ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

STUDY ON EFFECT OF POLYPROPYLENE FIBRES ON MECHANICAL PROPERTIES OF NORMAL STRENGTH CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY GGBS

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ABSTRACT

Concrete is most widely used construction material in the world because of its ability to cast in any form and shape. Concrete is a composite construction. It is absolutely necessary in modern society's fascination with new roads, buildings and other constructions. One industry expert has gone as far as to say that now "concrete is chemistry". This is due to the increasing development of admixtures which chemically affect certain properties of concrete. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementations material, aggregate and water and by adding some special ingredients. Hence concrete is very well suited for a wide range of applications.

In the present work the design mix consists of 426 kg/m^3 of cementations material in which increments of 0.5% each up to 2% is replaced with polypropylene fibers in case of

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

primary blends and for secondary blends, cement is replaced with 40% of GGBS and . Coarse aggregate of 20 mm size down aggregate is used.

KEYWORDS: Replacement, Polypropylene fibers, GGBS

1. INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be molded into any shape hardens into a rock-like mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with Ordinary Portland cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials (whatever may be their qualities) of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred contempt. Strength was emphasized without a thought on the durability of structures. Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement.

A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
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1.1 Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This "granulated" slag is then dried and ground to a fine powder. Although normally designated as "GGBS" in the UK, it can also be referred to as "GGBFS" or "Slag cement".

1.2 Polypropylene fibers are new generation chemical fibers. They are manufactured in large scale and have fourth largest volume in production after polyesters, polyamides and acrylics. About 4 million tonnes of polypropylene fibers are produced in the world in a year. Polypropylene fibers were first suggested for use in 1965 as an admixture in concrete for construction of blast resistant buildings meant for the US Corps of Engineers. Subsequently, the polypropylene fiber has been improved further and is now used as short discontinuous fibrillated material for production of fiber reinforced concrete or as a continuous mat for production of thin sheet components. Polypropylene fibres are Non-Magnetic, rust free, Alkali resistant, safe and easy to use. Polypropylene twine is cheap, abundantly available and is of consistent quality. Polypropylene fibres are also compatible with all concrete chemical admixtures and can be handled with ease. The high molecular weight of polypropylene, gives it many useful properties. Polypropylene fibres are chemically inert and hence, any chemical that will not attack the concrete constituents will not have any effect on the fibre also.

2.0 LITERATURE REVIEW

Kamran Muzaffar Khan et al. (2014) studied the effect of blending of portland cement with ground granulated blast furnace slag on the properties of concrete. He observed that there was an appreciable increase in the workability of concrete with increasing percent replacement of

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cement with GGBS, therefore w/c ratio can be reduced keeping the slump constant, which will result in an increase in compressive strength. Even if wlc ratio is decreased using water reducers, compressive strength can be increased up to strength of normal cement concrete. Effect of partial replacement was very small tensile strength and modulus of rupture.i.e, between strength of control mix & the blended cement concrete. GGBS is a waste product and only grinding makes it fit for use. so it very economical cement replacement material. Consequently it also reduces the cost of concrete. Using GGBS as cement replacement material is a suitable way for its disposal, so this technique is environment friendly.

The effect of polypropylene fibre on the compressive and flexural strength of normal weight concrete was conducted by **Abdul Nasser. M. Abbas** (2011) for mixes. Four mixes used polypropylene fibre weight with 0.4, 0.8, 1.0 and 1.5%of cement content. To provide a basis for comparison, reference specimens were cast without polypropylene fibre. The test results showed that the increase of mechanical properties (compressive and flexural strength) resulting from added of polypropylene fibre was relatively high. The increase was about 64 % for compressive strength, while and in flexural strength was about 55.5 %.

3.0 Materials and Methodology

3.1 MATERIAL USED

3.1.1 CEMENT

The typical raw materials used for making cement are limestone, sand, stale clay and iron. The chemical components of cement are calcium (Ca), silicon (Si), aluminium (Al), and iron (Fe). The chemical composition in ordinary Portland cement are given in the below table.

ISSN 2394-3777 (Print)
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Table 3.1 Composition of ordinary Portland cement

OXIDES	OPC
SiO_2	20.98%
Al_2O_3	5.42%
Fe_2O_3	3.92%
CaO	62.85%
MgO	1.76%
Na_2	0.28%
K_2O	0.53%
SO_3	2.36%
Loss of ignition	1.90%

In this present investigation Ordinary Portland Cement of 43 Grade with a brand name (Chettinad) is used. Tests are conducted in accordance with the Indian standards confirming to IS-12269:1987.

