International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.4., 2015
(July-Aug)

RESEARCH ARTICLE

ISSN: 2321-7758

EXPERIMENTAL STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF HIGH STRENGTH CONCRETE INCORPORATING GGBS AND STEEL FIBERS

ARVIND B. NAKUM[1],VATSAL N PATEL[2],VISHAL B. PATEL[3]

[1]PG Student,Structural Engineering Department,B.V.M. Engineering College,Vallabh Vidyanagar,India
[2]Associate Professor, Civil Engineering Department,A D Patel Institute of Technology,New Vallabh Vidyanagar,India
[3]Assistant Professor,Structural Engineering Department, B.V.M Engineering College, Vallabh Vidyanagar, India

VATSAL N PATEL

ABSTRACT

The experimental investigation is carried out to study the effect on mechanical and durability properties of M_{50} grade concrete made with replacement of cement with Ground Granulate Blast Furnace Slag (20%,30% and 40%) by weight and the addition of Steel Fiber in different percentages (1.5%,2% and 2.5%). Mechanical Properties were studied by performing Compression test (150mm × 150mm size cubes), Flexural test (500mm× 100mm×100mm size beams) and Split Tensile test (150mm diameter and 300mm length cylinders) and durability properties were studied by performing sulphate attack test(150mm × 150mm size cubes) and acid attack test(150mm × 150mm size cubes). The replacement of cement by 30% with GGBS and 2% fiber addition gave Higher compressive, Flexural and split Tensile Strength and lower reduction in strength after sulphate and acid exposure at all ages. This mix can be utilized in Construction industry for precast work, sewage pipe line and residential purpose with economy.

Keywords—Ground Granulated Blast Furnace Slag;Steel Fiber;compressive strength; split tensile strength;precast work

INTRODUCTION

Concrete is the most widely used construction material and has high compressive strength. But it is very brittle due to weak in tensile, flexure, impact strength and has low resistance against cracking. One method to improve the brittle behavior of the concrete is the addition of small fibers in concrete with randomly distributed. Such reinforced concrete is called Fiber Reinforced Concrete (FRC). The main reason for incorporating fibers into the cement matrix is to increase the tensile strength, the energy absorption capacity, toughness, flexural strength of concrete and also it improves the cracking deformation characteristics of the concrete composite. Today, the industrial waste by products such as Ground Granulated Blast – furnace Slag (GGBS), fly ash, silica fume, etc. are used as supplementary Cementitious materials in concrete. The incorporation of Supplementary Cementitious materials improve the mechanical properties of concrete and also reduce the cement consumption by replacing part of cement with these pozzolonic materials.

Ground Granulated Blast-furnace Slag (GGBS)

Ground Granulated Blast-furnace Slag (GGBS) also known as slag cement — is hydraulic cement that significantly improves the strength and durability of concrete. Slag cement begins in an iron blast furnace. Carefully controlled amounts of iron ore, along with limestone or dolomite, are fed into a blast furnace and heated to 1300 to 1500 degrees Celsius. When molten, the iron is tapped for steel production and the slag is diverted to a granulator. Here, the slag is rapidly quenched with large quantities of water. The process minimizes crystallization and forms “granulated slag,” which is

composed principally of calcium aluminosilicate glass. (Formation of this glass provides slag cement with its cementitious properties). At this point, the slag is the uniformly fine sand. It is then dewatered and dried. Finally, the slag is ground to a fine powder and becomes Ground Granulated Blast – furnace Slag (GGBS) or slag cement, or it is inter-ground with Portland cement clinker to make blended cement.

Fiber reinforced concrete

Fiber reinforced cement or concrete is a relatively new composite material in which fibers are introduced in the matrix as micro reinforcement, so as to improve the tensile, cracking and other properties of concrete. Fiber produced from steel, carbon, glass, plastic polypropylene, nylon, rayon, asbestos, basalt and natural fibers such as cotton, coir, sisal etc. are in use. However, for most structural and non-structural purposes, steel fibers are the most commonly used of all fibers. The addition of steel fibers to cement mortar or concrete leads to improvement in cracking and tensile strength of the matrix.

The present Experimental investigation is to study the Mechanical Properties of concrete with partial replacement of Ordinary Portland Cement by different percentage of GGBS. Also Steel Fibers are used in different percentage by weight of binder content.

material and properties

Cement

The cement used in this experimental work is Ultratech 53 grade Ordinary Portland Cement. The specific gravity of the cement is 3.15. Standard consistency of cement was 31.5%. All properties of cement are tested by referring IS 12269 – 1987.

