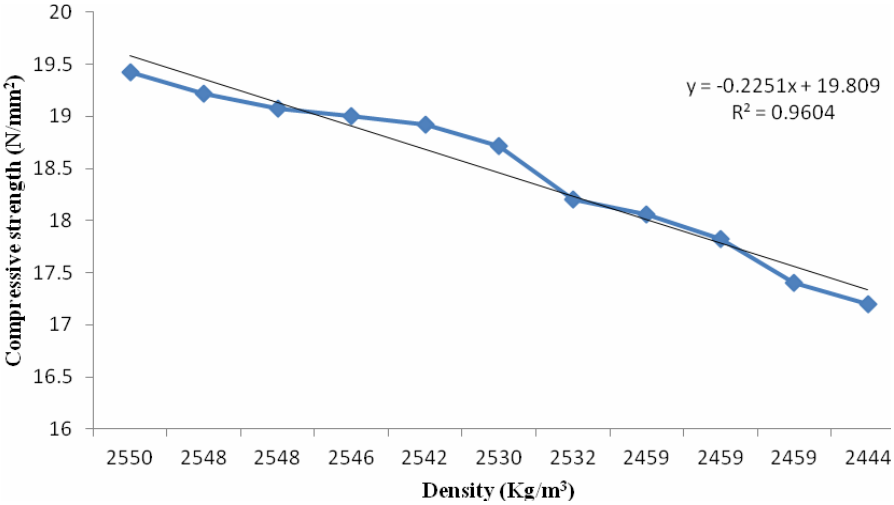

Figure-9. Variation of compressive strength with density at 14 days hydration period.

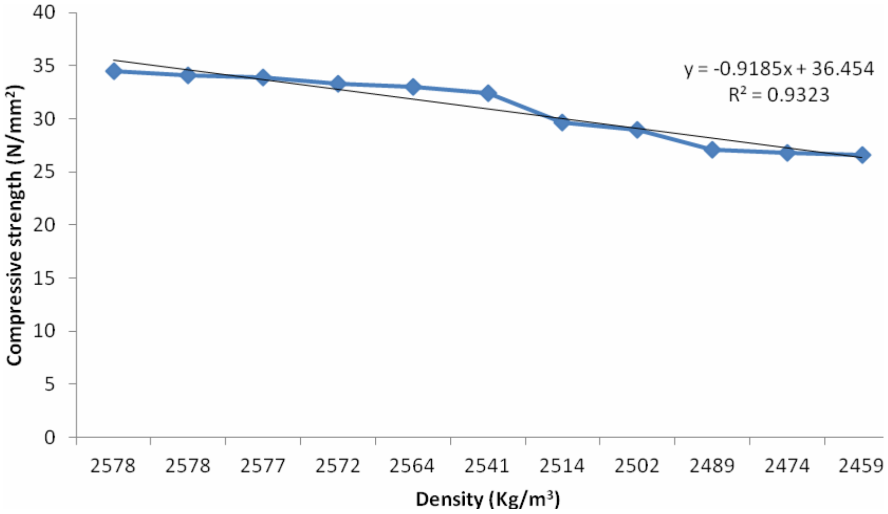

Figure-10. Variation of compressive strength with density at 28 days hydration period.

5. CONCLUSIONS

The following conclusions were drawn from the study:

a) The sieve analysis conducted on the CWSB met the aggregate requirements for concrete as spelt out by BS 882 (1992).
b) The specific gravity and the bulk densities of the CWSB were less than that of the natural sand.
c) The silt content, water absorption and porosity of the CWSB were higher than that of the natural sand.
d) Higher water content was required for mixtures containing CWSB to attain the same workability range as the conventional concrete thereby increasing the water-cement ratio as the CWSB content increased.
e) The design strength of $30\mathrm{N/mm^2}$ for normal concrete was attained with a CWSB content of up to 50% content.
f) The relationship between water-cement ratio and compressive strength was found to be inversely proportional.
g) The density of the concrete decreases as the percentage of the CWSB content increases.
h) Concrete containing up to 50% CWSB as fine aggregate compared favourably with normal concrete mixture and therefore 50% CWSB content is taken as the optimum for $30\mathrm{N/mm^2}$ design characteristic strength.

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