



Effects of Glass Wool Fibre on the Strength Properties of Hollow Sandcrete Block

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Blocks are widely used in construction industry for both load and non-load bearing walls, blocks are of different forms and shapes and the most common is hollow sandcrete blocks. Glass wool fibre is an industrial waste product which can be turned to a useful material in the construction industry. The effect of glass wool fibre on the strength properties of hollow sandcrete blocks was investigated.

Sieve analysis was done on the sand used. The batching of the materials were done by weight and the mix ratio used was 1:8 with an average water-cement ratio of 0.5. Block samples of 150x225x450 mm (6" block) were produced by hand moulding process. Glass wool fibre at 0%, 5%, 10%, 15% and 20% of cement were added to the mix and compressive strength test was done by the ADR Touch 1500 kN Compression Testing Machine on the block samples.

The Coefficient of Curvature (Cc) and Coefficient of Uniformity (Cu) of the sand were 1.04 and 4.47 respectively, the sand is well graded. The compressive strength test results of an average of 0.6, 0.8, 0.9, 1.1 and 0.4 N/mm² were obtained respectively.

It was concluded that the compressive strength of the hollow sandcrete block gradually increased and attained the maximum strength at 15% addition of glass wool fibre which is 33% increase in the compressive strength, where the weight also decreased by 1.6%. Therefore, the block at 15% addition of glass wool fibre can be used for non-load bearing walls such as fence and partition walls in building construction.

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1. INTRODUCTION

Blocks are widely used in construction industry for various jobs. The quality of block depends on the materials used and the method of production, a block can be either hand mould or machine fabricated.

British Standard 6073 [1] part 1 defines a block as a masonry unit of large size in all dimensions than specified for bricks but no dimension exceeds 650 mm nor should the height exceed either its length or six times its thickness.

Sandcrete blocks according to Nigerian Industrial Standard (NIS) 87 [2] is a composite material made up of cement, sharp sand and water and moulded into different shapes and sizes. Sandcrete blocks are widely used as load bearing and non-load bearing walling units in the construction industry and are very important in building construction (Table 1). Over 90% of physical infrastructures in Nigeria are being constructed using sandcrete blocks Abdullahi [4].

According to Yusuf and Hamza [5] the three main forms of sandcrete blocks are solid, cellular and hollow. Hollow sandcrete blocks are more economical in terms of weight, density and compressive strength, they are commonly used in construction works. Most commonly available hollow sandcrete blocks used in construction industry are, 150 mm x 225 mm x 450 mm (6" block) and 225 x 225 x 450 mm (9" block).

The range of minimum strength specified in NIS 87 [2] is between 2.5 N/mm² to 3.45 N/mm². Measured strengths of commercially available sandcrete blocks in Nigeria was found to be between 0.5 and 1 N/mm² which is far below the required strength.

Addition of coarse aggregates has been tried to improve block strength, since this is a cheap way to increase compressive strength, but since the

cement content of sandcrete is small, and the amount of water that is added to the sand/cement mix to cure it is also small even though there is a standard for cement and fine aggregate mix ratio and water-cement ratio also adding more solid materials makes the mix much less fluid, making it difficult to cast into blocks. Addition of solid materials will increase the weight of hollow sandcrete block which may not be safe and economical to use.

Glass fibre is in form of thin fibres of smaller diameter and have mechanical properties that is similar to carbon fibres and polymers although not as rigid as carbon fibres. According to Richard [6] glass fibre typically has a silica content greater than 50 percent, and the composition with different mineral oxides give the resulting product its distinct characteristics. Fibres used for structural reinforcement composites generally fall into the categories of E-glass, AR-glass and S-glass, of all the fibres available for structural strengthening and reinforcement, E-glass is by far the most used and is the least expensive.

The most common glass fibre is E-glass (alumina-calcium borsilicate glass), it is strong in tension that will help the sandcrete block to support tensile load for load bearing block, it is also alkali free, which will reduce the alkali-silicate reaction of cement in sandcrete block. It can undergo elongation before it breaks unlike other rigid materials. Glass fibres are good thermal insulators with thermal conductivity of 0.05 w/(m.k).

