Mechanical Behaviour of Steel Fibers Added High Strength Concrete with GGBS and Silica Fume Replacements

J.Srija, R. Abirami, Mounika Kethireddy

Abstract: Sustainable development implies meeting current needs without compromising the ability of future generation to meet their own needs. It also requires that development be undertaken, in a manner, that planetary resources are sustained by effective utilization, without unnecessary wastage. Cement production emits carbon dioxide gas and hence its partial replacement by GGBS and silica fume reduces them. These materials have cementitious properties. This is significant because the production of one ton of Portland cement results in emission of nearly equivalent amount of Carbon dioxide. The study undertakes the variation of important properties of M40 grade concrete, namely compressive, split tensile and modulus of elasticity with addition of these replacements in varying percentages. These properties determine the mechanical behaviour of concrete in structures. Steel fibres are also added as a fixed percentage to the concrete, as it improves its ductility and toughness and reduces its susceptibility to cracking. Comparison of the variation of properties with and without addition of steel fibres is also made, to bring out the beneficial aspects of its addition.

Keywords: Concrete, Compressive Strength, Ggbs, flexural, Silica fume Workability

I. INTRODUCTION

Concrete is one of the primary materials of construction that can be cast into any form and shape, thus having widespread and versatile applications in the construction industry all across the world. The properties of concrete namely strength, durability, density, high temperature resistance etc can be modified by varying the nature and proportion of its ingredients such as cementation material, aggregate, water and other additives. Additives such as silica fume, GGBS (Ground granulated blast furnace slag) improve the strength of concrete by reducing the voids and improving the density of concrete. Silica fume is used both, as a replacement of cement usually for economic reasons and also to improve the cast concrete properties in both fresh and hardened states. Steel fibres while improving the tensile strength of concrete also improve its crack growth resistance. Apart from improving the physical properties of concrete in cast condition, these additives also show a marked change in properties during the mix stage such as workability, etc. The appreciation in physical properties is observed, only when these additives are added in correct proportions. Fauth et al [1] concluded that strength of concrete with fixed percentage of steel fiber depends on percentage addition of silica fume. Gorav Gupta et.al. [2] observed that both silica fume and GGBS have good pozzolanic properties and can ideally replace cement in concrete to some extent. Ductility was also found to increase with addition of silica fume. R.H. Jadhav et al [3] finally results that by using GGBS-silica fume in concrete heat of hydration decreases which ultimately increases resistance to chloride attack and corrosion This paper investigates the accurate proportion of silica fume and ggbs in concrete mix with 1% steel fibres being constant.

II. MATERIALS AND METHODOLOGY

A. Cement

Ordinary Portland Cement - 53 grade [4] of UltraTech make was used in this study for casting of cubes and cylinders of different concrete mix types. It was ensured that cement is uniform and free of hard lumps. Various tests were conducted to establish physical properties such as constituency, initial and final setting times, specific gravity, fineness and compressive strength and the results are tabulated in Table I below.

| Particulars         | Experimental Results | IS Limits (IS:8112-1989) |
|---------------------|-----------------------|----------------------------|
| Specific gravity    | 3.15                  | -                          |
| Fineness            | 2.2%                  | Not less than 10%           |
| Initial setting     | 33min                 | Not less than 30min         |
| Final setting       | 7hr                   | Not more than 600min        |

B. Silica fume

Silica fume is produced as a by-product during the production of silicon metal or ferrosilicon alloys. Silica fume improves the strength and workability of concrete. Table II tabulates the composition of silica fume which was used in this study.
Table II :Physical properties of silica fume

| S.no | Parameters            | Test Value |
|------|-----------------------|------------|
| 1.   | Silica as SiO2,% by mass | 27-38      |
| 2.   | Lime as CaO,% by mass  | 34-33      |
| 3.   | Magnesia as MgO,% by mass | 0.2-1.6  |
| 4.   | Total Sulphur Content as SO3,% by mass | 1-1.09 |

Physical properties

| Value |  |
|-------|---|
| Colour | white |
| Moisture content | 0.1% |
| Specific gravity | 2.95 |

D. Steel Fibres

The influence of steel fibres in reinforced concrete resistance to compression tension and shear loads is dependent on volume fraction, aspect ratio, and orientation of fibres in the concrete matrix. The dimensions of steel fibres are tabulated below on table IV The fibres were added in random orientation to the mix.

