Experimental Ground Granulated Blast Furnace Slag in Partial Replacement of Fine Aggregate in Concrete

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Abstract

Concrete is probably the most extensively used construction material in the world. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption by the use of supplementary materials. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. **GROUND GRANULATED BLAST FURNACE SLAG (GGBS)** is a new mineral admixture, whose potential is not fully utilized. Moreover only limited studies have been carried out in India on the use of slag for the development of high strength concrete with addition of sisal fibres. The study focuses on the compressive strength, split tensile strength, flexural strength performance of the blended concrete containing different percentage of slag and steel fibre as a partial replacement of OPC. The cement in concrete is replaced accordingly with the percentage of 10 %, 20% and 30% by weight of slag and 1% by weight of sisal fibre. Concrete cubes are tested at the age of 7, 14, and 28 days of curing. Finally, the strength performance of slag blended fibre reinforced concrete is compared with the performance of conventional concrete. From the experimental investigations, it has been observed that, the optimum replacement of Ground Granulated Blast Furnace Slag Powder to cement is 20 % for M30 grade.

Introduction

The manufacture of concrete, primarily its ingredients; cement and aggregates; presents various sustainability issues that need to be dealt. The production of concrete has always lead to massive exploitation of natural resources. Manufacturing 1 tonne of Portland cement requires quarrying 1.5 tonnes of limestone and clay (Civil and Marine, 2007). Moreover, continuous extraction of natural aggregate; sand and gravel; from river beds, lake and other water bodies over the years have led to erosion which eventually leads to flooding and landslides. Further, there is less filtration of rainwater due to reduced amount of natural sand, causing contamination of water needed for human consumption. 1.4 tonnes of Ordinary Portland cement being produced yearly around the globe contributes to 5 percent of greenhouse gas, carbon dioxide, emissions worldwide (Civil and Marine, 2007). Not only burning fuel to heat the kiln emits carbon dioxide, but also decomposition of limestone emits even more gas. These identified problems clearly, contribute significantly to climate change. The ideal target to partly solve the above phenomenon is to develop a sustainable system loop which can turn resources which are landfilled as waste materials into useful products in the construction industry, thus preserving the natural resources.

Concrete is a tension-weak building material, which is often crack ridden connected to plastic and hardened states, drying shrinkage, and the like. The cracks generally develop with time and stress to penetrate the concrete, thereby impairing the water proofing properties and exposing the interior of the concrete to the destructive substances containing moisture, bromine, acid sulphate, etc. The exposure acts to deteriorate the concrete, with the reinforcing steel corrosion. To counteract the cracks, a fighting strategy has come into use, which mixes the concrete with the addition of discrete fibres and pozzolanic materials. Experimental studies have shown that fibres and pozzolanic materials improve the mechanical properties of concrete such as flexural strength, compressive strength, tensile strength, creep behaviour, impact resistance and toughness. Moreover, the addition of fibres and pozzolanic materials makes the concrete more homogeneous and isotropic.

2. Literature review

Abdul Rahuman and Saikumar Yeshika(2015), studied properties of sisal fibre reinforced concrete with different mix proportions and different percentage of fibre addition The study has concluded that there was an increase in slump value from 4mm to 53mm after addition of super plasticizer. Degree of workability for concrete mixture with 0.2% super plasticizer and water cement ratio 0.45 provided good workability. Compaction factor increases by 0.02 to 0.03 after addition of super plasticizer. Compression strength increased by 50.53% after addition of 1.5% fibre for M20 mix design, whereas the increase was up to 52.51% for the same percentage addition of fibre in M25. Tensile strength increment was almost same for 1% and 1.5% addition of fibre. The increased tensile strength for M20 mix design with 1% and 1.5% addition of fibre was 41.37% and 44.378%. There was a decrease in percentage increase in tensile strength for M25 when compared with M20. The increase in tensile strength for M25 mix design with 1% and 1.5% addition of fibre is 30.83% and 36.027%. It is concluded that 1.5% addition of fibre will give better strength.

