International Conference on Sciences, Engineering & Environmental Technology (ICONSEET), 7(13): 105 – 111, 2022

ISSN 0794-9650

www.repcomseet.org

THE SUITABILITY OF BROKEN BOTTLES AS A PARTIAL REPLACEMENT FOR RIVER SAND IN THE PRODUCTION OF HOLLOW SANDCRETE BLOCKS

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Abstract: Sandcrete block is a common material used as a building component in Nigeria and other nations of the world. It comprises of sand, cement and water. This research work examines the appropriateness of broken bottles as a partial replacement for natural sand in hollow sandcrete blocks production. The laboratory tests such as sieve analysis, moisture content as well as specific gravity tests were carried out on fine aggregates. The mix ratio of 1:6 was utilized and the batching was done by weight. 75 specimens of 450 mm x 225 mm x 225 mm hollow sandcrete blocks were moulded. The curing was done by wetting twice per day. The compressive strength test was performed on the sandcrete blocks for each percentage substitution on 3, 7, 14, 21and 28 days. The percentage of broken bottles replacement used were 0%, 5%, 10%, 15% and 20%. The results of sieve analysis of the fine aggregates showed that both the sand and broken bottles had higher percentage of coarse followed by medium and very small quality of fine aggregates. The moisture content result of sand was 0.066 which was insignificant. The values of specific gravity for sand and broken bottles were 2.35 and 2.36 respectively. It was found out from the results of the compressive strength tests that at 15% replacement of broken block yield a solid core sandcrete blocks suitable for non load bearing wall of a building. Since broken bottles are waste materials causing environmental pollution. Its uses will reduce the pollution and also enhance cost effective sandcrete blocks for the building purposes
Keywords: Broken Bottles, Compressive Strength, Curing, Pollution, Sandcrete Blocks

1.0 INTRODUCTION

Sandcrete is a composite material that is made up of cement, sand and water at an appropriate ratio which can be moulded into different sizes and shapes. They are used lengthily in virtually all African countries where Nigeria is not exempted. Hollow sandcrete blocks are generally utilized in partition and load bearing walls. The blocks are popularly utilized in Nigeria for the construction of load bearing as well as non-load bearing structures because the constituents of the blocks are available and they are averagely affordable (Odeyemi *et al*., 2018. Alohan (2012) reported that sandcrete block components provide means of controlling the effect of winds and infiltration of moisture. The sandcrete blocks are used in this part of the world as a result of its lower cost and adaptableness to environmental circumstances and all these make it extensively utilized in so numerous building construction works (Odeyemi *et al*., 2015; Odeyemi *et al*., 2018). Rigassi (1995) identified four major type blocks namely hollow blocks, perforated blocks, solid blocks and interlocking blocks. According to Baiden and Tuuli (2004) and Anosike and Oyebade (2012), majority of buildings in West Africa are built with sandcrete blocks and this makes them a valuable construction material for building. Anosike and Oyebade (2012) reported that after proper curing of sandcrete blocks, they are expected to have compressive strength stated in NIS 87:2007 between the value of 2.5 N/mm^2 and 3.45N/mm^2; this increases with an upsurge in density. However, the blocks are widely produced by artisans in several parts of Africa without following at all national or international specifications. Nonetheless, Odeyemi (2012) and Odeyemi *et al*. (2015) reported that sandcrete blocks are absolutely inexpensive when likened with other building materials. Moreover, they have higher resistance to crumbling, rusting, pest attack, insect and are non-toxic when likened with other materials used to construct building. Block moulding technology is now the backbone of infrastructural development in many countries (Onwuka *et al.*, 2013). Sandcrete blocks are the most popular and the commonest masonry walling components in Nigeria.

Sand is one of the major materials used in hollow sandcrete blocks production. It takes above 80% of the constituents of the blocks. As the cost and demand of the sand increasing on a daily basis, there is a need for other alternative materials that can serve the same purpose as sand in hollow sandcrete blocks. The researchers have worked on other alternative materials such as broken bottles, palm kernel shells, laterite soil, coconut husk etc. The Research work is aiming at using broken bottles as a partial replacement for sand in the hollow sandcrete blocks production.