Ground Granulated Blast Furnace Slag (GGBS)

The GGBS used in present study was obtained from Jindal Steel Ltd. The properties of GGBS are shown in Table I.

Table I Properties of GGBS

Characteristics	**Requirements as per BS: 6699**	**Test results**
Fineness (m^2/kg)	275 (min)	386.00
Residue by wet sieve on 45µ (%)	_____	2.92
Initial Setting Time (min)	Not less than IST of OPC	195
Insoluble Residue (%)	1.5(%)	0.30
Magnesia content (%)	14.0(max)	8.19
Sulphide Sulphur (%)	2.0(max)	0.62
Sulfate content as SO3	2.50(max)	0.24
Loss on Ignition (%)	3.0(max)	0.31
Manganese content (%)	2.0(max)	0.31
Chloride content (%)	0.10(max)	0.001
Moisture content (%)	1.0(max)	0.02
Glass content (%)	67(min)	95.35
Compressive Strength (N/mm^2)		
After 7 days	12.0(min)	22.07
After 28 days	32.5(min)	42.24
Chemical Moduli		
$CaO + MgO + SiO_2$	66.66(min)	78.05
$CaO + MgO/SiO_2$	>1.0	1.28
CaO/SiO_2	<1.40	1.04

(GGBS data obtained from Jindal Steel Ltd.)

Fine aggregates

Locally available sand of Bodeli is used in this study. Sand passing from 4.75 mm sieve and of specific gravity of 2.63 and fineness modulus of 2.84 are used.

Coarse aggregates

Aggregate of size 20 mm and 10 mm available from the local source Sevalia are used. Specific gravity of course aggregate is 2.77 and fineness modulus is 6.59.

Water

Fresh potable water free from acid and organic substances was used for mixing and curing concrete

Steel Fibers

Steel fibers were made available from Fibezone Private LTd., Ahmedabad and used in study with following Details.

Dimension: 60 mm length 1 mm diameter

Shape: hook ended

Density: 78500 N/m^3

Tensile strength: 128.21 kg/mm^2

Admixture

Super plasticizer (chemical admixture) based on Polycarboxylic technology – AURAMIX 400 supplied by Fosroc Chemicals (India) limited conforming to Indian Standard (IS: 9103 ,1999) with specifications Light Yellow colour, pH=6,Volumetric mass=1.09kg/litre, Chloride content=Nil and Solid Content of 33% was used for the work.

Experimental Work

A. Mix proportion

The mix proportion shown in Table II was made for a concrete with a slump 100mm and M_{50} grade as per method given by IS: 10262 – 2009[7].

Table II Mix Proportion

Material	Weight (Kg/m3)
Cement	399.32
Water	147.75
Fine aggregate	684.25
Coarse aggregate: 20 mm	791
10 mm	527
Chemical admixture	3.52
W/B ratio = 0.37	

III Casting and Curing

Casting was done as per the combinations shown in Table III

Table III Design of Mix

Mix name	GGBS (%)	Steel fiber (%)
SF-0-0	0	0
SF-20-1.5		1.5
SF-20-2	20	2
SF-20-2.5		2.5
SF-30-1.5		1.5
SF-30-2	30	2
SF-30-2.5		2.5
SF-40-1.5		1.5
SF-40-2	40	2
SF-40-2.5		2.5

Mixing of ingredients was done as per IS:516[10] by machine mixing. The concrete was filled in layers 5cm deep and compacted by table vibratos. The specimens were removed after 24 hours and submerged in water for curing. After a curing period of 7, 28 and 56 days specimens were taken out and tested.

IV Testing

Specimens were tested to find out mechanical properties at 7, 28, 56 and 90 days by performing following tests:

A. Compression test

Compression test on cubes of size 150mm was performed on compression testing machine. Average compressive strength of three cubes was taken after 7, 28 and 56 days [10].

B. Flexural test

Flexural test was performed on beams of 500×100×100mm size by placing them on universal testing machine. The failure load was recorded to find out the flexural strength [10].

C. Split Tensile test

Split tensile was performed on cylinders 150mm dia. and 300mm height on compression testing machine as per the method given in IS: 5816 – 1999[11]. The failure load was recorded to find out split tensile strength.

To study the durability properties, following tests were performed:

A.Sulphate Attack test

Solution of 5% Na_2SO_4 by volume was prepared and cubes of size 150×150×150mm were immersed in solution after 28 days normal curing after taking initial weights. The cubes were weighted and tested on compression testing machine after 28, 56 and 90 days.

