Enhancing The Property Of High Performance Concrete With Multi-Component Composite Cement

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ABSTRACT

In this paper studies are made to ascertain the properties of HPC M40 grade concrete by incorporating Metakaolin and GGBS as partial cement replacement and Quarry sand as partial fine aggregate replacement to determine the compressive, tensile and flexural strength experimentally. Nowadays, solid wastes generated by various industries are increasingly used in construction industry with a view of increasing environmental sustainability. In this investigation an optimum of 10% Metakaolin and 30% quarry sand are used by considering previous literatures. GGBS is partially replaced for cement at varying percentages and addition of 10% of GGBS is found to be optimum. Test results shows that there is an increase in flexural strength, Compressive strength, and split tensile strength for M40 grade of concrete mixes when 10% GGBS + 10% Metakaolin is replaced with 30% Quarry sand concrete. Hence, the combination of Metakaolin and GGBS with quarry sand concrete will be effective and can be safely used to increase the strength of concrete.

KEY WORDS: High performance concrete, Metakaolin, GGBS, Quarry sand, Strength.

1. INTRODUCTION

High Performance Concrete (HPC) is an engineered concrete which possess the most desirable characteristics while being a fresh concrete as well as hardened concrete. It is better when compared to the conventional cement concrete as the ingredients of HPC helps in incorporating various effective properties in concrete. The benefits that are achieved by HPC cannot be always achieved by using normal conventional concrete. In high performance concrete certain properties are developed for specific purpose and environment, so as to achieve excellent performance in the building or structure where it is to be placed, taking into consideration the environment exposure, and subjected load during its design life.

Chemical admixtures and Mineral admixtures are the extra ingredients that are added to the concrete to enhance the property of concrete. Nowadays admixtures are available even to resist freeze and thaw effect. Earlier strength attainment can also be achieved. With a lesser water cement ratio, higher workability of concrete with higher strength can be achieved by using admixtures. Finish ability of concrete is also improved.

Addition of mineral admixtures reduces the heat of hydration. With lesser heat of hydration, the thermal cracking in concrete is also reduced. Thus addition of mineral admixtures helps in enhancing the durability and serviceability of concrete. In this study Ground Granulated Blast furnace slag, Metakaolin and Quarry dust are being used. The main objective of this project is to study the mechanical properties of high performance concrete using chemical & mineral admixtures for achieving better concrete composite and to use waste materials such as GGBS & Quarry dust. By utilizing industrial byproducts and waste material environmental sustainability can be achieved.

2. MATERIALS AND EXPERIMENTAL PROGRAM

Cement concrete is a mixture of cement, sand, crushed stone and water held together due to binding property of the cement. Cement is the important building material used in all modern constructions. Cement concrete has a high compressive strength. This experimental study involves addition of mineral admixtures (GGBS & Metakaolin) and quarry sand.

Cement: Cement commonly used is Portland cement. Cement is a binding agent obtained by burning argillaceous and calcareous materials at a high temperature. For this experimental work, “ULTRATECH” (brand name) 53 grade of Ordinary Portland Cement is used.

Metakaolin: Metakaolin is one of the mineral admixtures, which is a dehydroxylated form of a clay mineral called kaolinite. Stone which are possess kaolinite mineral are called as kaolin or china clay. The particle size of metakaolin is small when considering the cement particles, but not as fine as silica fumes. Metakaolin confirming to IS 456 - 2000 has been used in this experimental work.

GGBS: Ground granulated blast furnace slag (GGBS or GGBFS) is a by-product of steel manufacturing industry. The addition of GGBS, helps in enhancing the concrete properties. It hardens slowly and hence it is combined with portland cement. The quality parameters of GGBS for use in concrete confirming to IS 3812(part 1) has been used.

Fine Aggregate: Fine aggregate is most importantly used to produce workability and uniformity in mixture. The locally available clean, well graded, natural river sand was collected for experimental work. Fine aggregate properties were evaluated as per the IS 383-1970 methods.

Quarry Sand: Quarry dust is the waste product obtained in the quarrying process. Recently it has gained good attention for being replaced with fine aggregate. The quarry rock sand obtained from local resource was used in concrete to cast test specimens.

Coarse Aggregate: Coarse aggregate is the strongest and the least porous of the various component of concrete. It is chemically stable material. Drying shrinkage and other dimensional changes occurring on account of movement of moisture can be reduced on the presence of these aggregates. Aggregates which are passing through IS 20mm sieve and retained on IS 10 mm sieve are used as coarse aggregate. The crushed stone or coarse aggregate were collected from the local quarry.

