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Strength Properties of Concrete Using Ternary System

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Abstract: Utilization of industrial waste materials and other supplementary materials in concrete compensates the lack of natural resources, solving the disposal problem of waste and to find alternative technique to safeguard the nature. Also it can be used to enhance the mechanical ad durability properties of the concrete. There are a number of supplementary materials such as silica fume (SF), Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash (FA), Rice Husk Ash (RHA) and more used as partial replacement of cement. This paper carries out a thorough assessment about the addition of SF and GGBFS, which can be adequately utilized in concrete as cement substitution. For that water cement ratio was fixed as 0.55 and the replacement level is from 5% to 20%. Totally nine mix were prepared in the range of 0 to 25 % of SF and GGBFS in binary and ternary system. Different properties were studied to identify optimum level of replacement such as physical properties, chemical properties of materials and mechanical properties.

Keywords: *Concrete, Slica fume, Ground Granulated Blast Furnace Slag, Ternary system, Mechanical Properties*

1. Introduction

Concrete is the most widely used construction material in the world. 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).The 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. The only defect in the use of concrete is that it is weak in tension. Since the concrete is weak in tension the possibility of formation of crack is more.

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (sio2).The individual particles are extremely small, approximately $1/100^{th}$ the size of an average cement particle. When silica fume is added to concrete, initially it remains inert. The addition of silica fume to concrete improves the latter's durability by reducing permeability and refining pore structure, leading to a reduction in the diffusion of harmful ions and the calcium hydroxide content, resulting in greater resistance to sulfate attack.

GGBFS is a recyclable material created when the molten slag from melted iron ore is quenched rapidly and then ground into a powder. This material has cementitious properties and has been used as a replacement for cement for over 100 years. If the molten slag is cooled and solidified by rapid water quenching to a glassy state, little or no crystallization occurs.

This process results in the formation of sand size (or frit-like) fragments, usually with some friable clinker like material. The physical structure and gradation of granulated slag depend on the chemical composition of the slag, its temperature at the time of water quenching, and the method of production. When crushed or milled to very fine cement-sized particles, ground granulated blast furnace slag (GGBFS) has cementitious properties, which make a suitable partial replacement for or additive to Portland cement.

2. Research Significance

SF and GGBFS are the effective cement replacement materials. Both materials are accepted and using (in binary system) for the strength and durability properties improvement in concrete, but the studies on ternary system of SF with GGBFS is limited. Hence this paper, mainly focusing the use of ternary system of SF with GGBFS in the strength improvement of concrete.

When used in certain proportions, SF and GGBFS (binary and ternary system) have shown to increase the compressive strength and splitting tensile strength of concrete. The experimental research conducted in this study showed the mechanical properties of concrete have improved when SF and GGBFS were used as partial replacement of sand in specified percentages (5% to 25%).

3. Materials

3.1. Cement

Ordinary Portland Cement (OPC) of 53 grade was used

3.2. Fine Aggregate

River sand of specific gravity of 2.41 with 4.5 mm size was used.

3.3. Coarse Aggregate

Well graded coarse aggregate of specific gravity of 2.6 with 22 mm size was used.

3.4. Water

Potable water is used for all mixes.

3.5. SF and GGBFS

Commercially available SF and GGBFS were used for entire experimental work.

4. Experimental Works

4.1 Preparation of SF and GGBFS test specimen

Commercially available SF and GGBFS were collected and were dried before use. The cement and SF and GGBFS were mixed thoroughly in binary (OPC + SF / GGBFS) and ternary (OPC + SF + GGBFS) system. Further sand and coarse aggregate were added to the mix. The materials were mixed in dry conditions for few minutes. Once all the materials were mixed well, the water was added to the dry mix in a standard concrete mixer. The resulting concrete mix was used to prepare 150 × 150 × 150 mm (6 in × 6 in × 6 in) cubes and 150 mm × 300 mm (6 in × 12 in) cylinders. The concrete was poured into the molds and was compacted 25 blows by a compaction rod. After that the cubes, beams, and cylinders were vibrated for 1 to 2 min on a vibrating machine and then the top surface of the specimens was finished using a trowel.
After that, the molds were left to dry for 24 hours. The specimens were then removed from the molds and were cured in water tank for curing for 28 days. The curing time was not a parameter in this study and hence no comparisons were made for the effect of SF and GGBFS on curing time. Several mixes were prepared with different percentages of granite powder as partial replacement of sand. All other ingredients were kept the same. The percentages of SF / GGBFS used were 0%, 5%, 10%, 15%, and 20% as binary system and SF + GGBFS used were 0%, 5% + 5%, 5% + 10%, 5% + 15%, 5% + 20% of cement. The mixes proportions for the mixes tested in this study are shown in Table 1.A total of nine mixes were tested: M0 – M8 by weight of cement respectively.

