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INVESTIGATION AND COMPARISON OF SOME ENGINEERING PROPERTIES OF BASALT AND STEEL FIBRE

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Abstract
Basalt is a solid, compact igneous rock which is formed when volcanic lava cools adequately to the point of solidification. It is found in many parts of the globe. It is mainly used as crushed rock in building and highway engineering. Both the staple and continuous type of fibres can be manufactured from basalt rocks. This study was aimed at investigating the observed properties of basalt fibre, and comparing same with that of the steel fibre in order to obtain their various performance levels, make comparisons and, if possible, explore the opportunity or otherwise, of replacing steel fibre with basalt. Sieve analyses, tensile tests, flexural tests, heat tests etc. were all carried out on the basalt and steel samples. The results showed that although both basalt fibre and steel are viable for use in concrete construction works, concrete with steel reinforcement provided more strength to a structure. Flexural test on the beam samples both with mixture of basalt fibre and steel reinforcement were found adequate for use in concrete structures. It is recommended that although expensive, heated samples at 28days should be employed in construction work as this yielded more strength both for steel bars and basalt fibres.

1. Introduction

Sequel to increase in urbanization and construction works in the world, which have resulted in greater demand for construction materials, hence the use of eco – friendly materials in construction. Basalt is a solid, compact igneous rock. Basalt is obtained from Basalt rock found around the world. The crushed rock used in industrial and highway engineering. Basalt can be used in manufacturing of fine and ultrafine fibers known as Basalt fibers. These fibers are superior as they possess excellent properties such as sound insulation, heat and vibration and stability. Basalt fibre has resistance to high temperature and possesses durability, as well as strength. Basically, basalt can be found in continuous fibers having unique mechanical and chemical properties, requiring resistance against high temperature, acid, solvent resistance, durability and low water absorption.

As it is well known due to its significant mechanical properties, basalt is utilized as fibre in the composite materials, and is known as basalt fibre reinforced polymer composite (BFRP). Basalt is a characteristic material that is obtained from volcanic rock affected by solidified magma, at temperature around 1500C to 1700C. Consequently, it might be necessary to design high voltage towers such as steel towers in future with basalt.

As said earlier, there has been a recent increase in the use of eco-friendly materials in construction. There is presently widespread interest in the use of natural fibers as reinforcement materials to produce lightweight, cheaper polymer composites. Therefore, it is required to use new type of materials that has high strength as well as light and minimum risk of corrosion. At present bigger lamp posts and telephone poles have been designed with steel and wood for years and there is need of new type of materials which is light, strong, with less risk of corrosion. The structural designers are looking for new types of materials for building, bridges and windmills. The density of basalt is approximately one third that of density of steel, which indicates that BFRP is lighter, and a stronger materiel compared to steel weight-wise.

Basalt is the most common rock type in the earth's crust (the outer 10 to 50 km). Basaltic

Magma is commonly produced by direct melting of the earth's mantle, the region of the earth below the outer crust. The ocean floor is mostly made of basalt. Huge outpourings of lava called "flood basalts" are found on many continents. In Nigeria Basalt can be found in the following locations: Bachit basalt formation, Ikom columnar basalt and the Kahwang rock formation as shown in Figure 1. Basalt is a very hard material with 8.5 Mohs on the hardness Mohs scale; this property greatly affects its resistance to abrasion in concrete.

Basalt fibre is a material made from extremely fine fibres of basalt. The manufacture of the basalt fibre is by melting the quarried basalt rock. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fibre. The basalt fibres do not contain any other additives in a single producing process, which gives additional advantage in cost. It is known that basalt fibres have better tensile strength than E-glass fibres, greater failure strain than carbon fibres as well as good resistance to chemical attack, impact load and fire with less poisonous fumes (Chiadighikaobi & Emiri 2018).