The tensile strength and compressive strength of E-glass fibre is 3445 MPa and 1080 MPa respectively, which is significantly high more than the compressive strength of block (which is 4.6 N/mm² maximum). A combination of glass fibre and sand in the production of sandcrete blocks will affect the strength to weight ratio of the hollow sandcrete block.

Table 1. Types of blocks and usages

Types of block	Work size (mm) Length x Height x Thickness	Work size (mm) Web thickness	Usages
Solid block	450 x 225 x 100	-	For non-load bearing and partitions
Hollow	450 x 225 x 113	25	For non-load bearing and partitions walls
Hollow	450 x 225 x 150	37.5	For load bearing walls
Hollow	450 x 225 x 225	50	For load bearing walls

(Source: NIS 587: 2007 [3])

This study investigated the effect of glass wool fibre on the production of hollow sandcrete blocks and its strength effectiveness, so as to determine its load-bearing and non-load bearing capability on walling units in the construction industry.

The use of fibre as reinforcement in the construction industry is not a new one. Straws were used for reinforcing mud used in brick production in Egypt. There are archaeological proofs that horse hair were used for reinforcing plaster by the Romans in ancient times.

In recent years steel fibre, polypropylene, cellulose fibres and glass fibres have been used for reinforcing cement products. Cement are hydraulic binders, and they are main binding element in the production of blocks. Cement has various chemical compounds that react with water to harden.

Sandcrete blocks are made from the mixture of sharp sand and cement, the production of sandcrete blocks in the construction industry is important because of the increase in development of both urban and rural areas. It has been studied that sandcrete blocks compressive strength should not exceed 4.60 N/mm^2 compared to the strength of concrete that is 40 N/mm^2 . Today there are various researches on the use of different fibres in the production of cement products to provide alternatives to the material used in the production of sandcrete blocks without compromise the minimum standard for the sandcrete blocks.

Standards Organization of Nigeria, a regulatory authority responsible for quality control of sandcrete blocks production in Nigeria specified a compressive strength value range of 2.5 N/mm^2 to 3.45 N/mm^2 for a load bearing wall and the value range of 1.8 N/mm^2 and 2.5 N/mm^2 for non-load bearing walls.

Sandcrete blocks are blocks made from cement, sharp sand in a ratio 1:6 and water and sometimes other ingredients like pozzolans are added. The sharp sand used gives it a distinct yellow white colour. Sandcrete blocks are usually hollow rectangular blocks with hollow that run from the top to the bottom and occupy around one third of the volume of the block. Thus, properties of sandcrete blocks may be influence by prevailing climatic conditions in an area. The quality of sandcrete blocks produced also depends on the quality of sharp sand Baiden and Tuuli [7].

Hollow blocks are in three major sizes namely: $450 \times 225 \times 100 \text{ mm}$, $450 \times 225 \times 150 \text{ mm}$ and $450 \times 225 \times 225$ and are commonly known as four inches (4"), six inches (6") and nine inches (9") blocks respectively. The blocks are joined together with mortars.

The compressive strength of sandcrete block depends on variables that affect it during production. These include the amount of cement, sharp sand, water, degree of compaction, the curing conditions, the age of the cement and the type of weather. The National Building Code has specified the minimum strength requirements of 2.00 N/mm^2 for sandcrete blocks. The maximum compressive strength of sandcrete block is 4.60 N/mm^2 which is very small to the when compared to the compressive strength of concrete 40 N/mm^2 .

Sorptivity is a measure of the capacity of a porous medium to absorb liquid by capillarity. According to a research done by Oyekan and Kamiyo [8] it was observed that the value of sorptivity of the sandcrete blocks gradually increases with the percentage content of Rice Husk Ash (RHA). This implies that blocks made with cement partially replaced with RHA are not suitable for drainage channels construction but could be useful for partitioning of building spaces.