B.Acid Attack test

Solution of 5% HCL by volume was prepared and cubes of size 150×150×150mm were immersed in solution after 28 days normal curing after taking initial weights. The cubes were weighted and tested on compression testing machine after 28, 56 and 90 days.

V. Results and discussion

Compressive Strength

Following are the results of compressive strength test shown in Fig. 1. Here concrete with 30% GGBS and 2% Steel fiber performed well. At 7, 28, 56 & 90 days increase in compressive strength is 6.95%, 5.78%, 7.19% & 7.8% respectively in comparison with control concrete and 5.51%, 16.18%, 12.45% & 8.9% respectively in comparison with the average of other fiber reinforced GGBS concrete. The reason of increased strength is pozzolanic action of GGBS and conversion of Calcium hydroxide into C-S-H gel.

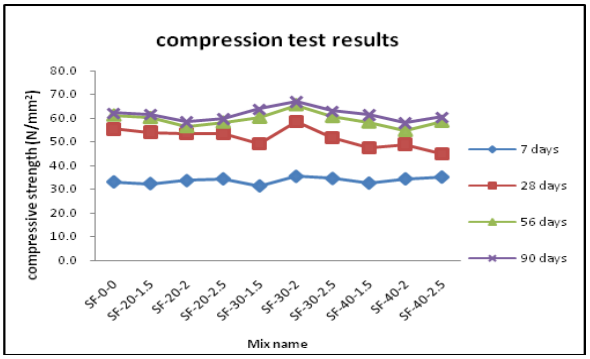

Fig.1. Compressive Strength

Flexural Strength

The results of flexural strength of concrete specimens are shown in Fig 2. The concrete mixture with 30% GGBS and 2% steel fiber has the highest flexural strength performance at all ages in comparison with all variations including non-fibers control Concrete. At 7, 28, 56 & 90 days increase in flexural strength is 21.14%, 17.35%, 9.44% & 15.27% respectively in comparison with control concrete and 22.1%, 24.16%, 10.95% & 10.06% respectively in comparison with the average of other fiber reinforced GGBS concrete. This is due to geometric form and more aspect ratio of steel fiber added into the mixes that enable them to develop high bond between the matrix and the fiber.

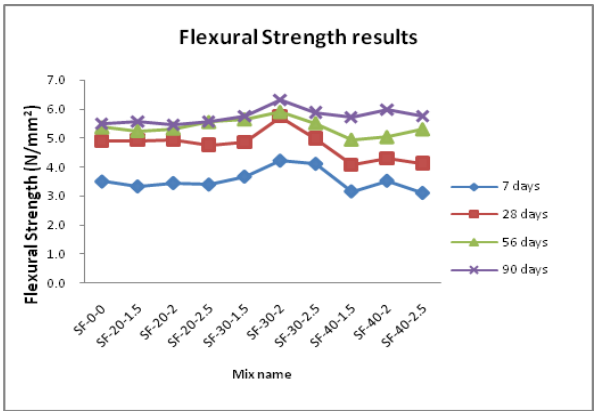

Fig.2. Flexural Strength

Split Tensile Strength

The results of split tensile strength of concrete specimens are given in Fig 3. The concrete mixture with 30% GGBS and 2% steel fiber has the highest Split Tensile Strength performance at all ages in comparison with all variations including non-fibers control Concrete. At 7, 28, 56 & 90 days increase in split tensile strength is 5.15%, 3.85%, 3.9% & 5.53 respectively in comparison with control concrete and 6.12%, 13.02%, 8.58% & 4.82% respectively in comparison with the average of other fiber reinforced GGBS concrete. Steel fibers make the concrete less brittle and more ductile and therefore the split tensile strength of fiber added concrete increases.

Sulphate Attack Test

The graph shown in Figure: 5.5 show results for 28, 56, & 90 days. The decrease in compressive strength for Mix SF – 30 -2 is only 2 % for 28 days, 5.24 % for 56 days and 11.25% for 90 days. These values are very less in comparison with control and other mixes. The highest strength lost is achieved 13.19% at 28 days for control mix, 18.01% at 56 days for SF – 20 - 1.5 and 23.93% at 90 days for control mix.