Fig. 1: Basalt Fibre Specimen

Many structures in Nigeria and around the world are facing severe problems of deterioration resulting in poor serviceability. This occurs as a result of several environmental factors, increase in loading, age of the structure and corrosion. Between 1987 and 1993, 200,000 tons of epoxy coated steel rebar have been used in bridge decks. A significant amount of the epoxy coated steel rebars have degraded. This gives an idea of the significant financial implications associated with the replacement of the existing structures with the new fibres, alongside the associated cost-benefits. This justifies the need for the introduction of steel and basalt fibres in the civil engineering structural application. This situation has triggered the comprehensive and extensive research on the properties, advantages, and applications of the fibres. Another significance of this research is the fact that it would provide sufficient background for the future study of long-term behaviour of the steel and basalt fibres as reinforcement materials. The study of the fundamental properties of any new material can be regarded as the prerequisite for any detailed study of that material.

One of the benefits of using Fibre Reinforced Polymer (FRP) as a strengthening material in concrete is that it is noncorrosive. In places where concrete structures are close to the sea, like houses or bridges, the maintenance of the concrete is needed on regular basis. In such conditions the common rebar is in constant danger of corrosion and therefore could become weak and hazardous in a short period of time.

The objective of this research was to thoroughly understudy basalt and steel fibre reinforcements as well as the effect of temperature on them. The goal was to replace conventional steel reinforcement in part or completely with fibres in construction works and load carrying structures. To reach the objectives mentioned above, experimental work was done which included investigating and evaluating the fresh and hardened properties of concrete reinforced with different types of fibres, namely steel fibres, and basalt fibres. Also, there was a comparison between steel and basalt fibres to find out which of the two fibre types gave a better overall performance. Several test including; compression, tension, flexural strength and modulus of elasticity methods was conducted to determine some engineering properties of fibre-reinforced concretes. The mechanical behaviour of concrete was enhanced with the inclusion of basalt fiber. Basalt fibre has the capacity to postpone the appearance and propagation of cracks as well as increase the compressive and tensile strength of concrete.

Steel fibre reinforced concrete behaviour can be classified into three groups namely; fibre volume, percentage and fibre effectiveness. Laboratory test done by many researchers have shown that the use of steel fibres in concrete reinforcement helps to increase the total energy that can be absorbed, (Johnston, 1974). The use of steel fibres has also been known to improve flexural, shear and impact strength as well as the fatigue properties of the concrete. There are different types of steel fibres and they can be basically classified into four groups depending on the manufacturing process.

2.0: Methodology

The individual materials, their composition, mix, manufacturing processes, curing, etc. are important factors that determine the structural and engineering properties of the concrete mix.

This makes them of outmost importance during the course of analysis. There are several processes involved in the preparation of the specimen for the needed experimental research. The tests that were carried out were for both fresh and hard samples, and the following processes were employed to prepare the samples for testing: Batching (measurement of individual materials according to standard quantities); mixing of concrete; casting of specimen; compaction; age of test.

2. Mixing of Concrete

This was done by mass. Mixing by mass is professionally preferable as it eliminates errors due to the variations contained in a specific volume. Hand mixing was used. The various quantities of the components were measured (excluding water) and mixed until there was an even distribution of the materials. Water was then added in batches until the desired consistency was achieved.

2.2 Casting of Specimen

Square, cylindrical and beam casting mould made of cast iron were used. Grease was used to oil the inner part of the cubes to aid in easy removal of the concrete cubes. The specimens were then cast in 3 equal layers and properly compacted in order to avoid honeycombs.

2.3 Compaction

In compacting, a tamping rod of 16mm diameter was used to compact the specimen. 35strokes were done in all parts of the cube to ensure proper compacting.

2.4 Age of Test

The cube was then immersed completely in water (curing) for the recommended time for a test and brought out only when the test was to be carried out. The time frame ranged from 1dayto 28days.

3.0: Experimental Analysis

To achieve the set out objectives, the following laboratory tests were performed: Slump test, Density test, Flexural strength, Impact test, Heating test

3.1: Concrete Slump Test

Slump is a test on fresh concrete to find out its workability. Slump tests measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which the concrete flows. It can also be used as an indicator of improperly mixed batch.

Apparatus: Slump cone, Tamping rod, Slump test base, Slump cone filling funnel, K-slump tester, Aluminum round bottom sample scoop, Measuring tape, Scrub brush.