Water:A higher water-cement (w/c) ratio will decrease the strength, water-tightness, durability and other related properties of the concrete. Addition of excess water leads to increase in capillary pores in the hardened concrete. The pH value of water lies between 6 and 8 and it should be free from organic matters, acids, suspended solids, alkalis and impurities. Potable water confirming to standard specified in IS: 456-200 is used**.**

Super Plasticizer: Conplast SP430 is a chloride free chemical admixture. It is available as a brown coloured solution which has the ability to disperse instantly when added to water. It is useful in providing early attainment of strength with low water cement ratio. Conplast SP 430 confirms to IS 9103:1999 and BS: 5075 Part 3.

Mix Proportion and Mix Details: Concrete mix design was designed as per IS 10262 – 1982. Materials required for 1 cubic meter of concrete M 40 grade is shown in Table.1.

Table.1. Mix Proportions

Volume of Concrete	Cement	Water	Fine Aggregate	Coarse Aggregate	Super Plasticizer
By Weight (kg/m^3)	350	140	710	1354	3.5
By Volume	1	0.4	2.03	3.87	1% of cement

Description of Mix:

Table2. Specimen Identification

S. No	Description	Specimen Identification
1	Conventional Concrete	CC
2	0% GGBS	MIX1
3	10% GGBS	MIX2
4	20% GGBS	MIX3
5	30% GGBS	MIX4
6	40% GGBS	MIX5

In this investigation an optimum of 10% Metakaolin and 30% quarry sand are used by considering previous literatures. GGBS is partially replaced for cement at varying percentages. Five different mixes were arrived by varying the percentage of GGBS, keeping the percentage of metakaolin and quarry dust as a constant.

3. RESULTS AND DISCUSSION

Compressive strength: Comparing the average compressive strength of cubes for a curing period of 7 and 28 days pertaining to various mixes are shown in fig.1. The effect of varying the percentage of GGBS in concrete can be seen from the following graph. It is found that the compressive strength of the concrete is found to increase on addition of GGBS. Addition of GGBS up to certain percentage increases the compressive strength after which the strength is found to decrease. The 7 day average compressive strength of CC is 29.36 N/mm² while the compressive strength of MIX1, MIX2, MIX3, MIX4 and MIX5 are 34.84, 38.75, 31.84, 28.14 and 24.98 N/mm² respectively. The maximum average compressive strength is found in MIX2 which has 10% GGBS. MIX2 has an average compressive strength of 38.75 N/mm² which is 32% greater than that of the conventional concrete.

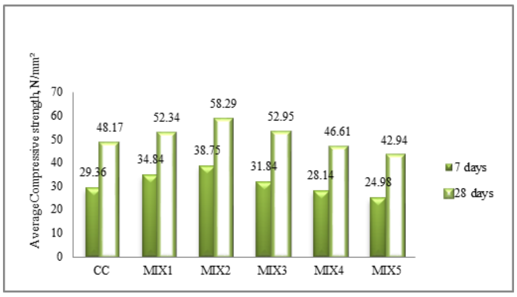

Figure.1. Average Compressive Strength (7 and 28 Days)

It is also ascertained that after a curing period of 28 days, the average compressive strength of CC is 48.17 N/mm² while that of MIX1, MIX2, MIX3, MIX4 and MIX5 are 52.34, 58.29, 52.95, 46.61 and 42.94 N/mm² respectively. The maximum average compressive strength is found in MIX2 which has 10% addition of GGBS. MIX2 has an average compressive strength of 58.29 N/mm² which is 21% more than that of the conventional concrete. It is also seen that the addition of GGBS until 30% increases the compressive strength, beyond which the strength decreases below the compressive strength of conventional mix.

Split Tensile Strength: Comparing the average Split tensile strength of cylinder for a curing period of 7 and 28 days pertaining to various mixes are shown in fig.2. The effect of varying the percentage of GGBS in concrete can be seen from the figure. The split tensile strength is also found to vary similar to that of the compressive strength.

It is noted that the split tensile strength of the concrete is found to increase on addition of GGBS. Addition of GGBS up to certain limit increases the tensile strength after which the strength is found to decrease. The 7 day average split tensile strength of CC is 2.12 N/mm² while that of MIX1, MIX2, MIX3, MIX4 and MIX5 are 2.41, 2.57, 2.34, 2.04 and 1.87 N/mm² respectively. The maximum average split tensile strength is found in MIX2 which has 10% GGBS. MIX2 has an average split tensile strength of 2.57 N/mm² which is 21% higher than the conventional concrete.