Table 3.2: The standard test results of Chettinad cement

REQUIREMENTS		RESULTS OBTAINED	SPECIFICATIONS
Fineness of grinding		273 m^2/kg	Not less than 225 m^2/kg
Compressive	7 days	38.5 Mpa	Not less than 33 MPa

strength	28 days	48.5 Mpa	Not less than 43 MPa and Not more than 58 MPa
Setting time by vicat's apparatus method	Initial	174 minutes	Not less than 30 minute
	Final	279 minutes	Not more than 600 minute
Soundness Test (unaerated cement)	Expansion after boiling for 3 hrs in Le-chateliers method.	1.2 minutes	Not more than 10 minutes
	By Autoclave test	0.079 %	Not more than 0.8%

TESTS ON CEMENT

- **Fineness**

Fineness or particle sizes of Portland cement affect hydration rate and thus the rate of strength gain. The smaller the particle size, the greater the surface area to volume ratio, and thus, the more area available for water cement interaction per unit volume.

Table 3.3: Fineness of cement

Details	1	2
Weight of cement taken (w_1) in g	100	100
Weight of residue on 90micron sieve (w_2) in g	2.4	2.6
Percentage fineness of cement = $(w_2/w_1)*100$	2.4%	2.6 %

% Fineness = 2.5 %

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- **Setting Time**

1) Initial set: occurs when the paste begins to stiffen considerably.
2) Final set: occurs when the cement has hardened to the point at which it can sustain some load.

Table 3.4: Setting time test

Serial no	Time in min	Penetration in mm
1	5	0
2	10	0
3	15	2
4	20	5
5	25	7
6	30	7

Initial setting time = 90 min Final setting time = 447 min

- **Specific gravity test**

Weight the empty dry clean density bottle and note down it as W_1 g. Fill the sample into the density bottle until the bottle is filled 1/3rd of the volume. Slow the take down the weight of the density bottle with the cement sample as W_2 g. Slow fill the density bottle completely with cement sample and kerosene as W_3 g. Empty the density bottle completely clean it property and fill it completely with the kerosene with water slow take the weight of density bottle along with as W_4 g.

Table 3.5: Specific gravity of cement

Particulars	1	2
Weight of empty bottle (w_1) g	14.18	14.18
Weight of empty bottle + 1/3 of cement(w_2)g	20.29	25.00

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Weight of empty bottle + cement +kerosene(w_3)g	42.78	46.4
Weight of empty bottle + kerosene(w_4)g	38.59	38.59
Weight of empty bottle + water(w_5)g	41.13	41.13
Specific gravity of kerosene, $G_k = (w_4-w_1)/(w_5-w_1)$	0.905	0.905
Specific gravity of cement wrt kerosene $G_{ck}= (w_2-w_1)/(w_4-w_1)-(w_3-w_2)$	3.43	3.59
Specific gravity of cement $G= G_k* G_{ck}$	3.10	3.20
Average specific gravity of cement = 3.15		

The specific gravity of cement = 3.15

- **Standard consistency of cement paste**

The standard consistency of cement paste is defined as that consistency which will permit the Vicat plunger to penetrate to a point to 7mm from the bottom of the Vicat mould, when the cement paste is tested in a standard manner as explained below

1) Type of cement : Chettinad cement
2) Grade of cement : ordinary Portland cement
3) Type of test : consistency

Table 3.6: standard consistency of a cement paste

Trail no	Weight of cement taken (g)	Percentage of water added	Quantity of water in (m)	Penetration in (mm)
1	400	25%	100	33
2	400	25%+1%	4	27
3	400	26%+1%	4	16
4	400	26%+1%	4	12
5	400	27%+1%	4	9
6	400	28%+1%	4	6

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Percentage of water required to make cement paste =29%

The normal consistency of cement = 6 mm

- **Strength**

Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water cement ratio, cement fine aggregate ratio, type and grading of fine aggregate, manner of mixing and moulding specimens, curing conditions and age. Since cement gains strength over time, the tine at which strength test is to be conducted must be specified. Typically times are 7days, 14days and 28 days. When considering cement paste strength tests.

3.1.2 COARSE AGGREGATE

Crushed black trap basalt rock as coarse aggregate confirming IS383-1970 was used. The coarse aggregate of two sizes, viz 20mm and 10mm .Coarse aggregate of size reduce the voids and provide well graded coarse aggregate. 20mm and 10mm coarse aggregate are selected by passing the aggregate through 20mm and 10mm sieves respectively. Particle shape of both the aggregate is angular. Different test are to be conducted like specific gravity, fineness modulus and water absorption. Coarse aggregate is dust free and free from surface moisture.

Flakiness and shape of coarse aggregates in general have an appreciable effect on workability of concrete. A rougher surface, such as that of crushed particles, results in a better bond due to mechanical interlocking; better bond is also usually obtained with softer, porous and mineralogical heterogeneous particles. Properties of aggregates as well as its shape and texture sustainability affect the overall performance of concrete.

