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INVESTIGATION OF THE STRENGTH PROPERTIES OF HYBRID FIBRE REINFORCED CONCRETE (HFRC) MADE WITH POLYPROPYLENE FIBRE (PPF) AND ALKALI RESISTANCE GLASS FIBRE (ARGF)

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ABSTRACT

This study experimentally investigated the strength properties of hybrid fiber reinforced concrete, using polypropylene fibers (PPF) and alkali resistance glass fibers (ARGF). The fibers were added to grade 25 concrete at different proportion of 0.5%, 1.0%, 1.5% and 2.0% by percentage volume of concrete. A total of sixty three cubes samples were tested for compressive strength, twenty four cylindrical samples were tested for split tensile strength and twenty four beam samples were tested for flexural strength and ductility test. Maximum compressive strength was attained at 1.5% fiber volume with hybrid fiber ratio of 80% ARGF and 20% PPF, maximum split tensile strength was attained at 1.0% fiber volume with hybrid fiber ratio of 80% ARGF and 20% PPF. The beam samples attained it maximum flexural strength at 1.0% fiber volume with hybrid fiber ratio of 60% ARGF and 40% PPF.

Keywords: hybrid fiber, polypropylene fiber, alkaline resistance glass fiber, reinforced concrete, compressive strength, flexural strength, split tensile strength, slump.

1. INTRODUCTION

Concrete is the most widely used construction material in the world, due to it structural properties, durability, cost efficiency and increase in infrastructural development. With this ever increasing consumption of concrete, the fundamental natural ingredients which make the concrete, that is fine and coarse aggregates are depleting at a very fast pace. This necessitates the need for the use of alternative materials which can be added to cement without lowering its performance.

Fiber reinforced concrete is defined as a concrete made of hydraulic cements, fine or fine and coarse aggregates and discontinuous discrete fibers [1]. A fiber is a small discrete reinforcing material produced from various materials like steel, plastic, glass, carbon and natural materials in various shapes and sizes. The combination of two or more types of fibers in the same concrete mixture can produce a composite with better engineering properties than that containing single fiber. Different types of fibers can be properly combined to produce hybrid fiber reinforced concrete.

Fiber reinforced concrete is relatively a new construction material developed through extensive research and developmental work during the last three decades. It has already found a wide range of practical applications and proved to be a reliable construction material having superior performance characteristics compared to conventional concrete. Addition of fibers in concrete can improved several properties like compressive and tensile strength, cracking resistance, ductility, durability, flexural strength, impact and wear resistance, toughness, post cracking behavior of concrete and fatigue resistance.

1.1 Previous work on polypropylene and alkali resistance glass fibers reinforced composites

The mechanical properties of polypropylene fiber reinforced concrete for M25 and M30 mixes was investigated by [2]. They observed that with the addition of fiber in the M25 concrete mix, the compressive strength of concrete cylinder increased by 3.23% at 0.5% fiber content, 12.15% at 1.0% fiber content, 10.48% at 1.5% fiber content, 7.57% at 2.0% fiber content, 2.98% at 2.5% fiber content and 1.53% at 3.0% fiber content. The optimum dosage for maximum fiber content was 1.0% giving compressive strength of 31.56MPa with 12.15% increase form control specimen.

The effect of polypropylene fibers on the strength properties of fly ash based concrete was also investigated by [3]. In the study, fiber volume fraction of 0.15%, 0.2%, 0.25% and 0.3% was used in fly ash concrete with CLASS Cfly ash of specific gravity of 1.96 obtained from NLC. Fly ash content was varied as 30%, 40% and 50%. 12mm (40%), and 20mm (60%) coarse aggregate with specific gravity of 2.7 was used. The compressive strength of concrete mixes made with and without fly ash and polypropylene fiber was determined at 28days as well as 56days. The summary of their result shows that compressive strength of concrete increases gradually by the addition of polypropylene fiber from 0.15% to 0.3%. There is increase in compressive strength as compared with normal concrete (without fiber).

An experimental study on glass fiber concrete using M20 grade concrete and glass fiber was undertaken by [4]. The glass fibers were added at ratio of 0.5%, 1.0%, 2.0% and 3.0%. The result of the compressive strength of concrete for 28 days was 27.06N/mm^2, 28.46 N/mm^2, 26.88 N/mm^2 and 26.108 N/mm^2 for fiber content of 0.5%, 1.0%, 2.0% and 3.0% respectively. The percentage increment compared to the normal concrete (without fiber) was 35.3%, 42.3%, 34.9% and 30.54% for the respective fiber content. The flexural strength of 0.5%, 1.0%, 2.0% and 3.0% fiber content at 28 days were observed to be 2.45N/mm^2, 2.94 N/mm^2, 2.60N/mm^2 and 2.45N/mm^2 respectively. The highest strength was observed at fiber content of 1.0% for both flexural strength and compressive strength. The split tensile strength was equally observed to be high at 1.0% having 2.83N/mm^2 for 7 days and 3.9 N/mm^{2}2 for 28 days.

