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The Effect of Cement-NBRRI Pozzolanic Material Blend on the Mechanical Properties of Glass Fibre Reinforced Concrete

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Abstract: *Cement is an essential material required for the production of concrete. However, its cost is on the steady rise in Nigeria leading to restricting the development of housing scheme. Although, some pozzolanic materials have been developed by Nigerian Building and Road Research Institute (NBBRI) known as NBRRI cement and it has being in production for some years back without any use whatsoever. Research carried out on cement reduction using NBRRI pozzolan shows that 12% of cement replacement results to almost 0% replacement, reducing the cost of concrete drastically. Moreover, it is pertinent to find a means of improving strength by adding on some reinforcements such as glass fibre (GF) that are cheap and readily available. Experimental program was carried out on NBRRI as partial replacement for cement (3% to 15% at the interval of 3%) with addition of glass fibre (0.2% to 0.4% at the interval of 0.1%) of 5mm length. Concrete mix, 1:1.5:3 was designed for all specimens with w/c of 0.45. Slump, compressive, split tensile and flexural strength tests were carried out on concrete samples in accordance with BS standards. It was observed from the results that concrete workability decreases as the amount of the NBRRI pozzolan increases with increase in the amount of glass fibre content. Optimum value of 38.99, 3.50 and 6.12 N/mm^2 were obtained for compressive, split tensile and flexural strength of the concrete at 12% addition of NBRRI pozzolan with 0.4% glass fiber content at 28 days curing age respectively. It is concluded that addition of glass fibre to concrete made by replacing cement with NBRRI pozzolan significantly improved the strength of the concrete.*

Keywords: *Cement, Concrete, Pozzolan, GF: Glass Fibre, NBRRI: Nigerian Building and Road Research Institute.*

1. INTRODUCTION

In construction industry, concrete is a composite material that is mostly used. Its constituent materials are cement, fine aggregate, coarse aggregate and water. However, admixtures are sometimes incorporated to produce special properties concrete. According to [1], concrete is widely used in construction because of its special properties of being able to modify within a wide range using appropriate ingredients and techniques. Cement is the binding agent of concrete and very expensive material, most especially, in developing countries such as Nigeria. [2] suggested the development of new concrete additives that can produce a stronger and more workable concrete while reducing the amount of cement required and the resulting carbon dioxide emissions. [3] also propose the reduced use of Portland cement in concrete by the use of blended and pozzolanic cements. Researchers in Nigeria have confirmed the suitability of agricultural waste products as pozzolanic materials that are capable of enhancing the compressive strength of the concrete whilst reducing the amount of cement required and the resulting CO_2 emissions [4, 5, 6].

The addition of reinforcing materials to concrete can seriously reduce its workability. [7] discussed some the reasons for the variability of water/cement (w/c) ratio. Such includes surface moisture of the aggregates leading to reduction of w/c ratio and porous aggregates that absorb water rapidly leading to the increase in w/c ratio, to mention a few. The fibre reinforced concrete absorbs energy more at the peak of load deflection curve. Traditionally, Glass fibre concretes (GFRC or GRC) are mainly used in exterior building façade panels and as architectural precast concrete. They are categorised into A-glass, C-glass, E-glass, AE-glass, AR-glass, S-glass and others depending on their compositions and characteristics [8].

Over the years, many researchers have studied GFRC. [9] reported significant improvement in concrete durability, resistance to acid attack and a reduction in concrete bleeding when glass fibres added to plain concrete. [10] observed that the use of glass fibre in concrete does not only improves the properties of concrete but also provide easy outlet to dispose the glass fibre as environmental waste from the industry. It was also noted that the flexural strength of the beam with 1.5% glass fibre shows almost 30% increase in the strength. According to [11] the effect of using the alkali resistance glass fibres mechanical properties of concrete was investigated. It was observed that 20 % polyester resin plus 79 % fine silica aggregate used to make polymer concrete has modulus of rupture of 20 MPa. This was found to increase by 55 % by adding 1.5 % glass fibres. [12] reported research on the use of glass fibre of two different sizes of 5m and 8mm, to improve the mechanical strength properties of concrete. Plain concrete without addition of glass fibre was used as the control specimen. It was observed that the workability of the concrete reduced with increase in glass fibre content at varying percentage (0, 0.2, 0.3, 0.4 and 0.5%). The mechanical properties such as the compressive, split tensile and flexural strengths increased with the addition of glass fibre and the optimum glass fibre content of 0.4% has the highest strength at 7, 14 and 28 days curing ages. It was concluded that glass fibre composite concrete with 5 mm length improves the concrete properties than 8mm glass fibre length.