Coarse aggregate used in our project work is 20mm and down size (aggregates passing through 20mm sieve and retaining on 10mm sieve)

<u>TESTS ON COARSE AGGREGATE</u>

- **Specific gravity of coarse aggregates**

Specific gravity of coarse aggregate is determined thoroughly washed, dried to constant mass at 100 to 110 cooled in air and immersed in water for 24 hr. its then removed from the water and

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dried to a saturated surface –dry state with a large adsorbent cloth. Care is taken to avoid evaporation of water from the aggregate pores during this operation.

Table 3.7: Specific gravity of coarse aggregate

Serial no	**Particulars**	**1**	**2**
1	Empty weight of pycnometer (W_1) in g	450	450
2	Weight of pycnometer+ coarse aggregates(w_2) in g	740	760
3	Weight of pycnometer + coarse aggregates + water (W_3) in g	1440	1450
4	Weight of Pycnometer +water (W_4) in g	1255	1255
5	Specific gravity $=(w_2-w_1)/\{(w_2-w_1)-(w_3-w_4)\}$	2.76	2.73
6	Average	2.7	

Specific gravity of coarse aggregates = 2.7

- **Sieve analysis of coarse aggregate**

The process of dividing the sample of the aggregates into fractions of same particle size is known as sieve analysis and its purpose is to determine the grading or particle size distribution of the aggregate.

A sample of aggregate is graded by shaking or vibrating a set of sieves with the largest sieve at top for specified time so that material retained on the each sieve represents the fraction coarser the sieve below but finer than sieve above.

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Table 3.8: Sieve analysis of coarse aggregate

Sl no	IS Sieves(mm)	Weight retained W(g)	Percentage retained (W/5000)*100	Cumulative Percentage retained.(C)	Percentage finer (100-C)
1	80	-	-	-	-
2	63	-	-	-	-
3	40	-	-	-	-
4	20	110	2.20	2.20	97.80
5	16	690	13.80	16.00	84.00
6	12.5	1640	32.80	48.80	51.20
7	10	520	10.40	59.20	40.80
8	4.75	2030	40.60	.99.80	0.20
9	2.36	-	-	-	-

n = 226.00

Fineness modulus of coarse aggregate,

SC= cumulative percentage weight retained/100= 226.00/100 =2.26

- **Water absorption of coarse aggregate**

Table 3.9: Water absorption of coarse aggregate

Sl no	Determination no.	Trail 1
1	Weight of saturated surface-dried sample in g (A)	1004
2	Weight of oven – dried sample in g (B)	998
3	Water absorption = ((A-B)/B*100	0.6%

Water absorption = 0.6%

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TESTS ON FINE AGGREGATE

- **Specific gravity of fine aggregates**

The specific gravity of an aggregate is the mass of the aggregate in air divided by the mass of an equal volume of water. An aggregate with a specific gravity of 2.45 would thus be two and one-half times as heavy as water. Each aggregate particle is made up of solid matter and voids that may or may not contain water. Since the aggregate mass will vary with its moisture content, specific gravity is determined at fixed moisture content. Four moisture conditions are defined for aggregates depending upon the amount of water held in the pores or on the surface of the particles.

Table 3.10: Specific gravity of fine aggregates

Serial no	Particulars	1	2
1	Empty weight of pycnometer (W_1) in g	585	585
2	Weight of pycnometer + fine aggregates(w_2) in g	1180	1170
3	Weight of pycnometer + fine aggregates + water (W_3) in g	1775	1805
4	Weight of Pycnometer + water (W_4) in g	1460	1460
5	Specific gravity $=(W_2-W_1)/\{(W_4-W_1)-(W_3-W_2)\}$	2.47	2.43
6	Average	2.45	

The specific gravity of fine aggregate = 2.45

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ISSN 2394-3785 (Online)
Available online at www.ijartet.com

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- **Sieve analysis of fine aggregate:**

The process of dividing the sample of the aggregates into fractions of same particle size is known as sieve analysis and its purpose is to determine the grading or particle size distribution of the aggregate.

A sample of aggregate is graded by shaking or vibrating a set of sieves with the largest sieve at top for specified time so that material retained on the each sieve represents the fraction coarser the sieve below but finer than sieve above.