Dr.N.R.Krishna murthy(2013), Studied Addition Of The Natural Fibres Into Concrete Slump is decreasing with the addition of fibres. More the fibre-cement ratio, more is the decrease in slump due to absorbency of water by fibres. Hence the use of proper super plasticizer which does not affect other properties except workability is recommended for higher fibre-cement ratios. The addition of fibres increased compressive strength with 0.5% fibre-cement ratio and little increase for 1% of fibre-cement ratio compared to plain concrete. But at 1.5% of fibre-cement ratio, though plasticizer is added, the compressive strength is decreasing compared to plain concrete**.** As the percentage of fibres is increased, the sudden and brittle failure of sample is resisted.

Reshma Rughooputh and Jaylina Rana(2014), Partial Replacement of Cement by Ground Granulated Blast furnace Slag In Concrete The partial replacement of OPC with GGBS improves the workability but causes a decrease in the plastic density of the concrete. The compressive and tensile splitting strengths, flexure and modulus of elasticity increases with increasing GGBS content. The drying shrinkage shows a slight increment with GGBS. GGBS fails the initial surface absorption test confirming that the surfaces of their concrete mixes were practically impermeable.

S.Arivalagan (2014), Sustainable Studies on Concrete with GGBS as a Replacement Material in Cement, It is observed that GGBS-based concretes have achieved an increase in strength for 20% replacement of cement at the age of 28 days. Increasing strength is due to filler effect of GGBS.

M.Pavan Kumar(2015), The Behaviour of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Cement with GGBS The compressive strength for partial replacement of fine aggregate with copper slag & cement with GGBS increased in the order of 3.59%, 6.10% and 8.65% for10%CS & 5%GGBS, 20%CS & 10%GGBS and 30%CS & 15%GGBS partial replacements respectively and decreased by 2% for 40%CS & 20%GGBS partial replacement with respect to control specimen.

Atul Dubey, Dr.R.Chandak (2012), Effect of blast furnace slag powder on compressive strength of concrete the results obtained from compressive strength tests conducted on concrete containing OPC and various percentage of blast furnace slag powder is comparable to that of concrete mix without slag powder. On replacement of OPC with 15% blast furnace slag powder the depreciation in 28day compressive strength is being near about 5 %.

A. Naveen Arasu, S Vivek, J Robinson, T Thilak Ranjith. International Journal of Chemtech Res. 2017 Volume 10, Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete. Test results indicated in increasing compressive strength of plain concrete by inclusion of WFS as a partial replacement of fine aggregate.

A. Naveen Arasu, M. Muhammed Rafsal, O. R .Surya Kumar, International Journal of Scientific and Engineering Research, volume 9, Experimental investigation of High Performance Concrete by partial replacement of fine aggregate by Construction Demolition Waste. It was observed that compressive strength & tensile strength of concrete with recycling natural fine aggregates with 20% replacement of crushed C & D waste fine aggregates. The strength has been increased to about 5% in compressive strength, 6% in flexural strength and 8% in tensile strength by different test.

3. Experiential Materials

a) Cement

Fig 1 Cement

Portland Pozzolana Cement (53 grade) conforming to IS: 12269 -1987 and with the specific gravity 3.15 was used for casting all the specimens. Tests conducted on cement are fineness of cement by sieve analysis (using 90 µ sieve), specific gravity using Le-chatlier's apparatus, initial setting time and final setting time using vicat apparatus.

Table 1. Properties of cement

Property of Cement	Values
Fineness Of Cement	2%
Grade Of Cement	53
Specific Gravity	3.10
Initial Setting time	29 minutes
Final Setting Time	600 minutes

b) Fine aggregate

Fig 2 Fine Aggragate

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve and as per IS: 383-1970 was used for all the specimens. Test conducted on fine aggregate are specific gravity using pycnometer, fineness modulus by sieve analysis.

Table 2. Properties of Fine Aggregate

Properties	Values
Specific Gravity	2.60
Fineness Modulus	2. 26

c) Coarse aggregate

Fig 3 Course Aggregate

Crushed granite aggregate with specific gravity of 2.6 and passing through 20 mm sieve and retained on 12.5 mm sieve and as given in IS: 383 - 1970 is used for all the specimens.

Table 3. Properties of Coarse Aggregate

Properties	Values
Specific Gravity	2.82
Size Of Aggregates	20 mm
Fineness Modulus	5.96

d) Water

Casting and curing of specimens were done with the potable water as per IS 456:2000.