Attempts have been made by various researchers to find partial replacement for the cement such as Nigerian Building and Road Research Institute (NBRRI) pozzolan. The issue of concern is the improvement on these characteristics with the addition of other cheap materials. However, the current study investigated the effect of using NBRRI pozzolan as replacement for cement (3% to 15% at the interval of 3%) with addition of glass fibre (0.2% to 0.4% at the interval of 0.1%) of 5mm length.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement

Dangote brand of ordinary Portland cement which is in accordance with [13] was used.

2.1.2 Aggregates

Both fine and coarse aggregates were obtained from the stockpile of rubbles on the site and they were air dried before the particle size distribution analysis was carried out in accordance with [14].

2.1.3 Water

Water which is equally suitable for human consumption obtained from the Departmental laboratory of the Osun State University was used for mixing and curing of specimens.

2.1.4 NBRRI pozzolan

The pozzolan used in this study was raw clay obtained from NBRRI pilot plant located at Idiroko, Ogun State, Nigeria. Its mineral and chemical compositions are shown in Tables 1 and 2.

Table 1: Material composition of NBRRI pozzolan

Sample	Smectite	Palygorskite	kaolinite	quartz	Calcite	Dolomite	Mica/illite
Ifenitedo	0.84	0.00	40.88	49.20	0.00	0.00	9.08
Calcined clay	0.11	0.99	2.53	89.44	0.00	0.04	6.89
Imoto yewa	0.39	0.00	20.38	78.62	0.30	0.00	0.32
Raw clay	0.06	0.00	30.13	60.08	0.00	0.00	9.73

Table 2: Chemical composition of materials of NBRRI pozzolan

Sample	CaO%	SiO_2%	Al_2O_3%	Fe_2O_3%	MgO%	SO_3%	Na_2O%	K_2O%	LOI%
Ifenitedo	0.5	55.03	24.51	2.17	0.24	0.03	0.04	0.18	15.29
Calcined clay	2.57	65.45	19.07	6.38	0.6	0.13	0.85	0.19	2.2
Imoto yewa	0.48	63.36	16.36	5.44	0.4	0.04	0.58	0.1	9.78
Raw clay	0.53	56.28	18.84	6.08	0.58	0.08	0.92	0.15	12.48

Source: [15]

2.1.5 Glass fibre

The glass fibres used were sourced locally and they were cut into 5mm length for the concrete production as shown in Figure 1. The characteristic information of the glass fibre used could be found in Table 3.

Table 3: Properties of Alkali Resistance Glass Fibre

Fibre	AR Glass
Specific gravity	2.67
Elastic modulus (GPa)	72
Tensile strength (MPa)	1700
Diameter (micron)	14
Aspect ratio	857.1
Length (mm)	5

Source: [12]

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Figure 1: Glass fibre

2.2 Methods

The methods of testing include the determination of the gradation of both fine and coarse aggregates. M30 grade concrete with mix ratio of 1:1.5:3 and water cement ratio of 0.45 was considered appropriate for the experiment. NBRRI pozzolan replacement (0%, 3%, 6%, 9%, 12% and 15%) by weight of cement were used for concrete production. 5mm glass fibres of 0.2%, 0.3% and 0.4% by volume fraction of concrete were used. Slump test was used to determine concrete consistency. Compressive, tensile and flexural strengths for all the ranges of NBRRI pozzolan replacement of cement and glass fibres were determined at 7, 14, 21 and 28 days after curing.

2.2.1 Sieve analysis

Materials were prepared and weighed accordingly; the sieves were arranged with the largest opening at the top and the pan at the bottom, pouring the aggregate at the top and shaking thoroughly, determining individual weights to the nearest 0.1g of aggregate retained on each sieve. This test is in accordance with the specifications of [16].