Procedures: The internal surface of the mould (cone) was cleaned thoroughly and freed from superfluous moisture and any set of concrete and placed on a smooth, horizontal, rigid and non-absorbent surface (slump test base). It was held firmly in place during the filling process. The mould was then filled in four layers, each approximately one-quarter of the height of the mould. Each layer was tamped with twenty-five strokes with the tamping rod; the strokes been distributed in a uniform manner over the cross section of the mould and the second and subsequent layers penetrated into the underlying layers. The bottom layer was tamped throughout its depth. After the top layer was tamped, the concrete was struck off level with a trowel so that the mould was exactly filled. After that, the surface of the concrete was compacted by means of screeding and rolling motion of the tamping rod. Any mortar which may have escaped out from between the mould and the base plate was cleaned out and the mould removed from the concrete by raising it slowly and carefully in a vertical direction. The concrete then subsided and the slump was then measured by determining the difference between the height of the mould and the height of the highest point of the specimen tested.

3.2: Interpretation of Results:
The slumped concrete took various shapes and, according to the profile of slumped concrete,
The slump was termed as 'true slump' (concrete simply subsides, keeping more or less to shape),
'Shear slump' (the top portion of the concrete shears off and slips sideways) or 'collapse slump' (the concrete collapses completely). If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. Only a true slump is of any use in the test. A collapse slump will generally mean the mix is too wet or that it is a high workability mix, for which the slump test is not appropriate. The following values can be used to determine if the workability of the concrete is adequate;

3.3: Workability Compaction Factor Slump (mm)

Very low 0.78 0 – 25

Low 0.85 25 – 50

Medium 0.92 50 – 100

High 0.95 100 – 175

3.4: Density Test
Density is also known as the unit weight. This was measured using a Type B pressure meter to verify the agreement with the project mix.

Apparatus: Container of known volume, weighing balance

Procedures: a container of known volume and weight is filled with concrete and then weighed. Subtract the empty container weight from the full container weight to get the weight of the concrete. Then divide the weight of the concrete by the volume of container to get the density or fresh unit weight of the concrete.

Density = (W 1 W 2)/V

Where W 1 = weight of container with concrete

W 2 = Weight of empty container

V = Volume of container

3.3.3 Flexural strength
The flexural strength is the ability to withstand bending. It is determined using beam specimens. After casting and curing, the beam was then placed on the flexure test machine provided with a steel roller mounted at a specific distance away from each other. The load to be applied was then divided equally between the two sides and the roller placed at the mid-point in such a manner that the load is applied axially and without subjecting the specimen to any torsional stress or restraint. The flexural strength is then given by;

F b = or

Where, a = distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = maximum load (kg)

3.3.4 Impact Test

To determine the aggregate impact value of coarse aggregate

Table 1: Particle Size Distribution for the Aggregates Used

PARTICLE SIZE DISTRIBUTION

DESCRIPTION: 19.0mm

SIEVE SZES	WEIGHT RETAINED (g)	CUMULATIVE WEIGHT RETAINED (g)	% RETAINED	% CUMULATIVE	% PASSING
20mm	20	20	1.3	1.3	98.7
14mm	954	974	63.4	64.8	35.2
10mm	166	1140	11.0	75.8	24.2
6.3mm	307	1447	20.4	96.2	3.8
4.75mm	38	1485	2.5	98.7	1.3
3.35mm	14	1499	0.9	99.7	0.3
2.36mm	3	1502	0.2	99.9	0.1
1.18mm	2	1504	0.1	100.0	
600µ					
425µ					
300µ					
212µ					
150µ					
75/63µ					
Passing 63µ					
Total					