A research on performance assessment of glass fiber reinforced concrete beams was carried out by [5]; they made the following conclusions from their result:

a) Alkali resistance glass fiber in concrete gives a reduction in bleeding. A reduction in bleeding improves the surface integrity of concrete, its homogeneity and reduces the probability of cracks occurring where there are some restraint to settlement.

b) Increasing the percentage of alkali resistance glass fiber by volume of concrete did not result in variation of the compressive strength The increase in percentage of compressive strength for 0.5% glass fibre (GF) was 5.4%, for 1.0% GF was 5.47% and for 1.5% GF was 8.9%. A very good variation on split tensile strength was also observed. The increase in percentage of split tensile strength for 0.5%GF was 25.0%, for 1.0%GF was 52.84% and for 1.5%GF was 72.78% but the increase in percentage of flexural strength was 16.49%, 47.64% and 87.17% respectively.

c) The ultimate load carrying capacity of glass fiber reinforced concrete beams are more than that of the control beams (plain concrete). Ultimate load carrying capacity of SET II beams to that of SET I beams increased from 72KN to 84KN, 68KN to 94KN, and 75Kn to 86KN. The ultimate load carrying capacity of Set III beams to that of SET I increased from 72KN to 90KN, 68KN to 102KN and 75KN to 98KN.

d) The load deflection behavior of the beams that the deflections of the glass fiber reinforced concrete (GFRC), were more than that of the control beams and the number of cracks are less than the control beams.

A research on fibre reinforced concrete composite using glass fiber with modulus of elasticity of 72GPA, filament diameter 14microns and 12mm in length was undertaken by [6]. Concrete M20 grade was used in preparing the fiber reinforced concrete. The observation from their result shows that the increase in compressive strength was up to 37% with the addition of 0.33% fiber content compares to conventional concrete. The percentage increase in flexural strength of glass fiber was observed to be 5.19% when compared with ordinary plain concrete. The percentage increase in flexural strength of glass fiber reinforced concrete using fiber content of 0.33% and 1.25% steel (12mm reinforced bar) was observed to be 150% when compared with glass fiber concrete without reinforcement.

This study investigated the strength and other properties of a hybrid fibre reinforced concrete made with polyproplylene fibre (PPF) and alkaline resistance glass fibre (ARGF). This combination of fibres has never been researched upon before now.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement

The cement used for this study is Portland Lime Cement (PLC) produced by Dangote cement factory and conforming to [7]. The manufacturer specification of the cement is “Dangote 3x cement, grade 42.5N”

2.1.2 Fine aggregate

The fine aggregate used for this study was river sand with specific gravity of 2.63 and fines modulus of 3.3, passing through BS4.75mm sieve and conforming to zone 2 as per [8]. The sand which was mined from a river in Port Harcourt was properly air dried and free from deleterious minerals like clay, silt constituent and chloride contaminants.

2.1.3 Coarse aggregate

The coarse aggregates used was crushed granite with specific gravity of 2.71, 52% of the aggregate was retained on BS13.2mm sieve and conforming to zone 3 as per [8]. The material was properly dried and free from deleterious materials like clay, silt content and chloride contaminants. The coarse aggregate was obtained from a quarry in Akampa cross river state Nigeria.

2.1.4 Water

Clean potable water which satisfies drinking standard and conforming to [9] was used for mixing and curing of concrete samples. It was obtained from the Civil Engineering Laboratory of the Rivers State University.

2.1.5 Polypropylene fiber

The polypropylene fiber used in this research work was obtained from Purechem Manufacturing Company in Lagos Nigeria. The properties of the fiber as obtained from the manufacturer is as indicated in Table-1. A sample of the polypropylene fibre is shown in Figure-1.

Figure-1. Polypropylene fiber.

2.1.6 Alkali resistance glass fiber

The alkali resistance glass fiber used for this research work is ACS19PH901X, produced by Nippon Electrical Company Limited in collaboration with Kanebo Limited in Lagos Nigeria. It is a high quality alkali resistance glass fiber containing a high percentage of zirconia (Z_rO_2). The letter P in the product code shows that the filament diameter is 18 microns, it has the highest integrity and it is most resistance to filamentization during mixing and processing. The mechanical and physical properties of the fiber is as shown in Table-1. Figure-2 is the picture of the sample of the ARGF.

Table-1. Fibers properties as specified by the manufacturer.

Type of fiber	Alkali resistance glass fiber	Polypropylene fiber
Zirconia content	19% minimum	Nill
Chopped length	19mm	12mm
Tensile strength	1300MPa	350MPa
Specific Gravity	2723.4Kg/m^3	0.91g/cm^3
young modulus	77.30Gpa	5500-7000MPa
Density	380Kg/m^3	215Kg/m^3
Aspect ratio	1055	400
Strain	More than 1.5%	

Figure-2. Alkali resistance glass fibre.

2.2 Method

2.2.1 Concrete mix design

The concrete mix design was done as per British standard using the DOE (Design of Experiment) method. The method is applicable to concrete for most purpose including roads. The detail of concrete mix design is as shown in Table-2. The proportion and quantities of materials for 1m^3 of concrete.

Table-2. Concrete mix design.

Concrete strength at 28 days	25MPa
Standard deviation (S)	6
K for 5% defective	1.64
Target mean strength $f_m = f_c$ + m =25 +(6 * 1.64)	34.84MPa
Type of cement	Ordinary Portland cement
Type of coarse aggregates	Crushed
Water/cement ratio	0.5
Maximum water cement ratio	0.55
Slump	100mm
Maximum size of coarse aggregate	20mm
Water requirement	210Kg/m^3
Maximum cement content = 210/0.5	420Kg/m^3
Minimum cement content = 210/0.55	381.8Kg/m^3
density of fresh concrete mix	2400Kg/m^3
Total density of aggregates (coarse + fine)	2400 - 420 - 210 = 1770Kg/m^3
Proportion of fine aggregate	37%
Weight of fine aggregate	0.37 * 1770 = 655Kg/m^3
Weight of coarse aggregate	1770 - 655 = 1115Kg/m^3

Table-3. Proportion and quantities of materials for 1m^3 of concrete.