According to a research done by Manasseh and Utyankpan [9] on the suitability of commercially available sandcrete blocks in Abuja municipal area for use as street side drain walling materials absorption values obtained from the five block moulding factories were higher than the maximum water absorption value of 7% specified for blocks by BS 2028 [10]. Based on the results of compressive strength test and the water absorption test, commercially available sandcrete blocks produced with only sand sample are not suitable for use as side drain walling materials, and this is one of the factors responsible for the collapse of side drain walls observed in Abuja Municipal area.

Glass wool fibre consist of fine, long, inorganic fibres bonded together by high temperature binder. These fibres (each of approx. 6 - 7 microns diameter) are distributed in such a way as to trap millions of tiny pockets of air in the product, thereby creating its excellent thermal and acoustic insulation properties. Glass wool fibre is produced in rolls or in slabs, with different thermal and mechanical properties. It may also

be produced as a material that can be sprayed or applied in place, on the surface to be insulated.

Glass wool fibre is light gold in colour and its superior tensile strength and resilience makes it ideal for applications in the areas vibration, jolting or high compression (Table 2). The light weight and the ease to handle of Glass wool fibre also offers significant advantages during transport and installation. In addition, Glass wool fibre is chemically inert and has no impurities such as iron shots, sulphur and chloride. It is non corrosive to metal and does not support mould grow.

The modern method for producing glass wool is the invention of Games Slayter working at the Owens-Illinois Glass Co. (Toledo, Ohio). Glass wool is manufactured from widely available and renewable raw materials and provides environmental benefits in terms of resource and energy saving in every stage from pre-manufacturing to end use.

The manufacture of a glass wool fibre is very similar to that of glass fibre. After the mixture of natural sand and recycled glass at 1,450°C, the glass that is produced is converted into fibers. It is typically produced in a method similar to making cotton candy, forced through a fine mesh by centripetal force, cooling on contact with the air. The cohesion and mechanical strength of the product is obtained by the presence of a binder that "cements" the fibers together. Ideally, a drop of bonder is placed at each fiber intersection. This fiber mat is then heated to around 200°C to polymerize the resin and is calendered to give it strength and stability. The final stage involves cutting the wool and packing it in rolls or panels under very high pressure before palletizing the finished product in order to facilitate transport and storage. The Glass wool is formed into products with various thickness and densities.

Table 2. Properties of glass wool fibre

Fibre	Glass wool
Specific gravity	2.6
Modulus of elasticity (GPa)	55
Length (mm)	14
Diameter (micron)	8
Aspect ratio	1750
Effect of temperature	Non-combustible

Source: Stamford, CT, Thermal Insulation Manufacturers' Association

2. MATERIALS AND METHODS

2.1 Materials

1. Portland cement
2. Sharp Sand
3. Potable Water
4. Glass wool fibre

2.1.1 Portland cement

The cement used was Elephant Portland Cement which was purchased at a local market at Ajibode Ibadan. It was stored under dry condition to prevent deterioration in its properties due to contact with the moisture, free of lumps it was of grade 32.5R and satisfies the provisions of NIS 444-1 [11] and BS 12 [12].

2.1.2 Sharp sand

Sharp sand are natural was sourced for locally available clean sand within the university community, free from deleterious substances and organic matter which conforms to BS 882 [13].

2.1.3 Water

Potable water free from any visible impurities conforming to BS 3148 [14] was used.

2.1.4 Glass wool fibre

The glass wool fibre used was sourced locally. Most of this glass wool fibre were previously used as insulation to prevent heat transfer in oven and incubator.

2.2 Methods

This section describes the experiments to be carried out on the hollow sandcrete blocks of dimension 150 mm x 225 mm x 450 mm (6" block). The block will be moulded with cement and sharp sand in ratio 1:8. Glass wool fibre was added at the percentage of 5%, 10%, 15% and 20% of cement. For control experiment, one block each 150 mm x 225 mm x 450 mm (6") was moulded with no glass fibre. The samples were tested for compressive strength test (after 28 days of curing). Sieve analysis was done to determine the grade of the particle of the sharp sand.