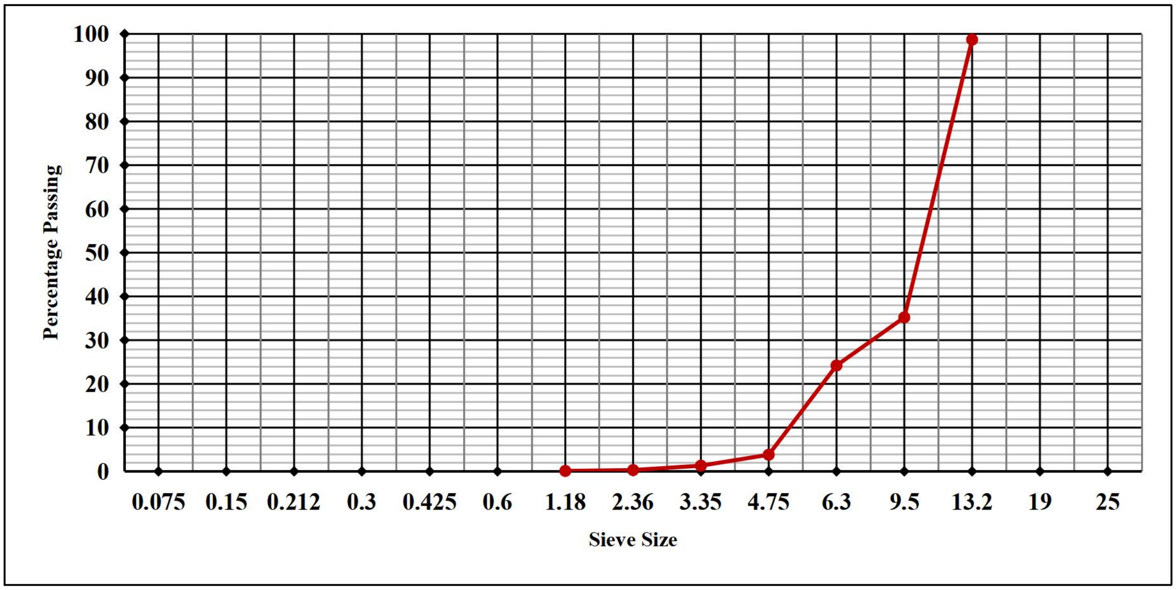

Figure 2: Result of Sieve Analysis

Table 2: Particle Size Distribution for the River Sand Used

PARTICLE SIZE DISTRIBUTION

DESCRIPTION: Crushed Sand

SIEVE SZES	WEIGHT RETAINED (g)	CUMULATIVE WEIGHT RETAINED (g)	% RETAINED	% CUMULATIVE	% PASSING
20mm					
14mm					
10mm					
6.3mm					100.0
4.75mm	6	6	0.4	0.4	99.6
3.35mm	38	44	2.5	2.9	97.1
2.36mm	55	99	3.7	6.6	93.4
1.18mm	155	254	10.3	16.9	83.1
600µ	228	482	15.2	32.1	67.9
425µ	48	530	3.2	35.3	64.7

300μ	271	801	18.1	53.4	46.6
212μ	153	954	10.2	63.6	36.4
150μ	162	1116	10.8	74.4	25.6
75/63μ	317	1433	21.1	95.5	4.5
Passing 63μ	68	1501	4.5	100.0	
Total	1501				