Materials	Weight (Kg)	Ratio
Cement	420	1
Fine aggregate (sand)	655	1.6
Coarse aggregate (gravel)	1115	2.7
Water	210	0.5

2.2.2 Concrete batching and production of HFRC

The mixing of fiber reinforced concrete was done in the laboratory according to [1]. Concrete batching was done by adopting a common mix ratio of 1:1.6:2.7 by weight of cement, sand and granite. It was design to give a compressive strength of 25MPa at twenty eight days and slump value of about 100mm. Concrete mixing was done by the use of a mechanical concrete mixer in the laboratory. The cement and the fine aggregate (sand) were first placed in the concrete mixer and allowed to rotate for about two minutes, followed by the addition of fibers and one third of water. The fibers were added by percentage volume of concrete in different proportion. Care was taken to avoid balling during the addition of fiber into the mix. The mixture was allowed to rotate in the mixer for two minutes before the addition of coarse aggregate and water. The mixture was allowed for another three minutes for proper mixing, care was taken to avoid bleeding of concrete. Slump test was conducted at every mix and the slump value recorded. The concrete was placed in oiled concrete molds and compacted with a table vibrator. The concrete samples were allowed in the molds for twenty four hours after which they were removed from the molds and placed in a curing tank for twenty eight days.

2.2.3 Compressive strength test

Concrete cubes were tested for compressive strength in accordance to [10] after 28 days of curing. Sixty five numbers of 150 x 150 x 150mm concrete cubes containing hybrid fiber in varying proportion per volume of concrete were tested and the result obtained for each cube recorded.

2.2.4 Splitting tensile strength test

The test was conducted as specified in [11]. Cylindrical concrete specimen of size 150mm diameter x 300mm length were cast and cured in water for 28 days.

2.2.5 Flexural strength test

The test was carried out in accordance to [12. 24 numbers of 100 x 100 x 500mm beams samples with varying ratio of hybrid fibers cured for 28 day were tested for flexural strength. The hardened concrete beams were placed in the hydraulic frame system, simply supported and subjected to symmetrical concentrated two point loading. The distance between the outer rollers (the span support) is equal to 3 times the distance between the inner rollers.

3. RESULTS AND DISCUSSIONS

3.1 Compressive strength

Table-4 shows the results obtained from compressive strength test. The H0 - P0G0 is the control sample. 4 sets of total volume reinforced fibre were cast as: 0.5%, 1.0%, 1.5% and 2.0%. The variations in the PPF and ARGF are also shown. 3 samples of each specimen ID were cast and the average value of the compressive strength recorded. The last column of Table-4 shows the percentage increase in compressive strength as compared to the control sample.

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Table-4. Compressive strength test experimental result.

			Volume of individual fiber		Compressive strength (N/mm^2)				
S/No.	**Specimen Id**	**Volume of HRF**	**PPF** (%)	**ARGF** (%)	**Sample 1**	**Sample 2**	**Sample 3**	**Average**	**% Increase in strength** (%)
1	H0 - P0G0	*0*	0	0	31.19	33.8	34.7	33.23	Control
2	H0.5 - P0G100	*0.5*	0	100	36.32	36.1	38.95	37.12	11.71
3	H0.5 - P100G0	*0.5*	100	0	40.08	39.96	38.85	39.63	19.26
4	H0.5 - P20G80	*0.5*	20	80	40.04	39.9	40.46	40.13	20.76
5	H0.5 - P40G60	*0.5*	40	60	37.95	38.29	38.46	38.23	15.05
6	H0.5 - P50G50	*0.5*	50	50	36.55	37.35	37.76	37.22	12.01
7	H1.0 - P0G100	*1.0*	0	100	40.33	39.32	39.57	39.74	19.59
8	H1.0 - P100G0	*1.0*	100	0	44.25	40.77	41.88	42.3	27.29
9	H1.0 - P20G80	*1.0*	20	80	39.43	35.63	38.37	37.81	13.78
10	H1.0 - P40G60	*1.0*	40	60	36.8	38.08	37.63	37.5	12.85
11	H1.0 - P50G50	*1.0*	50	50	36.03	33.81	33.33	34.38	3.46
12	H1.5 - P0G100	*1.5*	0	100	41.39	38.16	40.8	40.12	20.73
13	H1.5 - P100G0	*1.5*	100	0	35.2	31.28	31.88	32.79	-1.32
14	H1.5 - P20G80	*1.5*	20	80	43.43	41.97	42.7	42.7	28.50
15	H1.5 - P40G60	*1.5*	40	60	36.81	39.52	38.33	38.22	15.02
16	H1.5 - P50G50	*1.5*	50	50	38.06	41.61	39.2	39.62	19.23
17	H2.0 - P0G100	*2.0*	0	100	30.30	30.24	34.10	31.55	-5.06
18	H2.0 - P100G0	*2.0*	100	0	30.6	30.24	34.47	31.77	-4.39
19	H2.0 - P20G80	*2.0*	20	80	35.6	38.61	39.4	37.87	13.96
20	H2.0 - P40G60	*2.0*	40	60	36.95	36.76	37.35	37.02	11.41
21	H2.0 - P50G50	*2.0*	50	50	36.11	36.69	35.09	35.96	8.22