2.2.1 Production of blocks and curing

A total of forty-five (45) hollow sandcrete blocks were produced of 150 mm x 225 mm x 450 mm

dimension. Batching of the material was done by weight and 1:8 cement aggregate ratio and 0.6 water to cement ratio was adopted (National Building Code, 2006). The block was prepared by hand mixing and moulding was done manually by metal contraption. The mix was compacted in the contraption and demoulded. The demoulded blocks were kept in a damp place for 24 hours to prevent rapid drying.

Table 3. Percentage addition of glass wool fibre

Mix	Percentage of glass fibre addition	Weight (kg) Glass wool fibre	Cement	Sand
1	0%	0.000	7.27	58.12
2	5%	0.360	7.27	58.12
3	10%	0.727	7.27	58.12
4	15%	1.090	7.27	58.12
5	20%	1.454	7.27	58.12

2.2.2 Particle-size of sand analysis

This was carried out in accordance with BS 1377 [15].

2.2.3 Compressive strength test

This was carried out on cured block specimens at 28 days.

3. RESULTS AND DISCUSSION

The various test results (particle size distribution, compressive strength) are presented and discussed as follows:

3.1 The Block Moulding Observation

It was observed that the water-cement ratio used in the production of hollow sandcrete blocks without glass wool fibre is higher than the ones used with glass wool fibre.

There is a visible appearance of white glass wool fibre in the block samples and it became more visible with increase in the addition of glass fibre.

Soil Grading:

A soil is said to be well graded if the coefficient of curvatures (Cc) is between one and three (1 and 3) and the coefficient of uniformity greater than four and six (4 and 6) for gravel and sand respectively.

From Fig. 1,

$$\begin{aligned} D_{10} &= 0.19 \\ D_{30} &= 0.41 \\ D_{60} &= 0.85 \end{aligned}$$

Where D10, D30 & D60 are the intercepts for 10%, 30% and 60% of the cumulative mass

$$Cu = \frac{D_{60}}{D_{10}} = \frac{0.85}{0.19} = 4.47$$

$$Cc = \frac{D_{30}^2}{D_{10} \times D_{60}} = \frac{0.41^2}{0.19 \times 0.85} = 1.04$$

The sand particle Cc is 1.04 and the Cu is 4.47 which shows that the sand is well graded.

3.2 Compressive Strength Test Results

The results of the compressive strength test carried out on the block specimens are presented in Table 5. The results obtained using the ADR Touch 1500 Compression Testing Machine with digital reading are presented in Table 5.

From the results and graphs. It was observed that compressive strength of the block samples increased gradually until the 15% addition of glass wool fibre where maximum strength of the block sample was achieved. A further increase by 5% reduces the compressive strength of the glass wool fibre sandcrete hollow block. The 15% addition gave the optimum strength value, at this point the effect of the addition of glass fibre is maximum.

It was also observed that the glass wool fibre addition gives considerable strength to the hollow sandcrete blocks by increasing the compressive strength of the block by 33% and at the optimum percentage of 15% the compressive strength increased by 83%. However, the compressive strength decreased by 33% at the 20% addition of glass wool fibre.

Table 4. Particle size of sand distribution results

Sieve size (mm)	Weight of sieve (g)	Weight of retained sand (g)	Weight of retained sand (g)	Percent retained sand (%)	Percent passed (%)
4.750	535	545	10	2	98
2.360	390	440	50	10	88
0.850	495	630	135	27	61
0.425	455	605	150	30	31
0.212	420	525	105	21	10
0.150	410	440	30	6	4
0.075	420	435	15	3	1
Pan	375	380	5	1	0
			500	100	