Table IV Properties of steel fibres used

| Dimensions | Value |
|------------|-------|
| Length     | 40    |
| Diameter   | 0.62  |
| Aspect ratio | 65   |

M40 grade concrete is used as base concrete in this study.. The nominal coarse aggregate of size 12.5mm is used in concrete as per IS383-1970 [5] and has a specific gravity of 2.66 The mix proportion was done as per IS 10262[6]. Conventional mix proportion obtained was 1:1.593:2.67:0.43. The amounts of cement, water reducer, fine aggregate, coarse aggregate used in all concrete mixtures were 430kg/m3, 685kg/m3, 1151kg/m3,186kg/m3 respectively.. In this study Aspect ratios (l/d) of fibers were 65 and volume fractions (Vf) of steel fibers used was 1%. GGBS and Silica fume were added to concrete directly as the percentages of 0%, 5%, 10% and 15% by weight of cement

III. RESULTS AND DISCUSSIONS

A. Tests On Fresh Concrete

Slump test for workability were performed on fresh concretes. The test results are shown in fig 1

Since the silica fume was directly added to the concrete mix, a decrease in slump value depending on the increasing water requirement was observed due to the increasing silica fume content. The values vary from 72 to 110 mm. Therefore based on the specific requirement of a given, slump of the concrete can be achieved by appropriated addition of silica fume and GGBS additives

B. Tests On Hardened Concrete

1. Compression Strength Test

A Total of 20 cubes of 150mmx150mmx150mm specimens are tested by compression test machine after 7 days and 28 days curing. Load should be applied gradually at the rate of 140kg/cm2 per minute until failure takes place.. Results are shown in Fig 2 and 3 respectively.

A considerable increase for the compressive strength of the concretes with steel fibers was observed by increasing the silica fume content. The increase was determined to 63(N/mm2) at 15%usage of GGBS & 5%SF. This result can be clearly depend on increasing bond strength of cement paste–aggregate interface by means of filling effect of silica fume,ggb and properties of steel fibre

2. Split Tensile Strength

The splitting tensile strength test was performed on two specimens of each varying percentage replacement having a diameter of 150 mm and a thickness of 300 mm. The average of two values was taken as the splitting strength. The test results can be seen in Fig 4 and Fig 5
Depending on the results obtained from the splitting tensile strength tests, it can be said that the steel fibers of higher slenderness values present better performance.

3 Compressometer test

Modulus of elasticity test is determined after 28 days from casting, with the help of compressometer using a cylindrical specimen of diameter 100mm and height of 150mm. Strain readings were obtained by dial gauge fixed between two circular clamps. The strain values and Young’s modulus are represented in Fig 6 and Table V.

The theoretical flexural strength for given compressive strength is calculated as per IS 456. Data from the tests show that the strength after 28 days is marginally higher than strength as per code, thus validating the behaviour of the modified concrete in tension. It is also observed that the concrete mix 15% GGBS exhibits the best performance.

IV. CONCLUSION

These following conclusions are given based on the above experimental results:

- Experimental investigation on mixed concrete was conducted to study the improvement of concrete performance with addition of additives ggb,s, silica fume in varying percentages. Steel fibres were added to mix at a constant proportion of 1%
- The use of GGBS, Silica fume and steel fiber shows better workability and uniformity in mixing of concrete. It is a good water reducing agent.
- Slump values vary with percentage of additives. Workability decreases and test values indicate suitable range in slump values, that can be selected as per application requirements.

- The compressive strength, and split tensile strength increases with partial replacement of cement by additives. Highest compressive strength of 63.26 N/mm² and highest split tensile strength of 7.75 N/mm² was obtained for mix with 15% GGBS and 5% silica fume.
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- Flexural strength test conducted after 28 days indicate higher strength than the code values obtained from IS 456 for given compressive strength. The addition of 1% steel fibres therefore significantly improves concrete mix properties and resist the formation of cracks.
- Highest flexural strength of 12N/mm² is obtained for the addition of 15% GGBS and 5% of silica fume in concrete results in best performance of casted concrete and is therefore concluded as optimal mix ratio.
- The investigation distinctly demonstrates the improvement of concrete properties with the addition of cement replacement additives, GGBS and silica fume. The result is a more economical and environmental friendly concrete mix with improved properties.

REFERENCES

1. Fuat Ko’ksal a, Fatih Altun b,*, Ilhami Yig’it c, Yusuf Sahin” Combined effect of silica fume and steel fiber on the mechanical properties of high strength concretes”Construction and building materials,pp,1874-1880
2. Gorav Gupta, Nalin Varma, Lovekesh Gaur”Experimental study on the effect of GGBS and silica fume on the strength of concrete “ International Journal of Research and Technology vol.6, no.8,pp 88-92
3. R.H. Jadhav, Sadiya Shaikh, Rishabh Agrawal, Rajat Aryan Sharma, Faraz Khan & Aseem Anand Jha “Effect And Optimization Of Foundry Sand, Ggbs & Steel Fiber On Strength Of Concrete” International Journal of Civil Engineering (IJCE) ISSN (P): 2278-9987; ISSN (E): 2278-9995 Vol. 6, Issue 4, Jun- Jul 2017; 11-20
4. IS: 12269-1987, “Specification for 53 grade Ordinary Portland Cement”, Bureau of Indian Standard.
5. IS 383-1970, “Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete” (Second Revision), Bureau of Indian Standard
6. Bis:10262-2009, “Concrete mix proportioning- guidelines,” Bureau of Indian Standards
7. IS 516-1979, “Method of Tests for Strength of Concrete”, Bureau of Indian Standard
8. IS 456-2000, “Code of Practice for Plain and Reinforced Concrete Structures”, Bureau of Indian Standard

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