Table 3.11: Sieve analysis of fine aggregate

IS sieve no	Wt of sample W (gm)	% wt retained (W/2000)*100	Cumulative % C	% fine N = (100-c)
4.75	-	-	-	100
2.36	40	2	2	98
1.18	350	17.5	19.5	80.5
600	455	22.75	42.25	57.75
300	990	49.5	91.75	8.25
150	165	8.25	100	-
Pan	-	-	-	-

Fineness modulus of fine aggregate =cumulative percentage weight retained/100

= 255.5/100

=2.555

- **Gradation of fine aggregate**

Locally available sand has been used as fine aggregate in the present study. Sieve analysis is carried out and the results are shown in table 3.12. The fine aggregate confirms to zone II of IS 383-1970.

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Table: 3.12 Gradation of fine aggregate

Sieve size (mm)	% OF PASSING	PERCENTAGE OF PASSING AS PER IS-383-1970			
		I	II	III	IV
4.75	100	100	100	100	100
2.36	98	90-100	90-100	90-100	90-100
1.18	80.5	60-95	75-100	85-100	95-100
0.6	57.75	30-70	55-90	70-100	90-100
0.3	8.25	15-34	35-59	60-79	80-100
0.15	0	5-20	8-30	12-49	15-50
Pan	0	0-10	0-10	0-10	0-10
Total cumulative% retained =255.5					
Fineness modulus 2.55					

- **Water absorption on Fine aggregate**

Table 3.13 Water absorption of fine aggregate

Sl.no	Determination no.	Trail 1
1	Weight of saturated surface-dried in g (A)	1007
2	Weight of oven-dried sample in g (B)	987
3	Water absorption = (A-B)/B)*100	2.0%

Water absorption = 2%

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ISSN 2394-3785 (Online)
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3.1.4 WATER

Water available in the college campus conforming to the requirements of water for concreting curing as per IS: 456-2000.

3.1.5 GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)

GGBFS is a by-product of the iron/steel manufacturing industry. The molten slag from the production of iron in a blast furnace is rapidly cooled by high pressure water jets which subject the slag to instantaneous solidification in the form of granules; these are then dried and ground. GGBFS is off-white in color. It may be described as a latent hydraulic material which means it will gain strength on its own, but very slowly.

Table 3.14: Specific gravity of GGBFS

Particulars	**1**
Weight of empty bottle (w_1) g	18.5
Weight of empty bottle + 1/3 of ggbfs (w_2)g	27.31
Weight of empty bottle + cement +kerosene(w_3)g	44.09
Weight of empty bottle + kerosene(w_4)g	37.90
Weight of empty bottle + water(w_5)g	43.16
Specific gravity of kerosene, $G_k = (w_4-w_1)/(w_5-w_1)$	0.789
Specific gravity of cement wrt kerosene $G_{ck}= (w_2-w_1)/(w_4-w_1)-(w_3-w_2)$	3.39
Specific gravity of ggbfs $G= G_k* G_{ck}$	2.7

The specific gravity of GGBFS = 2.7

- **CHEMICAL COMPOSITION OF GGBFS**

The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or

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ISSN 2394-3785 (Online)
Available online at www.ijartet.com

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in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation.

Typical chemical composition:

Calcium oxide = 40% Silica = 35%

Alumina = 13% Magnesia = 8%

The glass content of slag suitable for blending with Portland cement typically varies between 90- 100% and depends on the cooling method and the temperature at which cooling is initiated. The glass structure of the quenched glass largely depends on the proportions of network-forming elements such as Si and Al over network-modifiers such as Ca, Mg and to a lesser extent Al. Increased amounts of network-modifiers lead to higher degrees of network DE polymerization and reactivity. It is a granular product with very limited crystal formation, is highly cementitious in nature and ground to cement fineness, and hydrates like Portland cement.

- **TYPICAL PHYSICAL PROPERTIES OF GGBFS**

Colour: off-white   Bulk density: 1200 Kg/m^3

Specific gravity 2.9   Fineness: 350 m^2 /kg

3.2 METHODOLOGY

The strength characteristics of concrete of M 20 grade- a most commonly used structural concrete, designed as per the mix design procedure of IS 10262-2009 is to be assed in terms of its compressive strength and split tensile strength.

The design mix consists of 426 kg/m^3 of cementations material in which increments of 0.5% each upto 2% is replaced with polypropylene fibres in case of primary blends and for secondary blends, cement is replaced with 40% of GGBFS and . Coarse aggregate of 20 mm size down aggregate is used.

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RESULTS AND DISCUSSIONS

4.1 GENERAL

The various results of materials used in the studies are detailed below,

4.1.1 Cement

In this present investigation Ordinary Portland Cement of 43 Grade with a brand name (Chettinad) is used. Tests are conducted in accordance with the Indian standards confirming to IS-12269:1987. The physical properties of the tested cement has been shown in table 4.1

Table: 4.1 Physical properties of cement

SL.NO.	PHYSICAL TESTS	RESULTS	REQUIREMENT AS PER IS
1.	Fineness (%)	2.5%	Not more than 10% as per IS 4031 part 1
2.	Standard consistency (%)	29%	Not more than 30% as per IS 4031 part 4
3.	Initial setting time (minute)	90mins	Not less than 30 minute as per IS 4031 part 5
4.	Final setting time	447mins	Not more than 600

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	(minute)		minute as per IS 4031 part 5
5.	Specific gravity	3.15	IS 269:1989

Permissible limit of specific gravity of cement is 3.15, obtained specific gravity is also 3.15 and hence it is in the permissible limit as per IS 269:1989.