2.2.2 Slump testing

Slump test was carried out in accordance with [17].

2.2.3 Compressive strength testing

Compressive strength test was done using cube size of 150mm x 150mm x 150mm. The concrete cubes were cast and cured for various ages of 7, 14, 21 and 28 days before being tested in accordance with [18].

2.2.4 Split tensile strength

The splitting tensile strength test was conducted using a cylindrical specimen of 150mm diameter and 300mm cylindrical length. The tests were carried out at 7, 14, 21 and 28 day curing ages for all the percentage contents and the NBBRI pozzolan replacements. The test was carried out according to [19].

2.2.5 Flexural strength testing

The mould size used for the flexural cast was 100mm x 100mm x 500mm length. The flexural tests were conducted at 28 day curing age for the range of NBRRI replacements in accordance with [19]

3. RESULTS AND DISCUSSION

3.1 Sieve Analysis

The results of fine aggregates sieve analysis is presented in Figure 2 while that of coarse aggregate is shown in Figure 3. It can be seen from the figures that both the fine and coarse aggregates are uniformly graded, conform to near single sized particles and satisfy the requirements of [21].

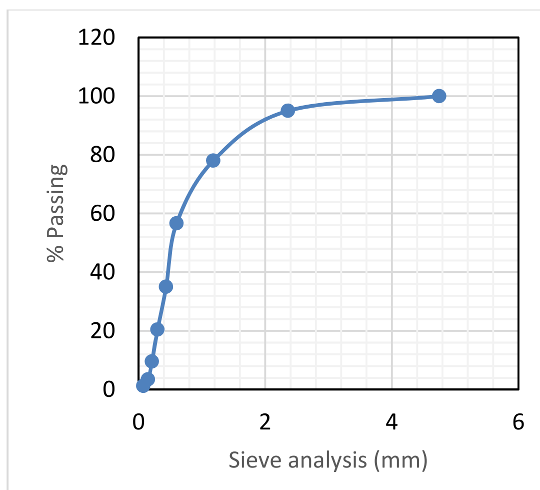

Figure 2: Graph of sieve analysis of fine aggregate

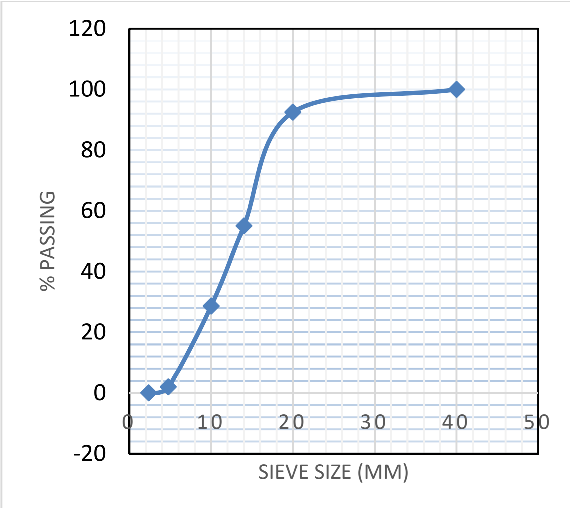

Figure 3: Graph of Sieve Analysis for Coarse Aggregate

3.2 Slump

Figure 4 shows the depreciation in the slump with the increasing content replacement of cement with NBBRI pozzolan at various levels of glass fibre addition. The workability of the concrete decrease as the percentage of NBRRI pozzolan increases. The increase in glass fibre content was the major factor that causes the workability of the fresh concrete to decrease. At 0.4% addition of glass fibre content compaction was difficult so the water cement ratio had to be increased from 0.45 to 0.55 to make it workable.