Otokpa (2008) stated that broken bottles are non-crystalline, non-plastic and hard materials. They are clear, transparent with thickness varying between 0.5 mm and 0.8 mm. The shape of the broken bottles depends on the shape of their parent bottles. Glass or broken bottle is a singular inert substance which can be recycled numerous times without affecting its chemical compositions. Unluckily, many broken bottles are not good for recycling due to numerous factors. First of all, the effectiveness of the method of collecting and categorizing for different glass colours, where different colours (clear, orangey, green etc.) are mixed, they become incompatible for producing new glass materials. Secondly, it is affected by the intensity of contaminates that might be presented in the build up stocks, and lastly the cost of transportation. In view of the fact that recycling factories are not in all the cities in the countries. Therefore, the key reason of environmental authorities is to lessen, as far as likely, the dumping of post-consumer glass in landfill or reprocess to glass goods. Consequently, it has been supposed that, if glass wastes can be used for building construction, it would drastically lessen the waste glass disposal or its utilization in lower esteemed works like in road construction and back filling materials (Shayan, 2002). Moreover, the major challenge in the utilization of waste glass in construction of building is the chemical reaction that is always occur between the alkali in cement and the silica-rich particles of glass (glass aggregate) (Shao *et al.*, 2000).

The use of broken glass in block production is a good direction for broken bottles recycling. The application of broken bottles in blocks making is an alternative way that helps to management of glass waste effectively and provides good environmental controls. Similarly, further advantages of using broken bottles in the production of hollow blocks comprise reduction of greenhouse gases emissions, conservation of natural resources from further exhaustion and obtained energy savings, in that way achieving sustainability and environmental greening (Olofinnade *et al.*, 2017; Albatayneh *et al.*, 2017). The utilization of recycled bottles as substitute for fine aggregate decreases the amount of materials cost for concrete (Tomas *et al.*, 2013). Weihua *et al.* (2000) reported that glass (bottles) utilized as aggregate for mortar and concrete has no reaction at all with the fine aggregates. Therefore, this indicates the viability of the waste glass use again as fine aggregates in mortar and concrete. However, he concluded that the percentage of glass in concrete should be small.

2.0 MATERIALS AND METHODS

The materials utilized and the methods of investigation adopted in this research work are thus presented.

2.1 Materials used for the Production of Hollow Sandcrete

The research materials used were river sand, cement, broken bottles and water. Table 1 shows the quantities of the materials used.

2.1.1 River sand

The river sands used are of 4.75 mm and smaller that is those who pass through a number 4 sieve. The sands were taken from Owere streams in Ede, Osun state, Nigeria. They were free from loam, dirt, organic matter and clay. The moisture content of the sand is 0.066 whereas the specific gravity is 2.35

2.1.2 Broken bottles

The broken bottles used were obtained from Brewery station, where broken were deposited in Osogbo, Osun State. The bottles were grounded into fine aggregates as shown in Plate 1. The specific gravity of the broken bottles is 2.36.

Plate 1: Grounded Broken Bottles

2.1.3 Cement
The cement used for this work is Dangote brand type of cement. It is in accordance with BS 12 (British standard Institution of 1971).

2.1.4 Water
Colourless, odourless, tasteless, portable water that is free from organic matter was used for the production and curing of the sandcrete blocks.

2.2 Production of Hollow Sandcrete Blocks

The mix proportion of 1:6 was utilized for this research work. 225 x225 x 450 mm block sizes were produced. The sand was replaced with broken bottles at 0% (control), 5%, 10%, 15% and 20%. Details of the mixture proportion for different percentages replacement of sand are shown in Table 1. The batching of the aggregates and cement were done by mass. In the manufacturing of the blocks, manual method was employed using spade. The aggregates were mixed with cement in dry state on a clean bay until homogeneity was achieved. Water was added until remarkable and workable mixes were obtained. The resulting mortar was rammed into a vibrating machine mould; it was compacted and smoothed off. The blocks produced were removed from the machine moulds and they were left on wooden pallets under a shed for the curing periods. The procedure was repeated for all percentage replacements. A total number of 75 blocks were produced. The hollow sandcrete blocks produced were cured by sprinkling of water two times daily at morning and night before crushing at day 3, 7, 14, 21 and 28 curing age.

The compressive strength tests were done at age 3, 7, 14,21and 28 days. Three specimens were crushed at each curing age and each percentage replacement of river sand with broken bottles.