4.1.2 Aggregates

a) Fine Aggregates

Locally available sand has been used as fine aggregate in the present study. Sieve analysis is carried out and the results are shown in table 3.11. The fine aggregate confirms to zone II of IS 383-1970.

b) Coarse Aggregate

For the experimental work, locally available crushed stone aggregates of size 20 mm downsize are used .The test results for physical properties of fine and coarse aggregates are shown in table 4.2

Table: 4.2 Physical properties of aggregates

SL NO	PHYSICAL TESTS	AGGREGATES	RESULTS	REQUIREMENT AS PER IS-383
1.	Specific gravity	Fine aggregate	2.45	2.4 to 2.6

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		Coarse aggregate	2.7	2.6 to 2.8
2.	Water absorption test	Fine aggregate	2%	1% to 2%
		Coarse aggregate	0.6 %	

Permissible limit of specific gravity of Fine aggregate is 2.4-2.6, obtained specific gravity is 2.45, and hence it is within the permissible limit as per IS 383.

4.1.3 GGBFS

GGBFS is a by-product of the iron/steel manufacturing industry. The molten slag from the production of iron in a blast furnace is rapidly cooled by high pressure water jets which subject the slag to instantaneous solidification in the form of granules, these are then dried and ground in a tube mill. GGBFS is off-white in color. It may be described as a latent hydraulic material which means it will gain strength on its own, but very slowly.

Table: 4.3 Physical properties of GGBFS

SL NO	PYSICAL TEST	OBTAINED VALUE
1	Specific gravity	2.7

4.1.4 POLYPROPYLENE FIBERS

In the present study commercially available RECRON 3S polypropylene fibers from reliance industries is used with the dosage of 0, 0.5,1,1.5 & 2% by weight of cement as the properties of fibers are shown in table.4.4 and polypropylene fiber used in this study is shown in figure.3.2 .

Table: 4.4 Properties of polypropylene fibers

Length	12 mm
Specific gravity	0.91
Cross section	Triangular
Dia. in mm	0.035

4.2 CEMENT CONCRETE MIX DESIGN

For present work concrete of M20 grade is adopted and the mix proportion of normal concrete is carried out.

For GGBFS concrete the same mix design was adopted, with the change that the cement content was partly replaced with GGBFS, i.e. with 40%. The proportions of materials obtained and used is in mix is as presented in table 4.5

Table: 4.5 Cement concrete mix design

GRADE OF CONCRETE	M20	M20 +40% OF GGBFS

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Cement (kg/m^3)	426	256
Water (L/m^3)	192	192
Coarse aggregates (kg/m^3)	1126.94	1113.21
Fine aggregates (kg/m^3)	626.75	619.115
GGBFS (kg/m^3)	-	170.4
Polypropylene (% by wt of cement)	-	0,0.5,1,1.5,2
Water cement ratio	0.45	0.45

4.3 COMPRESSIVE STRENGTH OF CONCRETE

The test results for compressive strength are presented in Tables 4.6 (40% of GGBS concrete) for M20 grades of concrete at room temperature for 7 and 28 days respectively.

Table: 4.6 Compressive strength of concrete

% GGBFS	% OF POLYPROPYLENE	COMPRESSIVE STRENGTH AFTER 7 DAYS(Mpa)	COMPRESSIVE STRENGTH AFTER 28 DAYS(Mpa)
0	0	11.8	24.36
40	0	10.16	17.52
40	0.5	11.68	18.84