Table 1 Mix Details

Mix ID	**Mix Descriptions**
M0	100% OPC
M1	95% OPC + 5% GGBF
M2	90% OPC + 10% GGBF
M3	85% OPC + 15% GGBF
M4	80% OPC + 20% GGBF
M5	90% OPC + 5%SF +5% GGBF
M6	85% OPC + 5%SF+10% GGBF
M7	80% OPC + 5%SF +15% GGBF
M8	75% OPC + 5%SF+20%GGBF

To check the fresh state properties such as slump cone test and compaction factor test were conducted according to Indian code specifications. The compressive strength test was carried out after 28 days, and split tensile tests were conducted over 28 days of water curing. The compressive strength and splitting tensile strength tests were carried out according to IS 516-1956 and IS 5816: 1999 respectively.

4.2 Results and Discussion

Compressive strength:

The test results for compressive strength of concrete on 28 days with 5%,10%,15% and 20% replacements of cement with the combination of GGBFS and Silica fume are tabulated as follows (Figure 1).

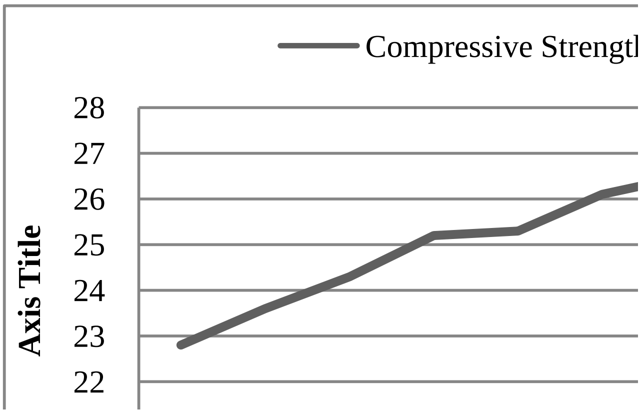

Figure 1. Compressive strength of concrete

At 7days, by comparing the compressive strengths of normal concrete, 5%GGBS, 10%GGBS, 15%GGBS, and 20% GGBS the last combination i.e, 20%GGBS achieves maximum strength of 25.3 N/mm^2. At 7days, by comparing the compressive strengths of normal concrete, 5%GGBS & 5% SF, 10%GGBS &5% SF and 15%GGBS & 5% SF, the last combination i.e,20%GGBS & 5% SF achieves maximum strength of 27.2 N/mm^2.

Split tensile strength:

The test results for tensile strength of concrete on 28 days with 5%, 10%, 15% and 20% replacements of cement with the combination of GGBFS and Silica fume are tabulated as follows (Figure 2). At 7days, by comparing the split tensile strengths of normal concrete, 5%GGBS, 10% GGBS, 15% GGBS, and 20%GGBS the last combination i.e, 15%GGBS achieves maximum strength of 3.54 N/mm^2 . At 7days, by comparing the split tensile strengths of normal concrete,

5%GGBS & 5% SF, 10%GGBS &5% SF,15%GGBS & 5% SFand 20%GGBS & 5% SF the last combination i.e,20%GGBS & 5% SF achieves.

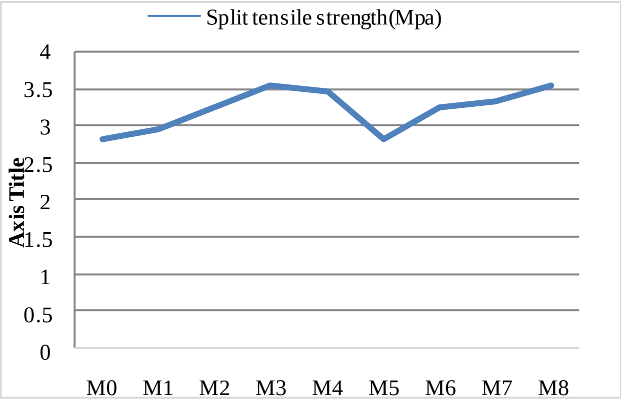

Figure 2 Split Tensile strength of concrete

5. Conclusion

Based on limited study carried out on performance of GGBFS and Silica fumes concrete in comparison with normal concrete of design strength of M20 following conclusion are drawn

- Use of GGBFS as cement replacement increases consistency.
- As the replacement level of cement by GGBFS increases there is an increase in split tensile strength &compressive strength for M20 grade of concrete up to 20% replacement level, and beyond that level there is a decrease in split tensile.
- As the replacement of cement with different percentages with Silica fume increases the consistency increases.
- As the replacement level of cement by silica fume increases there is an increase in split tensile strength for M20grade of concrete up to 5% replacement level, and beyond that level there is a decrease in split tensile and Compressive strength.
- The consistency and setting time (the initial and the final) of the cement increased with the increase of GGBFS contents. Water demands of blended cements are higher than that of pure cement paste. The increase in initial setting time of GGBFS incorporated cement paste is higher than the increase of final setting time with respect to cement paste. It indicates that the addition of GGBFS retards the initial hydration of cements.
- The compressive strength of concrete is decreasing at all ages with the increasing replacement of GGBS in cement concrete. However, the effect of replacement of GGBFS in compressive strength test is not so distinct in M3and M4 specimen at 28 days.
- The compressive strength of silica added concrete mixes has shown good improvement in early age's compressive strength as compared with the GGBFS cement mix. The early age compressive strength of silica added M6 and M7 is comparable, even better than control concrete.

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