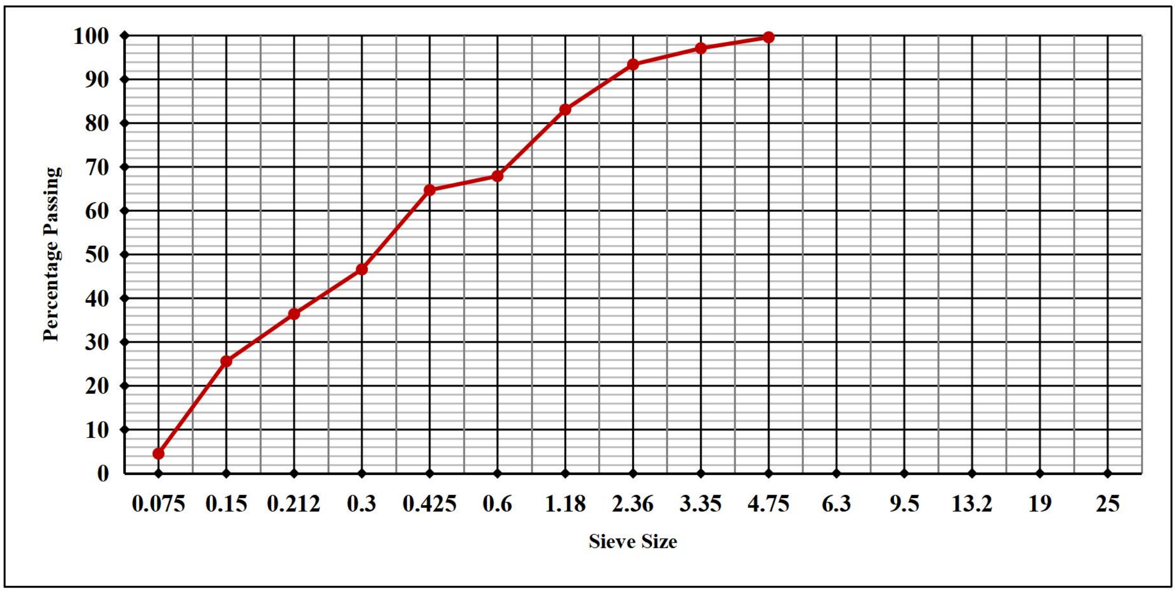

Figure 3: Result of Sieve Analysis

Table 3: Tensile Strength Test for Steel Bars (10mm Hys) Used for the Mix.

S/No	Bar Diameter (mm)	Length of test piece (mm)	Find length of test piece (mm)	Elongation (%)	Yield Diameter (mm)	Yield Stress (N/mm^2)	Max Load (KN)	Max Stress (N/mm^2)	Average Stress (N/mm^2)
I	HYS 10	350	399	14.00	9.50	30	38	483.77	492.26
II	HYS 10	350	400	14.29	9.50	31	40	509.23	
III	HYS 10	350	399	14.00	9.50	30	38	483.77	

Formula used:

- For Elongation: $\frac{Final\ Length - initial\ length}{initial\ length} x\ 100$ - Eqn 1
- FOR STRESS:= $\frac{load\ (P)}{area\ (A)}$ N/mm^2 - Eqn 2

Where, $A = \frac{\pi(d^2)}{4}$ and $\pi = 3.142$

Table 4: Tensile Strength Test for Basalt Prepared Samples.

S/N	Sample thickness (mm)	Original Gauge length (mm)	Final length test piece (mm)	Elongation (%)	Yield thickness (mm)	Max Load (KN)	Stress (N/mm^2)	Strain
1	0.7	165	172	4.42	0.6	19	383.84	1.04
2	0.7	165	171	3.64	0.6	17	343.43	1.04
3	0.7	165	170	3.03	0.5	14	282.83	1.03

Below formula were used to obtain the above data

- For stress:= $\frac{load\ (P)}{area\ (A)}$ N/mm^2 - Eqn3

Where, A= L x B

- For Strain: = $\frac{change\ in\ length}{original\ length}$ - Eqn 4

Flexural Test for Basalt Fibre (Bs) Samples (Beams)

No beams: THREE (3) BEAMS PER AGE OF SAMPLE

Mixed proportion & how measured: C25

Type of cement: ORDINARY PORTLAND CEMENT

CRUSHED AGGREGATE ($\frac{3}{4}$")

Coarse aggregate (type of grading): SHARP SAND (4.75MM-63μ)

Fine aggregate (type of grading): ____________________

Mixing time: ____________________ Hand Mixed: **Mechanical Mix**

3 LAYERS, 25 BLOWS

Details of mixed: ____________________ (compaction) to British standard 1880,108, 1983.