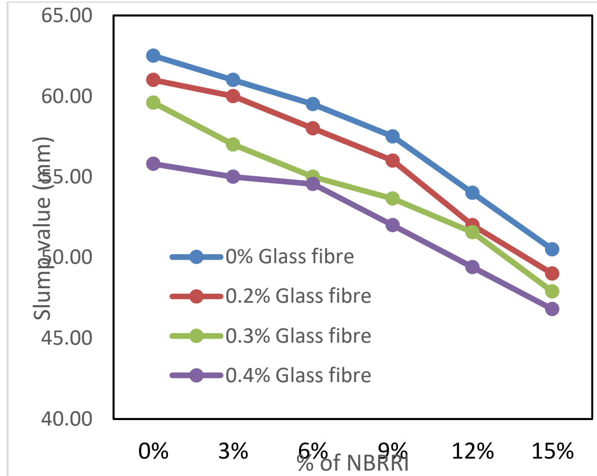

Figure 4: Graph of Slump Test

3.3 Compressive Strength

The result of the compressive strength tests for 7, 14, 21 and 28 days are presented in Table 4 and Figures 5, 6, 7 and 8 respectively. The compressive strength increases with number of days, it also increases as the percentage of NBRRI pozzolan increases up to 12% and finally declined at 15%. The addition of glass fibres further increases the compressive strength for all the range of glass fibre percentage addition. At the optimum NBRRI pozzolan replacement of 12%, the compressive strength increases from 30.92 MPa at 0% glass fibre to 38.99 MPa for 0.4% glass fibres addition. With plain concrete without NBRRI pozzolan replacement, the compressive strength is 34.93 MPa which is higher than optimum 12% NBRRI pozzolan replacement alone. The same trend is observed for other curing ages. Although, NBRRI pozzolan replacement alone, at optimum of 12% is slightly lower than plain concrete but addition of glass fibres significantly increases its compressive strength beyond plain concrete.

Table 4: Compressive Strength Results

NBRRI (%)	GLASS FIBRE (%)	COMPRESSIVE STRENGHT (N/mm^2)			
		7 DAYS	14 DAYS	21 DAYS	28 DAYS
0	0	23.49	25.63	31.45	34.93
	0.2	27.89	28.24	33.84	36.44
	0.3	28.23	29.14	36.29	38.11
	0.4	28.89	32.84	37.40	41.82
3	0	15.62	21.76	24.95	26.16
	0.2	15.84	23.54	26.24	28.95
	0.3	17.91	25.71	29.65	30.79
	0.4	22.35	27.44	31.57	33.92
6	0	19.01	23.67	25.60	27.47
	0.2	21.55	25.40	25.97	29.06
	0.3	23.62	26.54	28.55	31.72
	0.4	25.70	27.62	30.75	35.54
9	0	21.30	26.30	28.12	30.57
	0.2	22.60	26.50	29.5	32.61
	0.3	25.30	28.35	30.64	33.44
	0.4	27.52	30.53	31.31	36.02

12	0	21.92	26.56	28.75	30.92
	0.2	25.84	26.95	30.05	33.33
	0.3	27.47	29.05	31.36	36.45
	0.4	29.92	31.64	33.31	38.99
15	0	19.79	21.31	25.78	25.60
	0.2	21.34	23.52	26.54	26.76
	0.3	23.3	24.40	27.75	28.58
	0.4	25.36	27.29	29.63	31.99