Table 1: Mixture Proportion for Different Percentage Replacement of Sand

Sand Replacement (%)	Cement (kg)	Broken bottles (kg)	Sand (kg)
0	27.27	0	272.72
5	27.27	13.60	259.12
10	27.27	27.27	245.45
15	27.27	40.90	231.82
20	27.27	54.54	218.18

3.0 RESULTS AND DISCUSSION

3.1 Sive Analysis of Broken Bottles and Sand

The sieve analysis results of broken bottles together with sand are presented in Fig. 1. It can be deduced from the Fig. 1 that both the sand and broken bottles had higher percentage of coarse followed by medium and very small quality of fine aggregates. From the figure presented, the grading of both aggregates is very close. The grading is suitable for fine aggregates in sandcrete blocks as specified in BS 882 (1992).

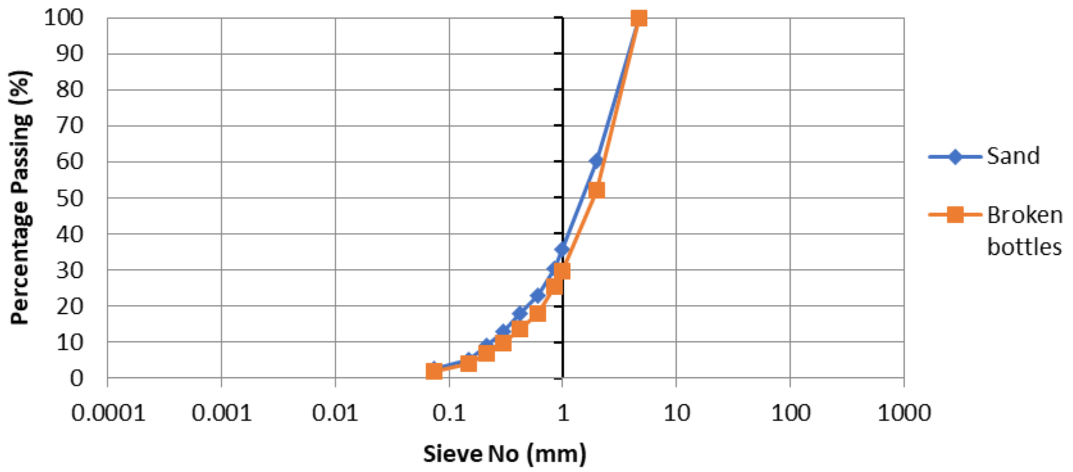

Fig. 1: Sieve Analysis for Sand and Broken Bottles

3.2 Compressive Strength

The outcomes of the compressive strength are presented in Fig. 2. The value of the result shows that strength of sandcrete blocks increase as the day of curing increases. The blocks develop more strength as the hydration of cement increases under adequate curing and temperature. However, the value of the results decreases as the quantity of broken bottles present in the making of the sandcrete blocks increases. This may be as a result of the following: bonding between cement pastes and the broken bottles, shape of the broken bottles and the texture of the broken bottles. This is similar to the outcome of the research carried out by Abdulwahab (2015). Furthermore, broken bottle cannot retain water like sand and this reduced the rate of hydration of cement in the sandcrete blocks containing broken bottles as fine aggregate and thus reduce the strength of the blocks produced. This is in line with the results obtained by Tomas *et al.* (2013).

The compressive strength of control at 28days is 3.52N/mm^{2}and 5% replacement reduces by 6% when compared with the control. However, 10% and 15% replacement reduce by 26% and 28% respectively when compared with the control. The mix with 20% replacement does not fall within the range of strength specified for blocks by NIS (2000) which is between 2.5 N/mm^{2}and 3.45 N/mm^2. Thus, 5% of broken bottles can be used for load bearing wall where strong structural strength is not required and up to 15% replacement can be utilized for non-load bearing walls.