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
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International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
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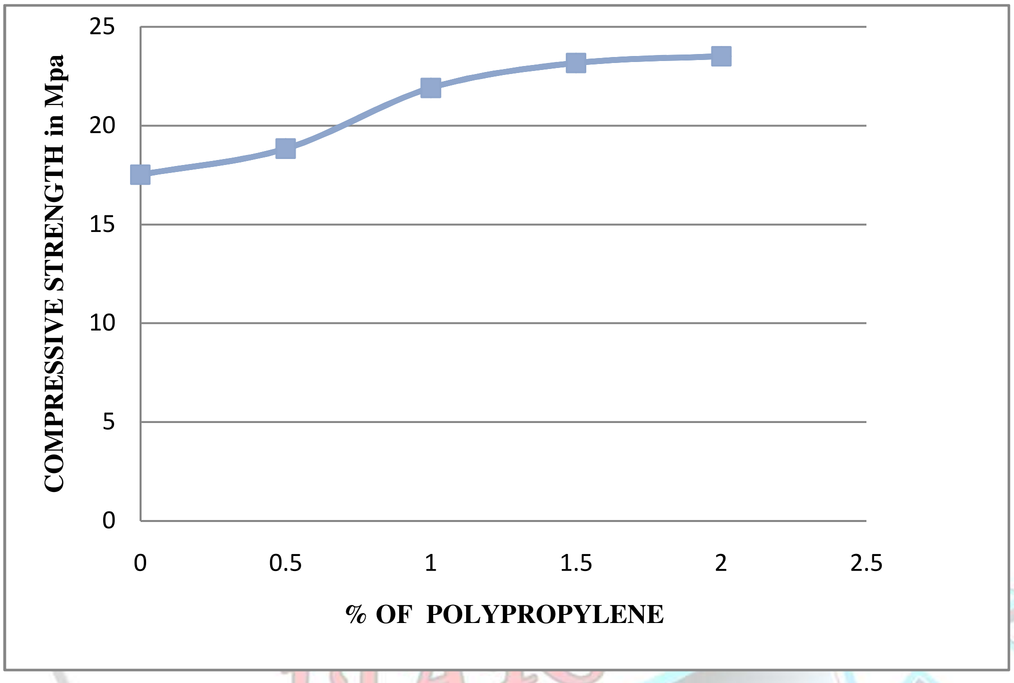
40	1	13.89	21.91
40	1.5	14.36	23.17
40	2	14.78	23.51



Graph 4.1 Compressive strength of concrete

In general, the improvement in cube strength observed in commonly used mixes due to fibre addition is small. The addition of polypropylene fibres to the mix increased the 28 day's compressive strength of the mix with the dosage of 1% by 25% due the confinement provided by fibres. The compressive strength at 1% dosage is slightly higher than strength at 2% dosage. Compressive strength increases for all dosage of fibres than normal concrete .Reason is that due to confinement provided by fibre bonding characteristics of concrete increases and hence compressive strength increases with the increases in the fibre content.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

As shown in the table, here 40 % of GGBFS is used as a constant and polypropylene fibre of 0%, 0.5%, 1%, 1.5%, and 2% is added to the plain concrete. After curing of 7 and 28 days, the compressive strength gradually increases.In plain concrete, the compressive strength of concrete at 7 days curing is 11.8 MPa and 28 days is 24.36 MPa. By adding 40% of GGBFS to the plain concrete, at 7 days curing it is not so increased but at 28 days, the compressive strength is 17.52 and is lesser than the plain concrete. By adding 0.5%, 1%, 1.5%, and 2% successively, the compressive strength increases from 7 days to 28 days of curing. By adding 40% of GGBFS and 2% of polypropylene fibres, the compressive strength of concrete is increased than that of plain concrete and it is also represented in graph 4.1.

It seems that the presence of polypropylene fibres in the concrete matrix resembles significant resistance against the propagation of the fine cracks in the direction of the load. This resistance is responsible for the delay of the formation of the main crack that causes failure. Besides, polypropylene fibres can reduce stress concentration accumulated around the cracks and consequently the strength increased.

4.4 TENSILE STRENGTH OF CONCRETE

The test results for tensile strength are presented in Tables 4.7 (40% of GGBS concrete) for M20 grades of concrete at room temperature for 7 and 28 days respectively.