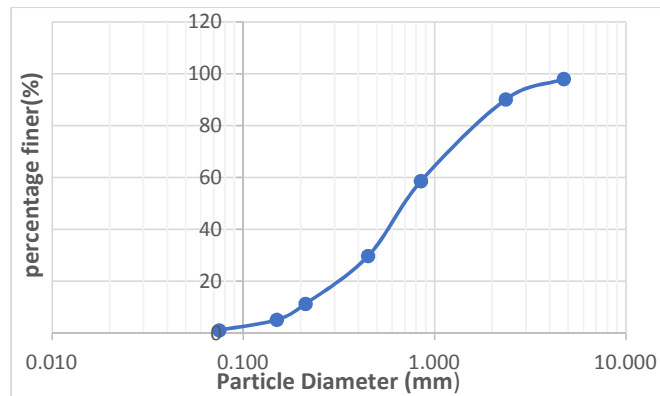


Fig. 1. Graph showing the sand particle size distribution of sand

Table 5. Compressive strength test results

Percentage of GWF (%)	Weight (Kg)	Crushing load (KN)	Average weight (Kg)	Average crushing load (KN)	Average compressive strength (N/mm ²)
0%	18.2	33.90	18.1	33.6	0.6
	18.2	31.00			
	18.0	35.80			
5%	19.0	65.50	18.2	41.1	0.8
	18.5	33.50			
	17.0	24.40			
10%	18.5	43.20	18.5	49.8	0.9
	18.5	43.00			
	18.5	63.20			
15%	18.0	64.20	17.8	60.5	1.1
	18.0	60.30			
	17.5	57.00			
20%	17.0	24.20	16.7	21.1	0.4
	17.0	17.90			
	16.0	21.20			

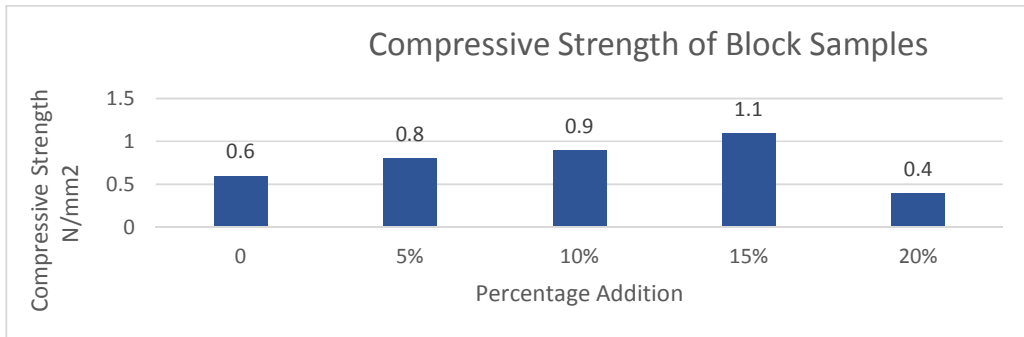


Fig. 2a. Graph showing the compressive strength test results (summary)

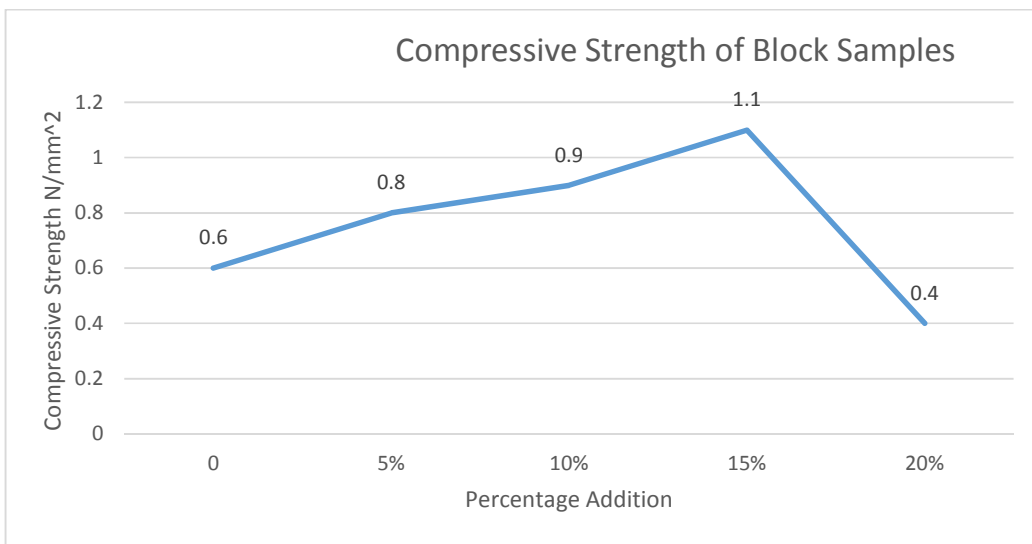


Fig. 2b. Graph showing the compressive strength test results (summary)