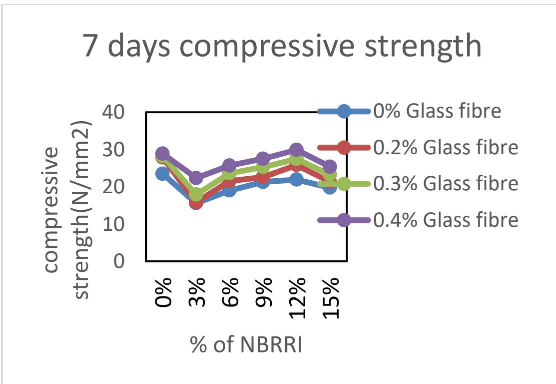

Figure 5: 7 Day Compressive strength of concrete

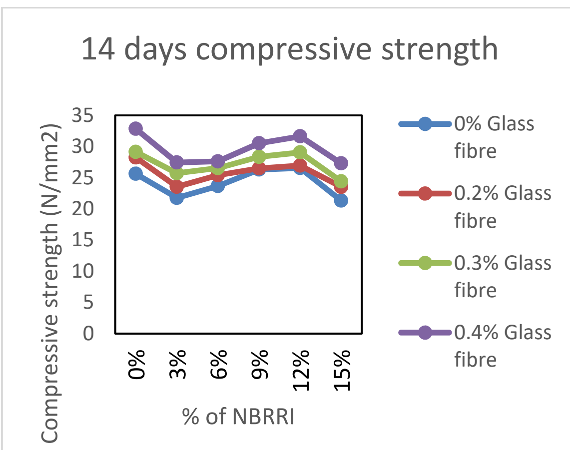

Figure 6: 14 Day Compressive strength of concrete

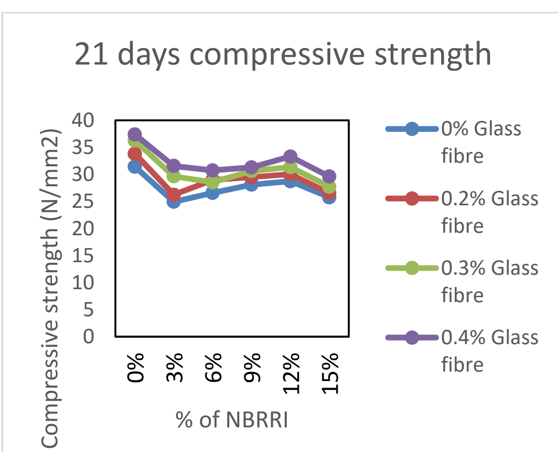

Figure 7: 21 Day Compressive strength of concrete

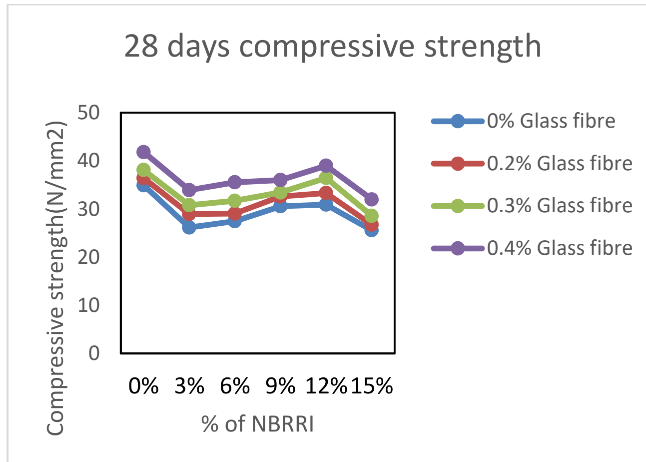

Figure 8: 28 Day Compressive strength of concrete

3.4 Split Tensile Strength

The results are presented in Table 5 and Figures 9, 10, 11 and 12 for 7, 14, 21 and 28 day curing ages. The split tensile strength increases as the percentage of NBRRI pozzolan increases up to 12% and finally declined at 15%. The addition of glass fibres further increases the split tensile strength for all the range of glass fibre percentage addition. At the optimum NBRRI pozzolan replacement of 12%, the split tensile strength increases from 3.11 MPa at 0% glass fibre to 3.65 MPa for 0.4% glass fibres addition. With plain concrete without NBRRI pozzolan replacement, the split tensile strength is 3.20 MPa which is higher than optimum 12% NBRRI pozzolan replacement alone. The same trend is observed for other curing ages. Although, NBRRI pozzolan replacement alone, at optimum of 12% is slightly lower than plain concrete but addition of glass fibres increases its compressive strength beyond plain concrete. This is a significant improvement.