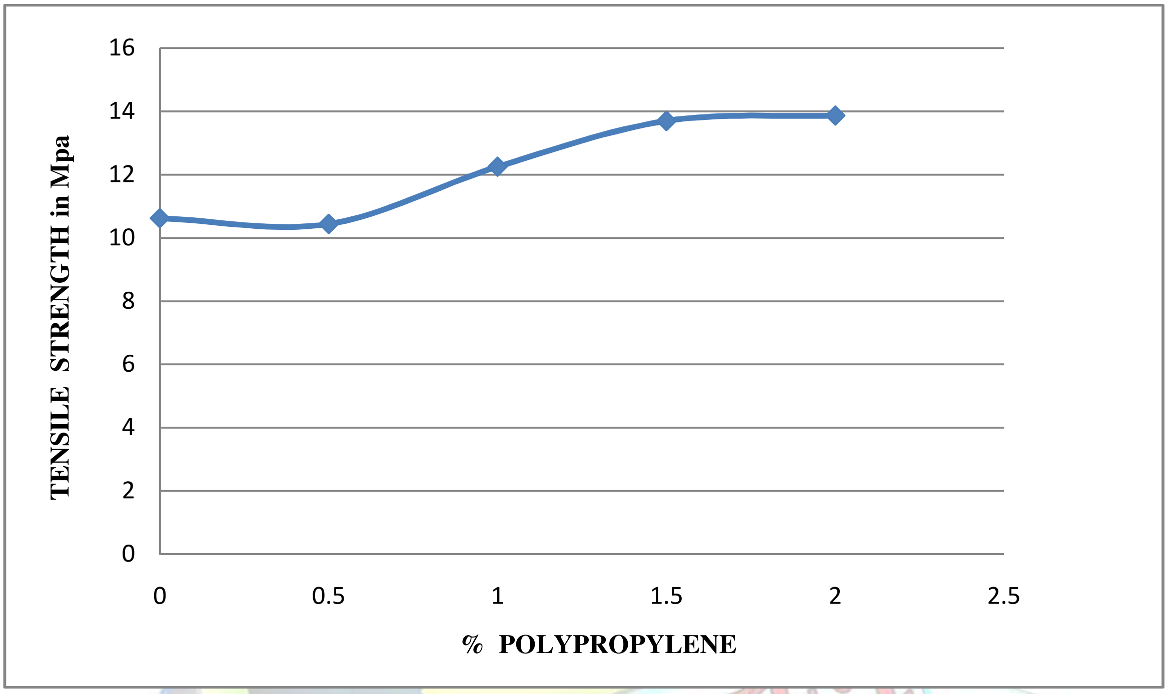
Table: 4.7 Tensile strength of concrete

% GGBFS	% OF POLYPROPYLENE	TENSILE STRENGTH AFTER 7 DAYS(Mpa)	TENSILE STRENGTH AFTER 28 DAYS(Mpa)
0	0	10.13	13.24
40	0	8.93	10.62
40	0.5	7.79	10.44
40	1	8.08	12.25
40	1.5	8.22	13.7

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

40	2	8.73	13.87



Graph 4.2 Tensile strength of concrete

The splitting strength of the concrete reinforced by polypropylene fibres content up to 1.5 vol. % represented higher values than that observed for concrete free of fibres as shown in Table 4.7. This behavior can be explained on the ability of polypropylene fibres to diminish the fine cracks in the concrete matrix. Once the splitting occurred and continued, the fibre bridging across the split portions of the matrix acted through the stress transfer from the matrix to the fibres and thus, gradually supported the entire load. The stress transfer improved the tensile strain capacity of the fibre reinforced concrete and therefore, increased the splitting tensile strength of the reinforced concrete over the unreinforced.

As shown in the table, here 40 % of GGBFS is used as a constant and polypropylene fibre of 0%, 0.5%, 1%, 1.5%, and 2% is added to the plain concrete. After curing of 7 and 28 days, the tensile strength gradually increases. In plain concrete, the tensile strength of concrete at 7 days

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

curing is 10.13 MPa and 28 days is 13.24 MPa. By adding 40% of GGBFS to the plain concrete, at 7 days curing it is not so increased but at 28 days, the compressive strength is 17.52 and is lesser than the plain concrete. By adding 0.5%, 1%, 1.5%, and 2% successively, the compressive strength increases from 7 days to 28 days of curing. By adding 40% of GGBFS and 2% of polypropylene fibres, the compressive strength of concrete is increased than that of plain concrete and it is also represented in graph 4.2.

The split tensile strength varies from 10.62 MPa to 13.87 MPa for 28 days. Test results shows maximum 15% increases in split tensile strength at 28 days. Split tensile test does not give perfect estimation about direct tensile strength due to mixed stress field and fibre orientation but its failure pattern gives good idea about ductility of the material. Failure patterns of splitting tensile test indicate that specimens after first cracking do not separate unlike the concrete failure. Large damage zone is produced due to closely spaced micro cracks surrounding a splitting plane. Fibre bridging mechanism is responsible for such enhanced ductile failure patter. [7] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