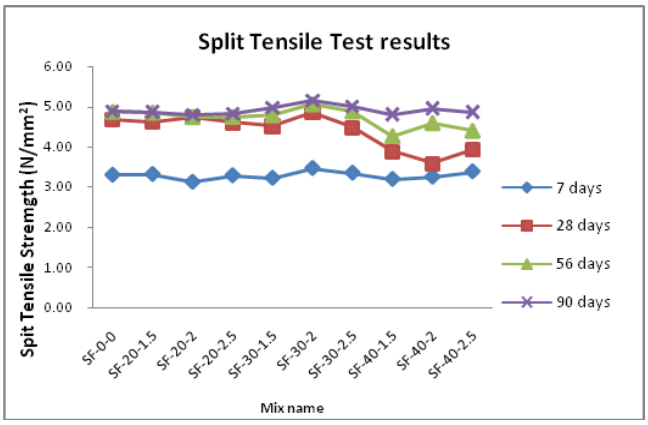

Fig.3. Split Tensile Strength

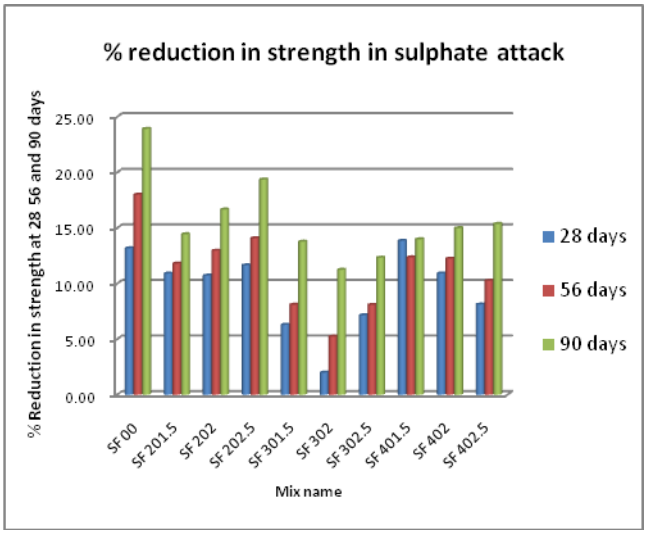

Fig. 4. % Loss of strength in Sulphate Attack test

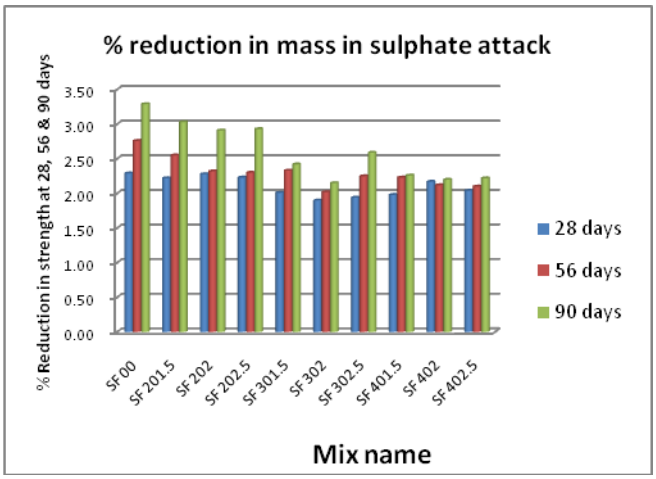

Fig. 5. % Loss of mass in Sulphate Attack test

Mass loss gave a very clear illustration of the amount of degradation that occurred in the samples as a result of Sulphate exposure. There was a relatively steady decline in the masses of all samples.

However, the 100% OPC concrete lost mass at a faster rate than those containing GGBS, and SF – 30 - 2 mix performed the best showing the lowest mass loss.

Acid Attack test

Fig. 6. Shows percentage reduction in mass and Fig. 7. Shows percentage reduction in strength. From results the maximum percentage loss in weight and percentage reduction in compressive strength due to Acids are 3.9% and 9.65% at 28 days for control mix, 4.88% and 21.22% at 56 days and 5.49% and 27.64% for the same mix. The minimum percentage loss in weight and strength are 3.21%, 2.2% at 28 days, 4.18%, 6.05% at 56 days & 4.41% and 10.79% for mix SF – 30 – 2.