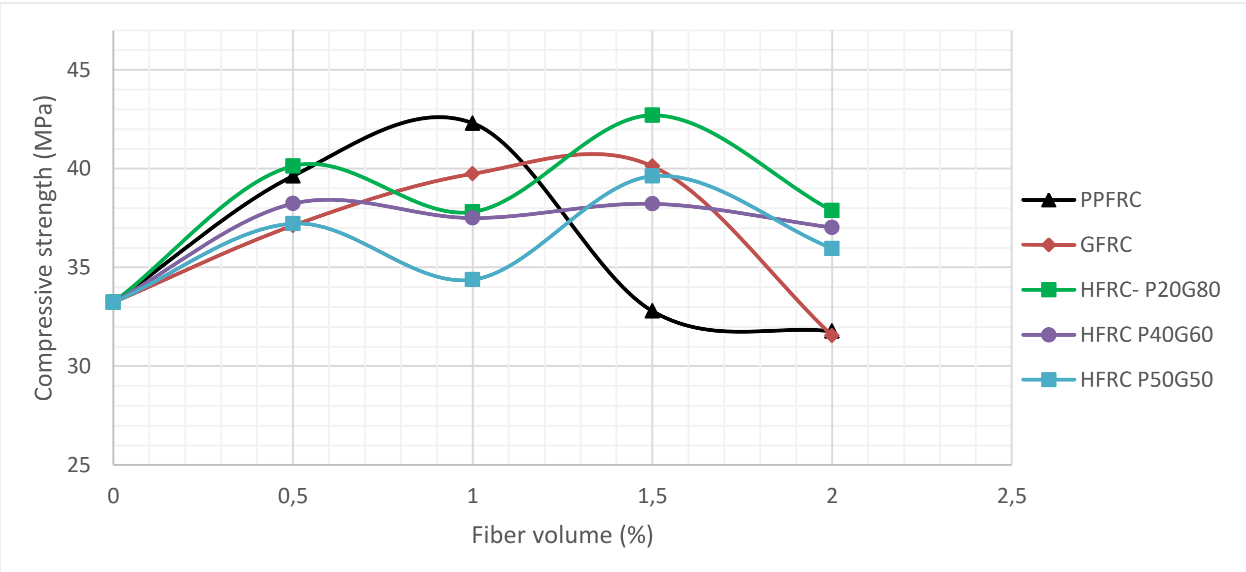

Figure-3. Plot of compressive strength result of HFRC against fibre volume.

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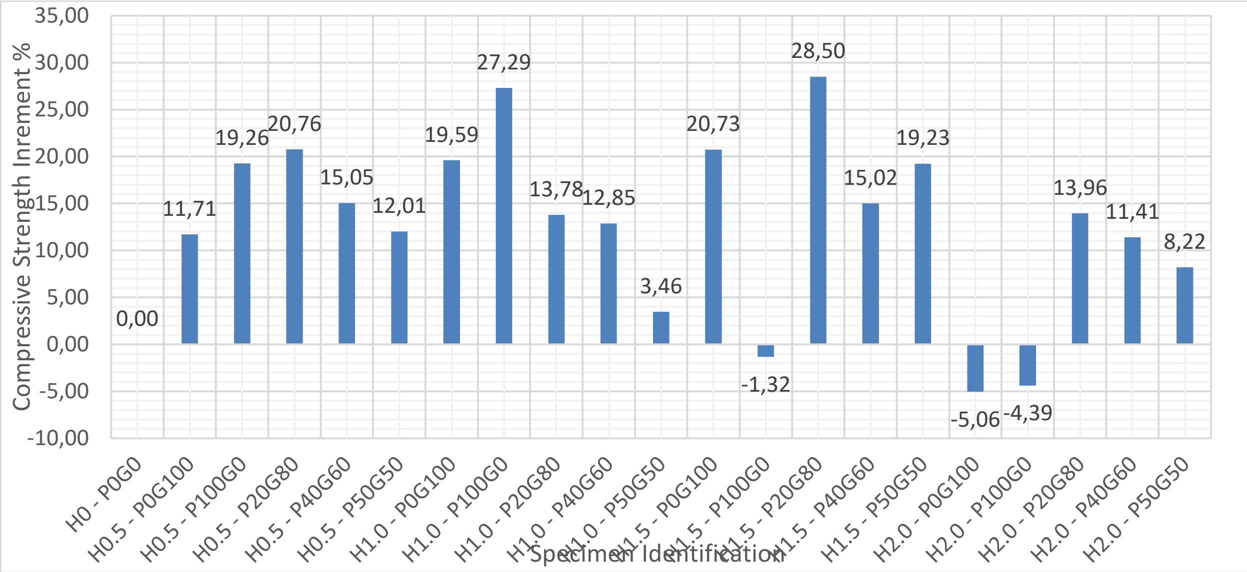

Figure-4. Plot of compressive strength increment against various fibre combinations.

Table-4 and Figure-3 show that the addition of fibers to concrete shows significant improvement in compressive strength. The compressive test result in table 4 shows that at 0.5% fiber volume, the result obtained for glass and polypropylene fiber reinforced concrete specimen H0.5P0G100 and H0.5P100G0 was 37.12N/mm^2 and 39.63N/mm^2 respectively showing an increment of 11.71% and 19.26% in compressive strength when compared with the control specimen (H0P0G0). The hybrid fiber specimen H0.5P20G80, H0.5P40G60 and H0.5P50G50 gave compressive strength of 40.13N/mm2, 38.23N/mm^2 and 37.22N/mm^2 respectively given an increment of 20.76%, 15.05% and 12.01% in strength. At the 0.5% of fiber addition, specimen H0.5P20G80 gave the maximum performance in strength.