Weight/Qty of Basalt Fibre: ____________________ IMMERSION

Method of curing: ____________________

Formula used: $F = \frac{PL}{bd^2}$ -Eqn 5

Where:

F = flexural Strength

P= failure load (N)

l= length of the beam

b= Breadth of the of the specimen

d= depth (height)

Table 5: Age of Beams for 3 Days

S/N	Age of Beam (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	3	100	100	400	5540	2.216
2	3	100	100	400	6620	2.648
3	3	100	100	400	6270	2.508

=2.457 N/mm^2

Table 6: Age of Beams for 7 Days

S/N	Age of Beam (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	7	100	100	400	11600	4,640
2	7	100	100	400	9880	3.952
3	7	100	100	400	11620	4.648

Average Flexural Strength: = 4.413 N/mm^2

Table 7: Age of Beams for 14 Days

S/N	Age of Beam (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	14	100	100	400	12870	5.148
2	14	100	100	400	11950	4.780
3	14	100	100	400	6280	2.512

Average Flexural Strength: = 4.147 N/mm^2

N/B:

At 3 days, Flexural Strength = 2.457 N/mm^2

At 7 days, Flexural Strength =4.413 N/mm^2

At 14 days, Flexural Strength =4.147 N/mm^2

Flexural Test for Steel (St) Reinforced Samples(Beams)

No of beams: THREE (3) BEAMS PER AGE OF SAMPLE.

Mixed proportion & how measured: C25

Type of cement: ORDINARY PORTLAND CEMENT

Coarse aggregate (type of grading): CRUSHED AGGREGATE ($\frac{3}{4}$")

SHARP SAND (4.75MM-63μ)

Fine aggregate (type of grading): ______________________________

Mixing time: ______________________________ Hand Mixed: **Mechanical Mix**

3 LAYERS, 25 BLOWS

Details of mixed: ______________________________ (compaction) to British standard 1880, 108, 1983.

HYS 10

Bar Diameter (mm):______________________________

IMMERSION

Method of curing: ______________________________

Formula used: $F = \frac{PL}{bd^2}$ - Eqn 6

Where:

F = flexural Strength

P= failure load (N)

l= length of the beam

b= Breadth of the specimen

d= depth (height)

Table 8:Age of Beams for 3 Days

S/N	Age of Beam (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	3	100	100	400	10150	4.060
2	3	100	100	400	10131	4.050
3	3	100	100	400	10425	4.170

Average Flexural Strength: = 4.094 N/mm^2

Table 9:Age of Beams for 7 Days

S/N	Age of Beam (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (KN)	Flexural Strength (N/mm^2)

1	7	100	100	400	12000	4.80
2	7	100	100	400	12970	5.188
3	7	100	100	400	12710	5.084

Average Flexural Strength: = 5.024 N/mm^2

Table 10:Age of Beams for 14 Days

S/N	Age of Beam (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	14	100	100	400	25380	10.152
2	14	100	100	400	18050	7.220
3	14	100	100	400	28270	11.308

Average Flexural Strength: =9.56 N/mm^2

N/B:

At 3 days, Flexural Strength = 4.094 N/mm^2

At 7 days, Flexural Strength =5.024 N/mm^2

At 14 days, Flexural Strength =9.56 N/mm^2

Heated and Unheated Samples for Basalt Fibre (Bs)

No of beams: THREE (3) BEAMS PER AGE OF SAMPLE

Mixed proportion & how measured: C25

Type of cement: ORDINARY PORTLAND CEMENT

CRUSHED AGGREGATE ($\frac{3"}{4}$)

Coarse aggregate (type of grading): SHARP SAND (4.75MM-63μ)

Fine aggregate (type of grading): ______

Mixing time: ______ Hand Mixed: **Mechanical Mix**

Details of mixed: 3 LAYERS, 25 BLOWS (compaction) to British standard 1880, 108, 1983.

Weight of Basalt Fibre: ______

Method of curing: IMMERSION

Formula used: $F = \frac{PL}{bd^2}$ - Eqn 7

Where:

F = flexural Strength

P= failure load (N)

l= length of the beam

b= Breadth of the specimen

d= depth (height)

Table 11:Tables for Heated Samples

S/N	Age of Specimen (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	28	100	100	400	8240	3.296
2	28	100	100	400	6520	2.608
3	28	100	100	400	6840	2.736

Average Flexural Strength: = 2.880 N/mm^2

Table 12: Table for Unheated Samples

S/N	Age of Specimen (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	28	100	100	400	6170	2.468
2	28	100	100	400	6100	2.400
3	28	100	100	400	6150	2.460