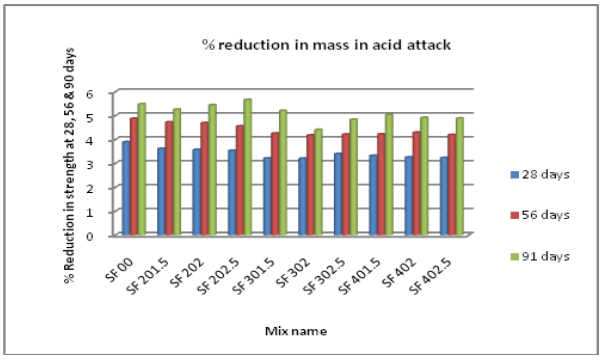

Fig. 6. % Loss of mass in Acid Attack test

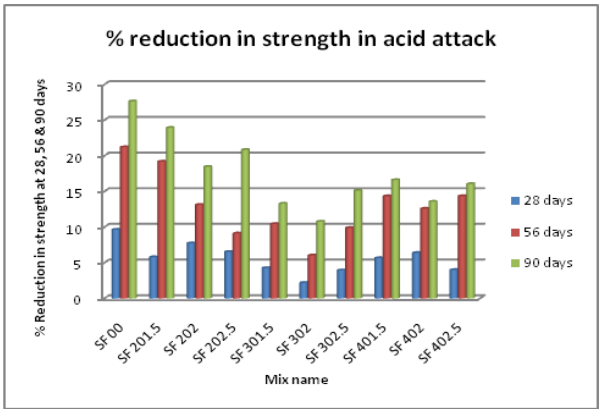

Fig. 7. % Loss of strength in Acid Attack test

The acid attack test parameters observation presented in above graph shows the influence of acid attack on concrete with GGBS and Steel fiber and normal concrete. The average loss of weight and loss of compressive strength of concrete is considerably lesser in GGBS concrete.

In the case of HCL attack the calcium salt formed is soluble in water and which is leached out therefore mass loss is higher and that can also cause micro cracking without introducing any internal stresses and hence major loss is found. The decrease in compressive strength is because of more and more ettringite with increase in age of acid immersion.

VI CONCLUSION

The concrete mixture with 30% GGBS and 2% steel fiber has the highest compressive strength, flexural strength and split tensile strength performance at all ages in comparison with all variations including non-fibers control Concrete.

In terms of durability test in sulphate attack and acid attack, concrete with 30% GGBS and 2% steel fiber gave better results for 28, 56 & 90 days compared to control and other mix.

Hence the optimum value is achieved for 30%GGBS and 2% addition of steel Fibers.

GGBFS can be utilised as a mineral admixture in concrete due to economical and environmental benefits, without any compromise with its performance.

REFERENCES

[1]. Oner and S. Akyuz, “An experimental study on optimum usage of GGBS for the compressive strength of concrete” Cement & Concrete Composites vol. 29. pp. 505 - 514 2007.

[2]. Yun Yeau K. and Kyum Kim E., (2005) “An experimental study on corrosion resistance of concrete With ground granulate blast-furnace slag”, Cement and Concrete Research 35, pp.1391– 1399.

[3]. I Arribas, I. Vegas, J.T. San-Jose, Juan M. Manso “Durability studies on steelmaking slag concretes” Materials and Design 63 (2014) 168–176

[4]. Kyong Yun Yeaua, Eun Kyum Kimb “An experimental study on corrosion resistance of concrete with ground granulate blast-furnace slag” Cement and Concrete Research 35 (2005) 1391– 1399

[5]. S Pavia and E. Condren, “Study Of Durability Of OPC versus GGBS Concrete on Exposure to Silage Effluent.” DOI: 10.1061/ASCE 0899-1561 2008 20:4 313

[6]. D Neeraja “Experimental investigation on strength characteristics of Steel Fiber Re – inforced concrete” International Journal of

scientific and Engineering research, vol. 4. February – 2013

[7]. Mr. Nikhil A. Gadge1, Prof. S. S. Vidhale2 "Mix Design of Fiber Reinforced Concrete (FRC) Using Slag & Steel Fiber" International Journal of Modern Engineering Research Vol. 3, Issue. 6

[8]. Saud Al-Otaibi "Durability of concrete incorporating GGBS activated by water-glass" Construction and Building Materials (2008) 2059–2067

[9]. M. V. Mohod, "Performance of steel fiber reinforced concrete" International journal of Engineering and Science, vol. 1. pp. 01 – 04 December 2012.

[10]. M S Shetty, Concrete Technology Theory and Practice, S Chand Publication,2013

[11]. M. L. Gambhir "Concrete technology"

[12]. IS:10262-2009 "Concrete Mix Proportioning – Guidelines"

[13]. IS:383-1970 "Specifications for course and fine aggregates from natural sources for concrete"

[14]. IS:4031-1996 "Method of physical tests for hydraulic cement"

[15]. IS:516-1959 "Methods of tests for strength of concrete"

[16]. IS:5816-1999 "Splitting Tensile Strength Of Concrete."

[17]. IS:455 – 1989 "Portland Slag Cement – Specification"