Similarly, at 1.0% fiber volume, specimen H1.0P0G100 and H1.0P100G0 gave a compressive strength of 39.74N/mm^2 and 42.3N/mm^2 resulting in strength increment of 19.5% and 27.29%. The hybrid fiber specimens H1.0P20G80, H1.0P40G60 and H1.0P50G50 gave compressive strength of 37.81N/mm^2, 37.5N/mm^2 and 34.38N/mm^2 respectively, showing increment of 13.78%, 12.85% and 3.46% in compressive strength compared with the control specimen. Specimen H.10P100G0 gives the maximum compressive strength at this fiber volume.

At 1.5% fiber volume, specimen H1.5P0G100 and H1.5P100G0 gave compressive strength of 40.12N/mm^2 and 32.79N/mm^2 corresponding to an increment of 20.75% and -1.32% in compressive strength. Specimen H1.5P100G0 gave a compressive strength below the control specimen. From the hybrid fiber specimens H1.5P20G80, H1.5P40G60 and H1.5P50G50 compressive strength value of 42.7N/mm^2, 38.33N/mm^2 and 39.62N/mm^2 were obtained giving an increment in strength by 28.5%, 15.02% and 19.23% respectively. It was observed that specimen H1.5P20G80 had the maximum strength of 42.7N/mm^2.

At 2.0% fiber volume, compressive strength of specimen H2.0P0G100 and H2.0P100G0 was 31.55N/mm2 and 31.77N/mm^2 indicating a reduction in strength when compared with the control specimen. The strength reduction was -5.06% and -4.39% respectively. The hybrid specimen H2.0p20G80, H2.0P40G60 and H2.0P50G50 gave strength increment of 13.56%, 11.41% and 8.225 compared with the

3.2 Split tensile strength

The results obtained for split tensile strength test on specimens is presented in Table-5 and in Figure-5.

While the plot of the incremental values of the split tensile strength is presented in Figure-6.

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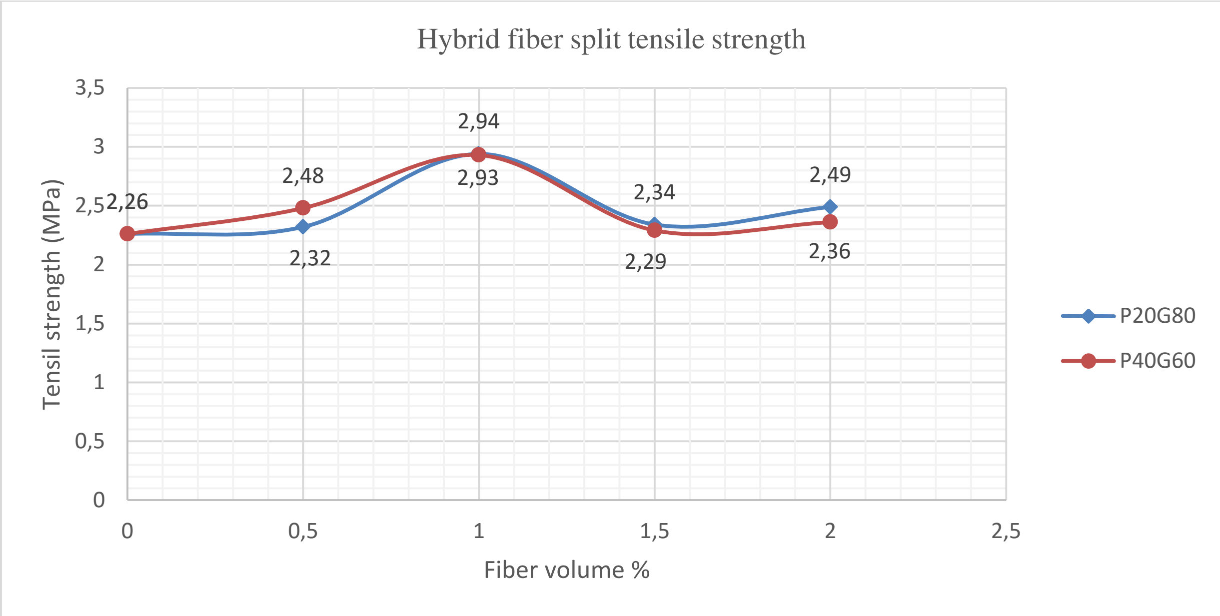

Figure-5. Plot of Split Tensile Strength against percentage fibre volume.