Table 5: Split tensile strength

NBRRI (%)	GLASS FIBRE (%)	SPLIT TENSILE (N/mm^2)			
		7 DAYS	14 DAYS	21 DAYS	28 DAYS
0	0	2.44	2.52	2.63	3.20
	0.2	2.65	2.84	3.12	3.48
	0.3	2.84	3.08	3.35	3.67
	0.4	3.02	3.37	3.88	3.94
3	0	1.98	2.30	2.53	2.68
	0.2	2.16	2.36	2.61	2.72
	0.3	2.20	2.45	2.79	2.83
	0.4	2.40	2.68	2.84	2.88
6	0	2.11	2.36	2.58	2.77
	0.2	2.22	2.39	2.68	2.83
	0.3	2.38	2.54	2.73	2.89
	0.4	2.59	2.80	2.91	2.93
9	0	2.24	2.50	2.62	2.94
	0.2	2.33	2.57	2.76	3.06
	0.3	2.55	2.61	3.04	3.15
	0.4	2.72	2.94	3.12	3.30
12	0	2.40	2.64	2.79	3.11
	0.2	2.56	2.67	2.82	3.18
	0.3	2.76	2.93	3.14	3.43
	0.4	2.77	3.23	3.39	3.65
15	0	2.36	2.58	2.66	2.88
	0.2	2.40	2.60	2.71	2.93
	0.3	2.59	2.68	2.83	3.14
	0.4	2.65	2.85	3.06	3.20