The mathematical equations for forecasting compressive strength of broken bottle sandcrete blocks gotten from the linear regression analysis results are also depicted in Fig. 3. For illustration, for 0% of broken bottles, the equation of compressive strength at 3 days of curing is

$$y_3 = 0.399x + 1.433 \quad ---------- \quad (i)$$

Where y_3 is the 3 days compressive strength in N/mm^2 of broken bottle sandcrete block and x is the days of curing. Likewise, for 5% of broken bottles, the equation of strength at 7 days of curing is

$$y_7 = 0.349x + 1.453 \quad ------ \quad (ii)$$

For 10% of broken bottles, the equation of strength at 14 days of curing is

$$y_{14} = 0.24x + 1.589 \quad ---------- \quad (iii)$$

For 15% of broken bottles, the equation of compressive strength at day 21 curing age is

$$y_{21} = 0.285x + 1.345 \quad ---------- \quad (iv)$$

For 20% of broken bottles, the equation of strength at 28 days of curing is

$$y_{28} = 0.28x + 1.036 \quad ---------- \quad (v)$$

From equations (i) – (v), it displays that there is linear relationship between strength of sandcrete blocks and percentage of broken bottles. This implying that the strength of sandcrete block diminutions as the percentage of broken bottles increase and upsurges as the days of curing increases. Moreover, the R – square value of the sandcrete blocks containing 5% and 10% of broken bottles in the Fig. 2 are closer to 1 while those containing 15% and 20% of broken bottles are not closer to 1. This means that the linear relationship between compressive strength of sandcrete blocks containing 5% and 10% broken bottles and the days of curing are more accurate than the one containing 15% and 20% broken bottles.

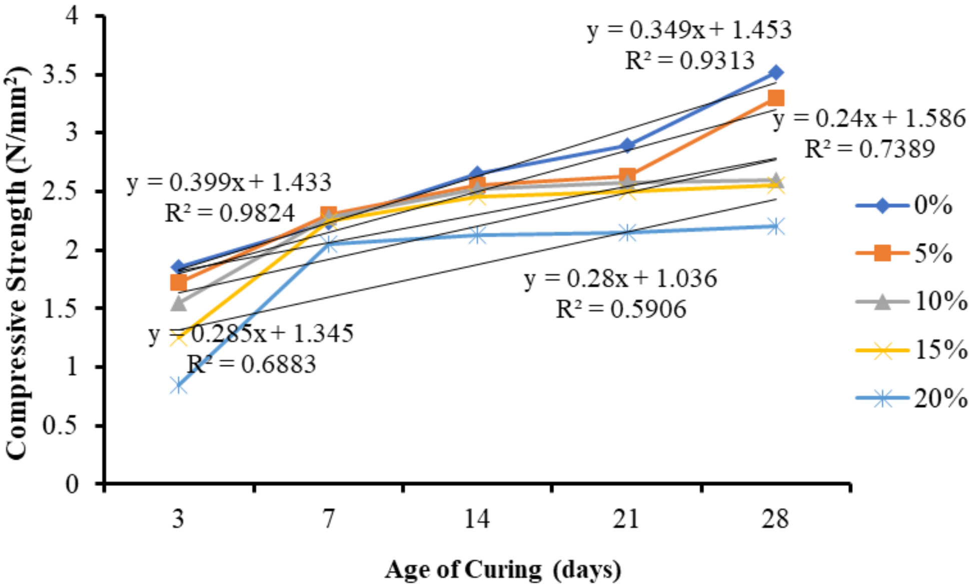

Fig. 2: Effect of Curing Days on the Compressive Strength of Hollow Sandcrete Blocks Containing Different percentages of Broken Bottles

4.0 CONCLUSION

The subsequent conclusions were drawn from the results of the tests carried out:

1. The grading of broken bottles as fine aggregates is very close to that of sand. Thus, broken bottles are suitable to be used for fine aggregate in sandcrete blocks.
2. The compressive strength of sandcrete blocks always upsurges as the curing days upsurges too. The sandcrete blocks produced with 0% broken bottle has the highest strength values than the sandcrete blocks produced with different percentages of broken bottles.
3. As the percentages of broken bottle increases, the strength of sandcrete block decreases
4. The compressive strength of the sancrete blocks containing 5% and 10% broken bottles obtained at 28 days are 3.31 N/mm^2 and 2.60 N/mm^2. These strengths indicate that broken bottles have the potential to replace natural fine aggregate and could be used for load bearing wall where strong structural strength is not required.
5. The use of broken bottles in sandcrete blocks is an effective method of reducing the cost of sandcrete blocks production since the broken bottle is a waste and has no cost value.

ACKNOWLEGEMENT

The assistance received from Surajudeen Kolawole, Aderibigbe Usman Akin and the laboratory Technician in person of Mr Yisa Adegbile of Civil Engineering department, Federal Polytechnic Ede, Osun state, Nigeria worth mentioning. They are therefore acknowledged.

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