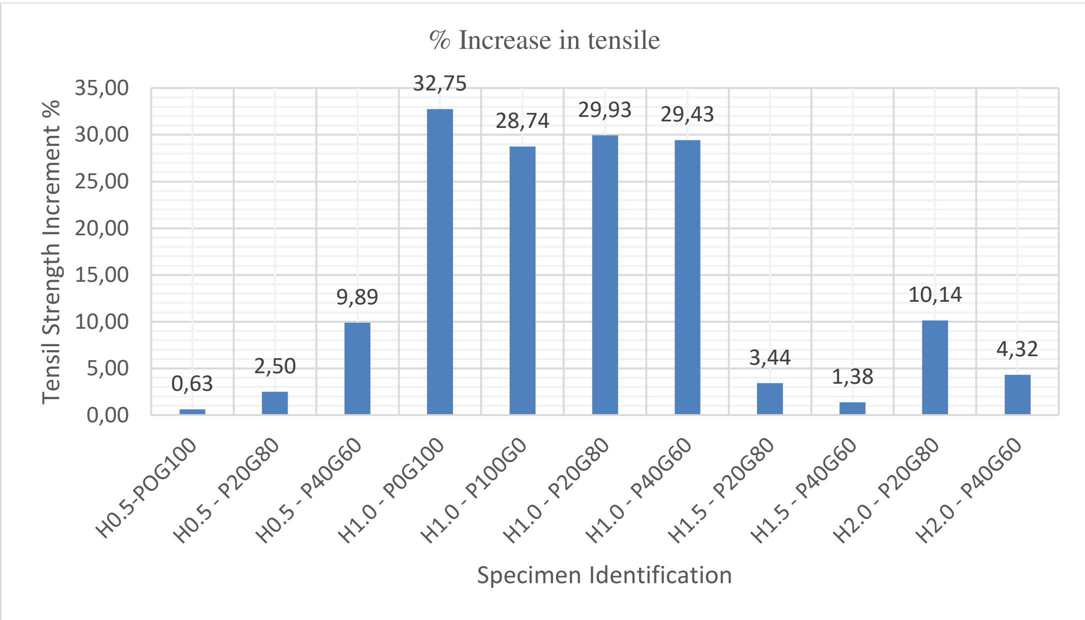

Figure-6. Plot of tensile strength increment against fibre volume.

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Table-5. Split tensile strength test experimental result.

			Volume of individual fiber				
S/No.	**Specimen Id**	**Volume of HRF**	**Polypropylene** (%)	**ARGF** (%)	**Split force**	**Tensile Strength** (N/mm^2)	**% Increase**
1	H0 - P0G0	0	0	0	159.7	2.26	Control
2	H0.5-POG100	0.5	0	100	160.7	2.27	0.63
3	H0.5- P20G80	0.5	20	80	163.7	2.32	2.50
4	H0.5- P40G60	0.5	40	60	175.5	2.48	9.89
5	H1.0- P0G100	1	0	100	212	3.00	32.75
6	H1.0- P100G0	1	100	0	205.6	2.91	28.74
7	H1.0- P20G80	1	20	80	207.5	2.94	29.93
8	H1.0- P40G60	1	40	60	206.7	2.93	29.43
9	H1.5- P20G80	1.5	20	80	165.2	2.34	3.44
10	H1.5- P40G60	1.5	40	60	161.9	2.29	1.38
11	H2.0- P20G80	2	20	80	175.9	2.49	10.14
12	H2.0- P40G60	2	40	60	166.6	2.36	4.32

3.3 Split tensile strength

Results obtained from the experiment prove that the addition of fibers to concrete have positive effect on the split tensile strength of concrete.

At 0.5% fiber volume, though there was no significant improvement in split tensile strength, but the hybrid fiber specimens H0.5P20G80 and H0.5P40G60 have higher tensile strength than the control specimen and ARGF specimen H0.5P0G100. The tensile strength result shows significant increase in strength at 1.0% fiber volume. Specimen H1.0P0G100 and H1.0P100G0 have tensile strength values of $3.0N/mm^2$ and $2.91N/mm^2$ resulting in 32.75% and 28.74% tensile strength increment. The hybrid fibers H1.0P20G80 and H1.0P40G60 gave tensile strength of $2.94N/mm^2$ and $2.93N/mm^2$.

There was significant drop in tensile strength as the fibers volume increased above 1.0%. It was observed that alkali resistance and polypropylene hybrid fiber reinforced concrete specimen attain maximum split tensile strength at fiber volume of 1.0%, while specimen H0.5P0G100 gave the lowest split strength.

3.4 Flexural strength

The flexural strength values for the tested beams are shown in Table-6 and Figure-7.

While Figure-8 is a plot of Flexural Strength Increment against fibre volume.