Average Flexural Strength: = 2.456 N/mm^2

N/B:
At 28 days, heated samples' Flexural Strength = 2.880 N/mm^2

At 28 days, unheated samples' Flexural Strength =2.456 N/mm^2

Table 13:Table for Heated Samples

Heated and Unheated Samples with Steel (St) Reinforcement

Data Collection and Tabulation

No beams: THREE (3) BEAMS PER AGE OF SAMPLE

Mixed proportion & how measured: C25

Type of cement: ORDINARY PORTLAND CEMENT

Coarse aggregate (type of grading): CRUSHED AGGREGATE ($\frac{3}{4}$")

Fine aggregate (type of grading): SHARP SAND (4.75MM-63μ)

Mixing time: ______ Hand Mixed: **Mechanical Mix**

Details of mixed: 3 LAYERS, 25 BLOWS (compaction) to British standard 1880, 108, 1983.

Size of steel reinforcement:________IMMERSION________

Method of curing: ______________________

Formula used: FOR FLEXURAL i.e. $F = \frac{PL}{bd^2}$ - Eqn 8

Where:

F = flexural Strength

P= failure load (N)

l= length of the beam

b= Breadth of the specimen

d= depth (height)

Table 14: Table for Heated Samples

S/N	Age of Specimen (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	28	100	100	400	21170	8.468
2	28	100	100	400	22640	9.056
3	28	100	100	400	20590	8.236

= 8.587 N/mm^2

Average Flexural Strength: ______________________

TABLE 15:**FOR UNHEATED SAMPLES**

S/N	Age of Specimen (Days)	Depth of Specimen "a" (mm)	Width of Specimen "b" (mm)	Length of Specimen (mm)	Load 'P' (N)	Flexural Strength (N/mm^2)
1	28	100	100	400	23100	9.240
2	28	100	100	400	23320	9.328

Age (days)	Flexural strength of basalt fixed samples (N/mm^2)	Flexural strengths of steel reinforced samples (N/mm^2)
3	2.457	4.094
7	4.705	5.024
14	4.147	9.56
28(i)(heated)	2.880	8.587
28(ii)(unheated)	2.456	7.685

3	28	100	100	400	11220	4.488

Average Flexural Strength: = 7.685 N/mm^2

N/B:
At 28 days, heated samples' Flexural Strength = 8.587 N/mm^2

At 28 days, unheated samples' Flexural Strength =7.685 N/mm^2

Comparing flexural strength test results for basalt fibre and reinforced concrete beam samples

4.0: Results and Discussion

Tables 5 – 7 showed the flexural strength ($N/mm^{2)}$ while tables 11 to 15 showed the results for theheated and unheated samplesof beams for various ages. At 28 days, heated samples' flexural strength was 8.587N/mm^2. At 28 days, unheated samples' flexural strength was 7.685$N/mm^{2.}$ At 3 days, flexural strength was 4.094N/mm^2 7 days, flexural strength was5.024 N/mm^2At 14 days, flexural strength was 9.56N/mm^2At 3 days, flexural strength was 2.457 N/mm^2. At 7 days, flexural strength was 4.413N/mm^2 and at 14 days, flexural strength was4.147 N/mm^2

5.0: Conclusion and recommendations

In respect to this study carried out on the performance comparison between basalt fibre and steel in concrete, the various tests carried out showed that although both basalt fibre and steel are viable for use in concrete construction work, as they increase the strength of the structure; it is important to note that steel reinforced structures provides more strength to a structure. It was also concluded that hence; using grade C_2O of ratio 1:1:5:3, whose specification indicates that for flexural strength, value should be three to three point five (3-3.5) N/mm^2 (pure concrete mix), adding basalt fibre or steel bars, among other functions; makes it develop more strength.

Recommendation

- Flexural test on the beam samples both with mixture of basalt fibre and reinforcement are adequate for use in concrete structures.
- It is also recommended that, though it is considered more expensive, heated samples at 28days old (also known as the peak of the sample strength) will provide more strength to

a concrete construction, either with the use of basalt fibre or steel bars.

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