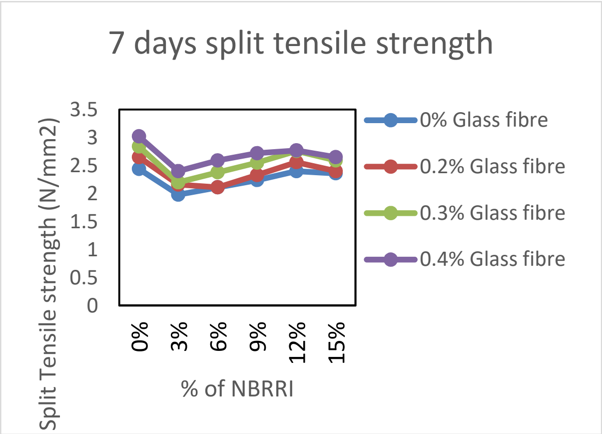

Figure 9: 7 Day Split tensile strength

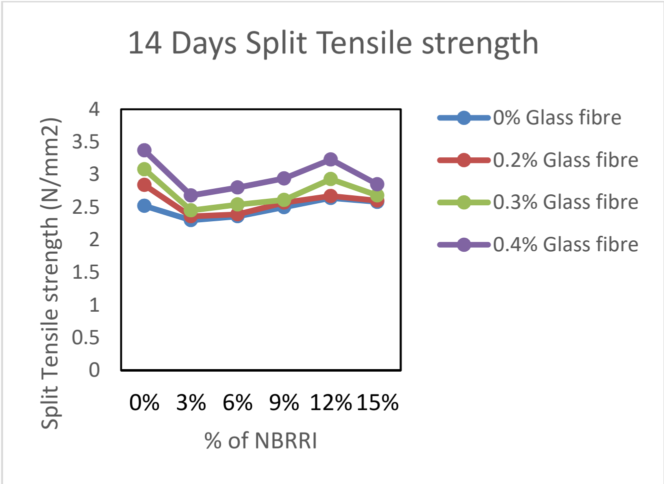

Figure 10: 14 Day Split tensile strength

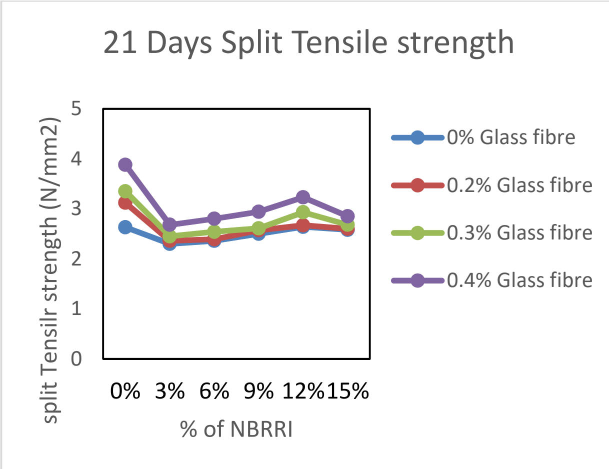

Figure 11: 21 Day Split tensile strength

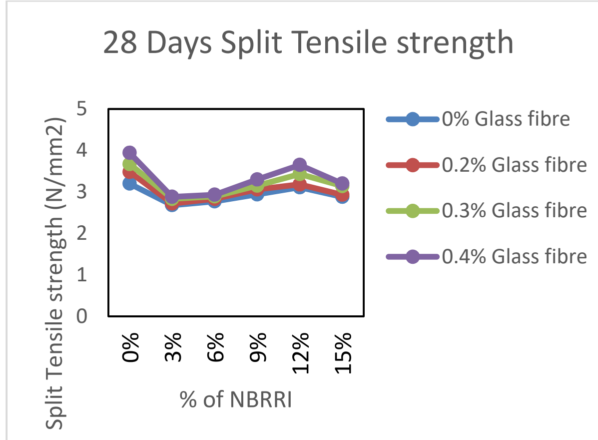

Figure 12: 28 Day Split tensile strength

3.5 Flexural Strength

The results are presented in Table 6 and Figure 13. The flexural strength of NBRRI pozzolanic concrete increases as the percentage of glass fibre increases. These strength also increases as the number of days of curing increases. It is evident that the optimum flexural strength was recorded at 12% NBRRI pozzolan content and 0.4% glass fibre addition. However, the control result is slightly higher than the optimum value of NBRRI pozzolan replacement when 0.3 and 0.4% of glass fibre were used.

Table 6: Flexural Strength

NBRRI (%)	GLASS FIBRE (%)	FLEXUAL STRENGHT (N/mm^2)
		28 DAYS
0	0	5.12
	0.2	5.20
	0.3	6.55
	0.4	7.05
3	0	3.85
	0.2	4.56
	0.3	5.00
	0.4	5.76
6	0	4.08
	0.2	4.92
	0.3	5.24
	0.4	5.80
9	0	5.40
	0.2	5.44
	0.3	5.52
	0.4	5.88
12	0	5.48
	0.2	5.56
	0.3	6.00
	0.4	6.12
15	0	4.84
	0.2	4.32
	0.3	5.00
	0.4	5.52

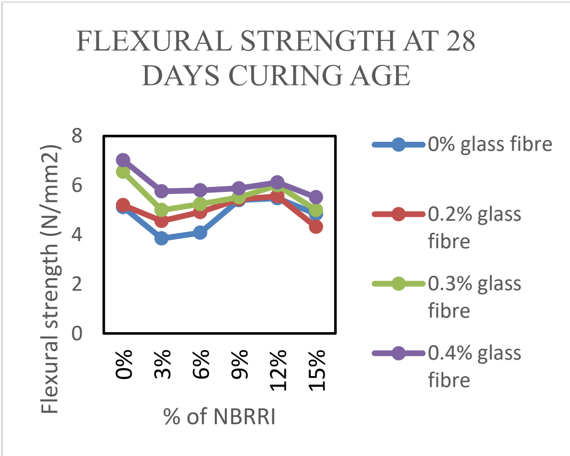

Figure 13: 28 Day Flexural strength.

4. CONCLUSIONS

The purpose of this research was to investigate the effect of cement-NBRRI pozzolanic material blend on the mechanical properties of glass fibre reinforced concrete M30 grade concrete with mix ratio of 1:1.5:3 and water cement ratio of 0.45 was adopted for the experiment. NBRRI pozzolan replacement (0%, 3%, 6%, 9%, 12% and 15%) by weight of cement and 5mm glass fibres (0.2%, 0.3% and 0.4%) by volume fraction of concrete were used for concrete production. Slump test was used to determine concrete consistency. Compressive, tensile and flexural strengths for all the ranges of NBRRI pozzolan replacement of cement and glass fibres were determined at 7, 14, 21 and 28 days after curing.

It was observed that the workability of the concrete decreases as the percentage of NBRRI pozzolan and glass fibre increases respectively. Replacing cement with NBRRI pozzolan alone results to almost plain concrete strength. The addition of glass fibre to concrete made by replacing certain percentage of cement with NBRRI pozzolan improves the strength of the concrete significantly. However, in situations where high strength concrete are required, the use of NBRRI pozzolan without glass fibre cannot be relied upon to cater for such requirements.

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