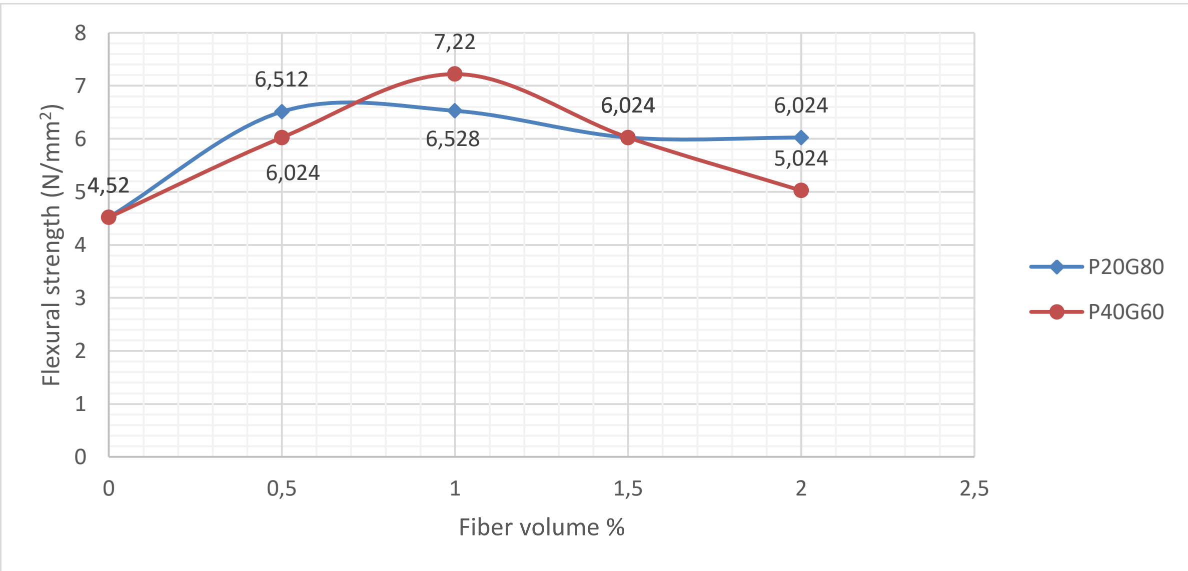

Figure-7. Plot of flexural strength against fibre volume.

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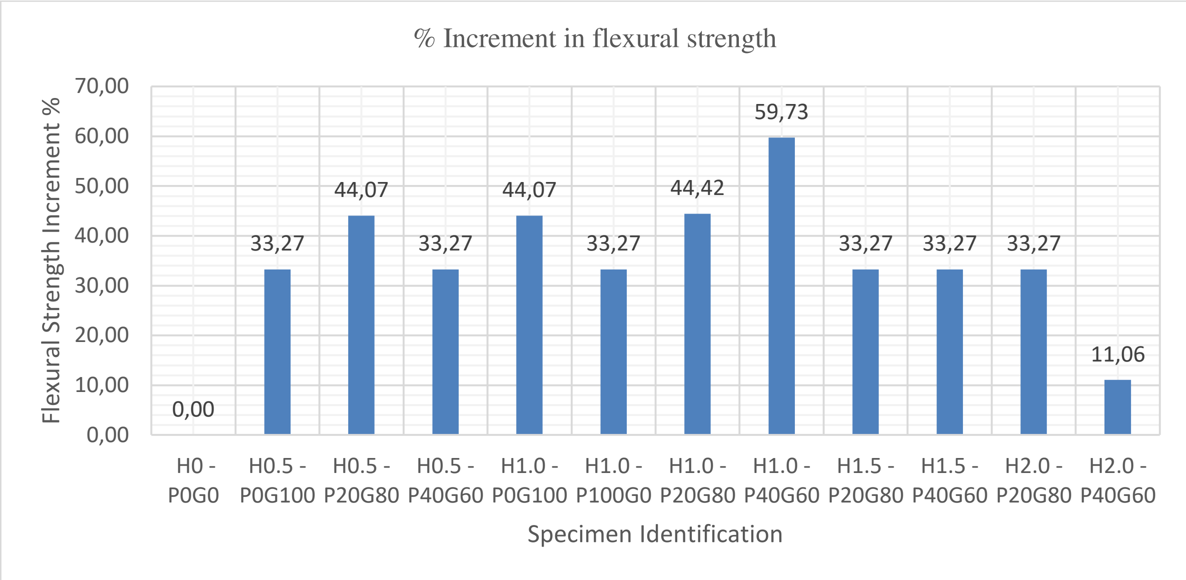

Figure-8. Plot of flexural strength increment against fibre volume.

Table-6. Flexural strength test experimental result.

S. No.	**Specimen identification**	**Yield load** (KN)	**Ultimate load** (KN)	**Flexural strength** (KN/m^2)	**Flexural strength % increment**
1	H0 - P0G0	10.04	11.3	4.52	0.00
2	H0.5 - P0G100	11.3	15.06	6.024	33.27
3	H0.5 - P20G80	11.3	16.28	6.512	44.07
4	H0.5 - P40G60	11.3	15.06	6.024	33.27
5	H1.0 - P0G100	15.06	16.28	6.512	44.07
6	H1.0 - P100G0	15.06	15.06	6.024	33.27
7	H1.0 - P20G80	15.06	16.32	6.528	44.42
8	H1.0 - P40G60	16.32	18.05	7.22	59.73
9	H1.5 - P20G80	12.55	15.06	6.024	33.27
10	H1.5 - P40G60	12.55	15.06	6.024	33.27
11	H2.0 - P20G80	11.3	15.06	6.024	33.27
12	H2.0 - P40G60	11.3	12.55	5.02	11.06

The flexural strength test result shows that the fiber combination of 40% PPF and 60% ARGF at fiber volume fraction of 1.0% with 59.73% increment in flexural strength when compared with the control specimen gave the highest value of flexural strength; the ultimate load attained was 18.05KN. Specimen H2.0P40G60 gave the lowest flexural strength of 5.02N/mm2 at fiber volume fraction of 2.0% having a flexural strength increment of 11.06%.

At 0.5% fiber volume fraction, the hybrid fiber specimens H0.5P20G80 with flexural strength increment of 44.07% shows better performance than the control sample. ARGF specimen at the same fiber volume fractions gave strength increment of 33.27%.with a flexural strength of $6.024N/mm^2$. Specimen H0.5P0G100, H0.5P40G60, H1.0P100G0, H1.5P20G80, H1.5P40G60 and H2.0P20G80 attain the same flexural strength of $6.024N/mm^2$, with strength increment of 33.27% compared to the control sample. It was observed that specimen H1.0P40G60 had the highest flexural strength with a value of $7.22N/mm^2$.