Table 4. pH Value Test

WATER	pH VALUE
Sample 1	7
Sample 2	7
Sample 3	7

e) Sisal fibre

Fig 4 Agava plant

Fig 5 Sisal Fibre

Sisal fibre is a species of Agava. It is botanically known as Agave sisal Ana. The material is chosen to improve the various strength properties of the structure to obtain sustainability and better quality structure. Short discrete vegetable fibre (sisal) was examined for its suitability for incorporation in cement concrete. The physical property of this fibre has shown no deterioration in a concrete medium. Leaves are dried, brushed and baled to form fibre.

f) Ground granulated blast furnace slag

GGBS, a by-product of iron manufacture, is a glassy, non-metallic granular material which exhibits cementitious properties on its own while others do so in the presence of Portland cement and calcium sulphate which are activators. Thus, GGBS acts as pozzolans and is therefore combined with Portland cement; resulting in a hardened cement of GGBS combined with Portland cement, which has more of smaller gel pores and fewer larger capillary pores than that of normal Portland cement which consequently results in lower permeability and hence greater durability. Moreover, it contains less free lime, which in its presence forms ettringite or efflorescence, and makes the resulting hardened cement more chemically stable. In addition, GGBS has a lower content of C3A than normal cement.

Fig 6 GGBS

Chemical Composition of GGBS

GGBS has the same main chemical constituents as ordinary Portland cement, but in different proportion.

Table 5. Chemical Composition of GGBS

chemical constituents	Portland	GGBS
CaO	65%	40%
SiO_2	20%	35%
Al_2O_3	5%	10%
MgO	2%	8%

Table 6. Physical Properties of GGBS:

Colour	Off-white powder
Bulk density (loose)	1.0-1.1 tonnes/m^3
Bulk density (vibrated)	1.2-1.3 tonnes/m^3
Relative density	2.85-2.95
Surface area	400-600m^2/kg Bline

g) Super plasticizer

A substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. A high range water reducing admixture (HRWRA) is also referred as Super plasticizer, which is capable of reducing water content by about 20 to 40 percent has been developed. The effect of Super plasticizers lasts only for 30to 60 minutes, depending on composition and dosage and is followed by rapid loss in workability. Super plasticizers are added to reduce the water requirement by 15 to 20%.

4. Results and discussion

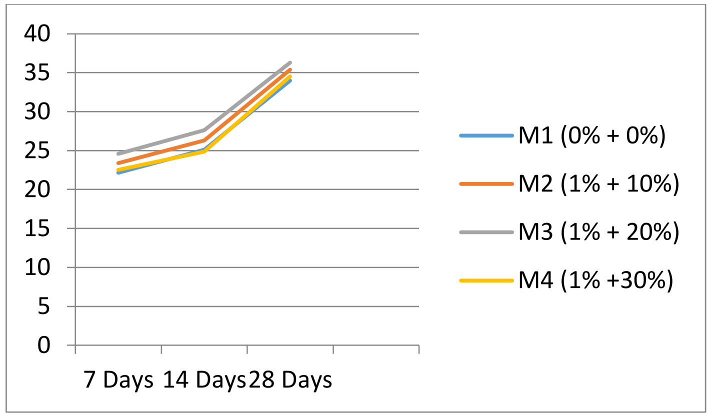
a) Compressive strength test

Cubical specimens of size 150 mm were cast for conducting compressive strength test for each mix. The compressive strength test was carried out as per IS: 516-1979. The compressive strength of any mix was taken as the average of strength of three cubes.