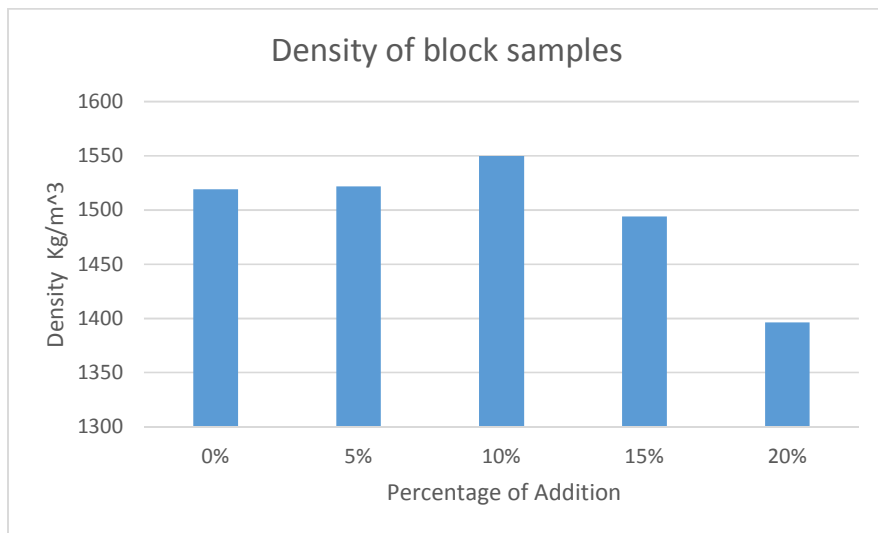


Fig. 3. Graph showing the bulk density results

Table 6. Bulk density results

Percentage addition %	Dimension		Weight (kg)	Volume	Density (Kg/m ³)
	Ext. (mm)	hole (mm)			
0%	150x225x450	85x170	18.1	0.01194	1519
5%	150x225x450	85x170	18.2	0.01194	1522
10%	150x225x450	85x170	18.5	0.01194	1550
15%	150x225x450	85x170	17.8	0.01194	1494
20%	150x225x450	85x170	16.7	0.01194	1396

3.3 Bulk Density Results

From the above Table 6 showing the density of the block samples. It was observed that the density of block sample without glass wool fibre is 1520 kg/m³, the density then increases gradually until 1550 kg/m³ at the 10% addition of glass fibre in the block sample. It was observed that the density dropped at 15% where the optimum compressive strength occur and further decreased at 20% addition. This implies that the bulk density at 15% addition of glass fibre of the maximum strength of block give a 1.6% reduction in the density of the block sample.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Based on the analysis of the results of this investigation, the following conclusions were drawn;

1. The water-cement ratio needed by the glass wool fibre hollow sandcrete block is slightly higher than the one for the hollow sandcrete blocks without glass wool fibre.
2. The white wool glass fibre was visible on the block and become more visible as the percentage is increased.
3. The density of the hollow sandcrete blocks increased up to the optimum which occurred at 10% addition of glass wool fibre.
4. The addition of glass wool fibre should be at 15% for optimum results in the hollow sandcrete block production.
5. There is abundant glass wool fibre in form of industrial waste and as such this waste can be considered for the production of non-load bearing hollow sandcrete blocks.

4.2 Recommendations

It is, therefore, recommended that;

1. While working with glass wool fibre (GWF) safety precautions such as wearing of hand gloves and use of nose cover are recommended.
2. Further study should be carried, to compare the effect of glass wool fibre on hollow sandcrete blocks to other fibres, so as to study the difference in the compressive strength.
3. Glass fibre hollow sandcrete blocks can be used for non-load bearing purposes.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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