4.5 Comparison of compressive strength characteristics of GGBFS concrete with plain concrete.

Table: 4.8 Comparison of compressive strength

NUMBERS OF DAYS	COMPRESSIVE STRENGTH	
	PLAIN CONCRETE	40% GGBFS
7	11.8	10.16
14	15.07	13.84
28	23.36	20.52
56	26.23	27.5

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ISSN 2394-3785 (Online)
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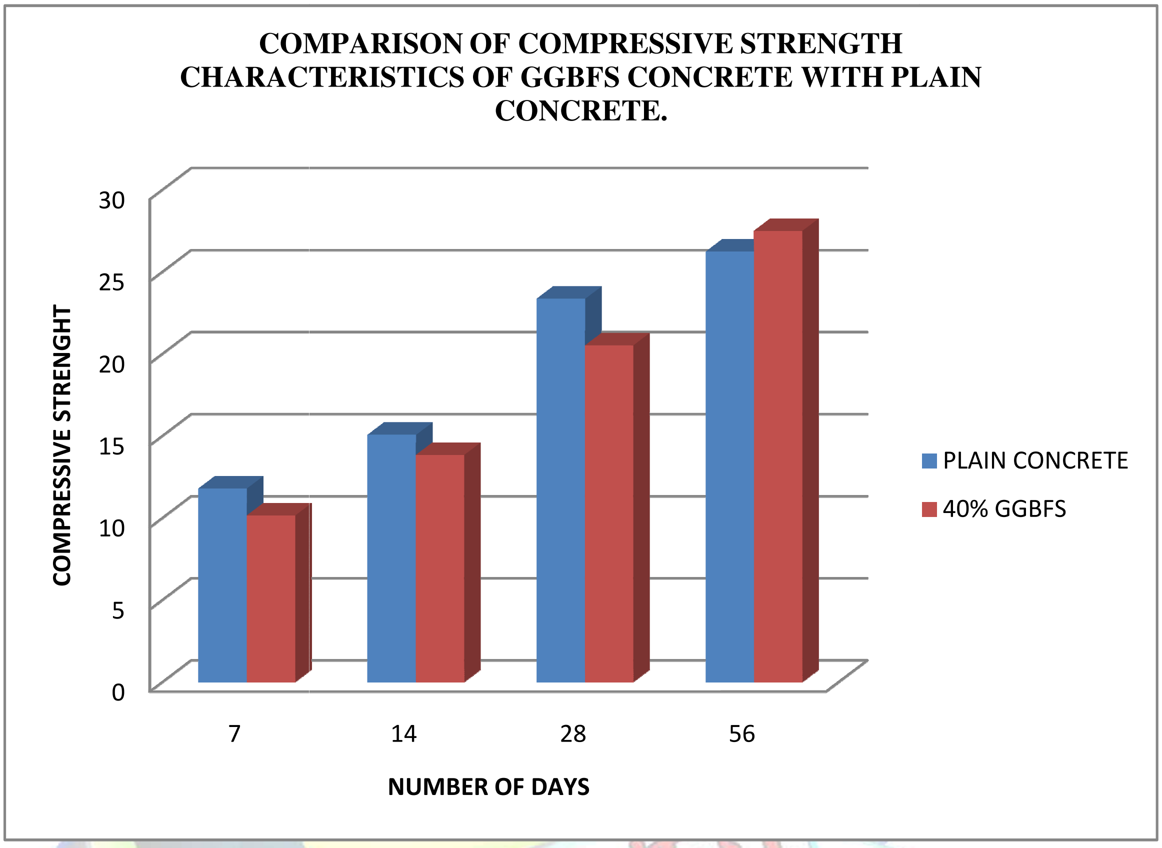
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018



Graph 4.3 Comparisons Of Compressive Strength Characteristics Of GGBFS Concrete With Plain Concrete.

The Table 4.8 shows that comparison of compressive strength characteristics of GGBFS concrete with the plain concrete. It shows that compressive strength of plain concrete and GGBFS concrete at 7, 14, 28 and 56 days. We can observe that, the compressive strength of GGBFS concrete for 7, 14 and 28 days is slightly lesser than that of the compressive strength of plain concrete as shown in bar graph 4.3 . But GGBFS at 56 days of curing gains strength greater than that of the plain concrete.

5. CONCLUSIONS

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

- Durability of concrete significantly increased and maximum compressive strength slightly increased with increasing the content of polypropylene fibres up to 2 vol. % in the tested concrete.
- Further increase of polypropylene fibres (higher values than 2 vol. %) did not increase the ultimate bond strength, but it provided much more ductile bond behavior.
- Regarding their advantageous properties and beneficial price, the use of Polypropylene fibres is often recommended recently to enhance some performances of normal concrete strength, particularly its poor ductility behavior. Besides that, some mechanical properties of normal-strength concrete can also be improved by use of 1 to 2 % polypropylene fibres by volume of concrete.
- Results showed 40% replacement of GGBS shows significantly increase in strength and also it has same cost as compared to normal concrete and 14% less cost as compared to fibre reinforced concrete for 20 mm aggregate concrete.
- The tensile strength of all the aggregate grouped concrete shows that all mix having 40% GGBS was optimum level which gives 5 to 7% more strength than normal concrete.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
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International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 1, January 2018

International Journal of Innovative Research in Science, Engineering and Technology, ISSN(Online) : 2319-8753 ISSN (Print) : 2347-6710, Vol. 4, Issue 8, August 2015