Fig 7 Compressive strength test

Table 7. Compressive Strength of Normal Concrete and sisal fibre & GGBS Added Concrete – 7, 14, 28 days

S. No.	Name of the specimen	% of replacement (sisal fibre + GGBS)	Compressive strength (N/mm²)		
			7 Days	14 Days	28 Days
1.	M1	0% + 0%	22.14	25.1	34.0
2.	M2	1% + 10%	23.4	26.32	35.37
3.	M3	1% + 20%	24.56	27.63	36.29
4.	M4	1% + 30%	22.52	24.88	34.5



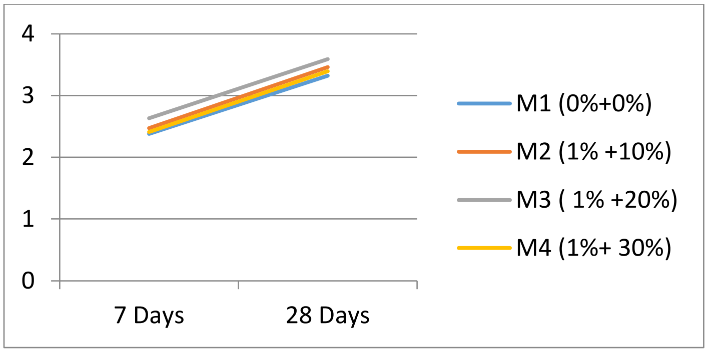
b) Split tensile strength

The split tensile strength is the indirect measurement of the tensile strength by placing a cylindrical specimen horizontally between the loading surfaces. This method consists of applying a diametric compressive force along the length of a cylindrical specimen. This loading includes tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder and the load is applied until failure of the cylinder, along the vertical diameter. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength of concrete.

Fig 8 Split tensile strength

Table 8. Split Tensile Strength of Normal Concrete and sisal fibre & GGBS Added Concrete – 7, 28 days

S. No.	Name of the specimen	% of replacement (sisal fibre + GGBS)	Split Tensile strength (N/mm²)	
			7 Days	28 Days
1.	M1	0% + 0%	2.38	3.32
2.	M2	1% + 10%	2.47	3.46
3.	M3	1% + 20%	2.63	3.59
4.	M4	1% + 30%	2.41	3.39

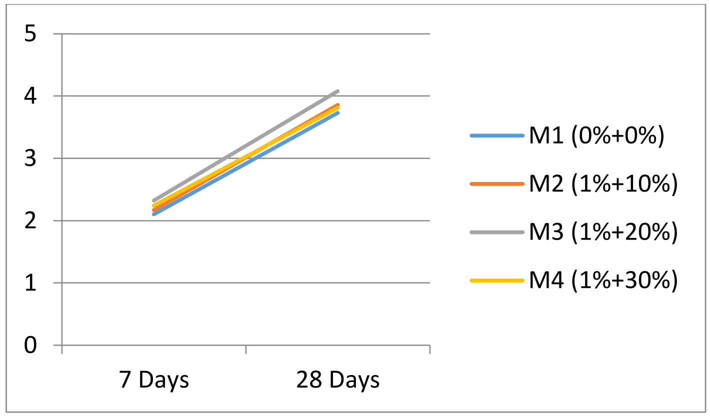


c) Flexural strength test

For each of the different dosages, three prisms with the dimensions of 100 × 100 × 500 mm concrete were prepared. A hand poker vibrator was used for compaction of concrete in prisms. All 12 prisms were de-moulded after one day and immersed in the water tank for a period of 28 days to assure adequate curing. After 28 days, each prism was tested under flexure using the four point loading test setup.

Table 9. Flexural Strength of Normal Concrete and Sisal &GGBS Added Concrete – 28 days`

S. No	Name of the specimen	% of replacement (sisal fibre + GGBS)	Flexural strength (N/mm²)	
			7Days	28Days
1.	M1	0% + 0%	2.10	3.73
2.	M2	1% + 10%	2.17	3.86
3.	M3	1% + 20%	2.32	4.08
4.	M4	1% + 30%	2.24	3.81



CONCLUSIONS

This study was carried to obtain the results, tests conducted on blast furnace slag powder modified cement concrete mix, in order to ascertain the influence of blast slag powder and sisal fibre on the characteristic strength of concrete.

- The optimum dosage for partial replacement of cement by ground granulated blast furnace slag is 20%
- The rate of gain of compressive strength of GGBS concrete is slow in the initial stag i.e. up to 14 days & as the curing period increases strength also increases
- The compressive strength, tensile strength and flexural strength of sisal & GGBS added concrete increases with increase in GGBS content
- The compressive strength, tensile strength and flexural strength of concrete decreased at the dosage of 30% replacement of cement by GGBS.

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