3.5 Concrete slump

Concrete slump test was used to determine the workability of the hybrid fibre concrete mix. The result obtained from slump test is shown in Figure-9, the slump values decrease with increase in fiber addition, the minimum slump obtained was 13mm representing the slump value for specimen H2.0P0G100. It was observed that all fiber reinforced mixes responded well to

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mechanical vibration and was placed and compacted without much effort.

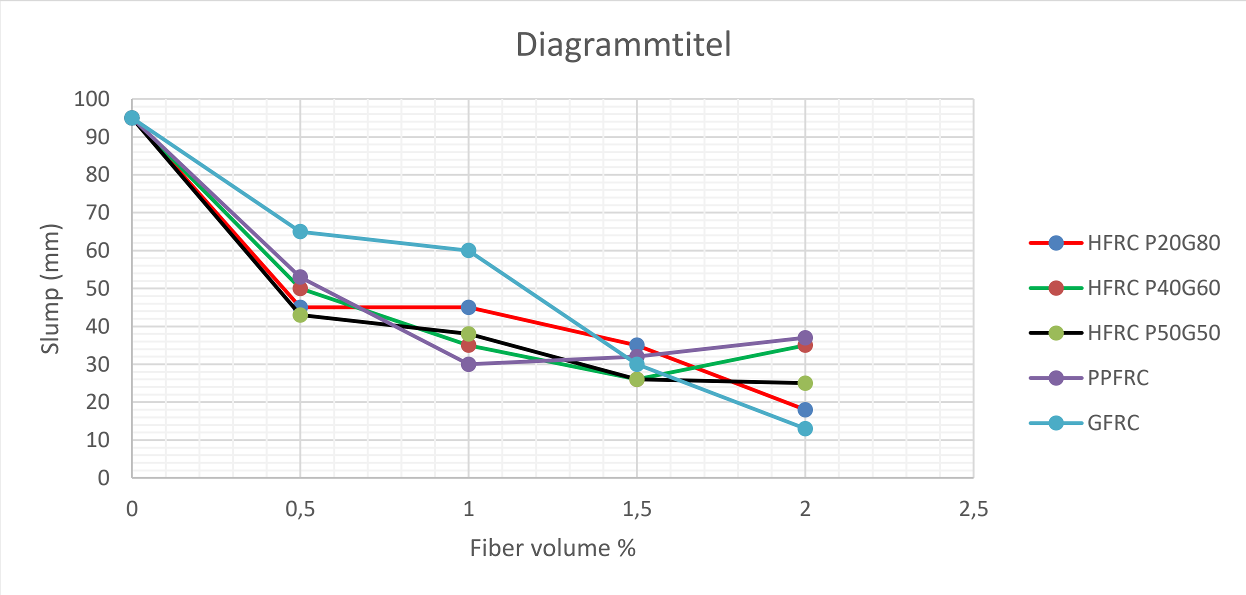

Figure-9. Specimens slum test result.

4. CONCLUSIONS

Base on the results obtained from experimental investigations presented in this study, the following conclusions where derived.

a) Alkali resistance glass - polypropylene hybrid fiber reinforced concrete specimen attain maximum compressive strength of 42.7N/mm^2 at fiber volume of 1.5% with fiber ratio of 80% ARGF and 20% PPF.

b) At 2.0% fiber volume fraction, there was a significant drop in compressive strength of ARGF and PPF reinforced concrete specimens, while the hybrid fiber reinforced concrete specimens shows significant increase in compressive strength, this is because the presence of both fibers tend to bridge the micro cracks in the concrete, thus creating an increase in compressive strength.

c) At 0.5% and 1.0% fiber volume ratio, polypropylene fiber reinforced concrete specimens because of it lower fiber aspect ratio tends to have higher increment in compressive strength than alkali resistance glass fiber reinforced concrete specimens with higher aspect ratio.

d) Split tensile increases with the addition of fibers. Maximum split tensile strength for the hybrid fiber reinforced concrete specimens was 2.94N/mm^2 attained at 1.0% fiber volume and fiber ratio of 80% ARGF and 20% PPF.

e) The ultimate flexural strength attained for the hybrid fiber reinforced concrete specimens was 7.22N/mm^2, with strength increment of 59.75% at 1.0% fiber volume and fiber ratio of 60% ARGF and 40% PPF.

f) The load carrying capacity of concrete beam samples were increased with the addition of hybrid fibers, ultimate load capacity was 18.05KN attained at 1.0% fiber volume.

g) Addition of a hybrid of alkali resistance glass fiber and polypropylene glass fiber to concrete had effect on concrete workability. The slump decreases with increase in fibers, with alkali resistance glass fiber having more effect on the concrete slump due to its aspect ratio.

Abbreviations

ACI	:	American Concrete Institute
AFRC	:	Asbestos Fiber Reinforced concrete
ARGF	:	Alkali Resistance Glass Fiber
ARGFRC	:	Alkali Resistance Glass Fiber reinforced Concrete
ASTM	:	American Society of Testing Materials
CFRC	:	Carbon Fiber Reinforced Concrete
FRC	:	Fiber Reinforced Concrete
GF	:	Glass Fiber
GFRC	:	Glass Fiber reinforced Concrete
HFRC	:	Hybrid Fiber reinforced Concrete
PFRC	:	Polymer Fiber Reinforced

		Concrete
PPF	:	Polypropylene Fiber
PPFRC	:	Polypropylene Fiber Reinforced Concrete
NLC	:	
SFRC	:	Steel Fiber Reinforced Concrete
UTM	:	Universal Testing Machine

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