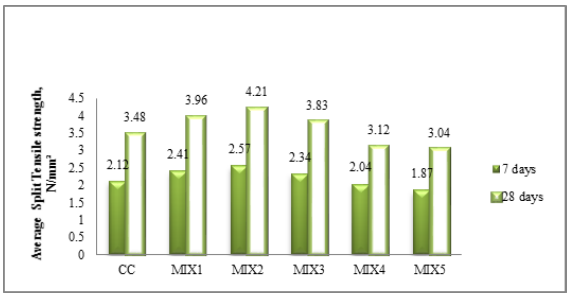

Figure.2. Average Split tensile Strength (7 and 28 Days)

It is also found that at the age of 28 days, the average split tensile strength of CC is 3.48 N/mm² while that of MIX1, MIX2, MIX3, MIX4 and MIX5 are 3.96, 4.21, 3.83, 3.12 and 3.04 N/mm² respectively. The maximum average split tensile strength is found in MIX2 which has 10% addition of GGBS. MIX2 has an average split tensile strength of 4.21 N/mm² which is 21% higher than that of the conventional concrete. It is also noted that the addition of GGBS up to 30% increases the tensile strength, beyond which the strength was found to decrease below the tensile strength of conventional concrete.

Flexural Strength: The comparison of average flexural strength of prism for 7 and 28 days pertaining to various mixes are shown in fig. 3.3. The effect of varying the percentage of GGBS in concrete can be seen from the figure. The flexural strength is found to vary similar to that of the compressive and tensile strength.

It is ascertained that the flexural strength of the concrete is found to increase on addition of GGBS. Addition of GGBS up to certain limit increases the flexural strength after which the strength is found to decrease. The 7 day average flexural strength of CC is 3.84 N/mm² while that of MIX1, MIX2, MIX3, MIX4 and MIX5 are 4.49, 4.68, 4.51, 3.79 and 3.74 N/mm² respectively. The maximum average flexural strength is found in MIX2 which has 10% GGBS. MIX2 has an average flexural strength of 4.68Mpa which is 22% higher than that of the conventional concrete.

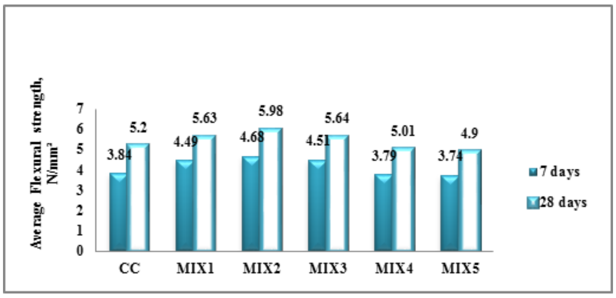

Figure.3. Average Flexural Strength (7 and 28 Days)

It is also found that at the age of 28 days, the Average flexural strength of CC is 5.20 N/mm² while that of MIX1, MIX2, MIX3, MIX4 and MIX5 are 5.63, 5.98, 5.64, 5.01 and 4.90 N/mm² respectively. The maximum average flexural strength is found in MIX2 which has 10% addition of GGBS. MIX2 has average flexural strength of 5.98 N/mm² which is 15% higher than that of the conventional mix. It is also observed that increase in the percentage of GGBS up to 30% increases the flexural strength, beyond which the strength was found to decrease below the flexural strength of conventional concrete.

Reinforced Concrete beams: An experimental programme consists of casting and testing two beams in given size 100 x 150 x 1200mm out of which the first one is control beam [CB] and another one was optimum mix. Test results like flexural strength, diagonal cracking load and ultimate shear strength are to be compared with ACI 318-08 & CSA code provisions and detailed study on crack pattern and flexural behavior was to be made. Adequate tensile reinforcement was provided in all specimens to ensure shear failure prior to flexure failure with minimum shear reinforcement as per ACI 318-08 code.

Load - deflection behavior: Load-Deflection relation for conventional beam and optimum beam are drawn. Both the beams exhibited typical flexural failure mode, characterized by the crushing of concrete from inclined towards the load point at failure. The crack patterns were essentially dominated by shear cracks which spread throughout the support. The ultimate load of the optimum beam is 70kN which is 22% higher than that of conventional beam. Cyclic loading was applied to the beam and the first crack appeared at 34kN and the corresponding deflection is 5.07 mm which is shown in fig.4.

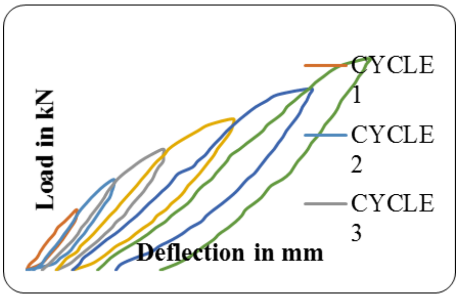

Figure.4. Load – Deflection curve for for MIX2

Ductility factor and cumulative ductility factor: Ductility factor is parameter considered important in the design of large deformation structures. Ductility of a structure is a highly desirable feature as it enables flexural members to undergo significant deformation prior to failure serving to warn of potential failures. For obtaining the deflection at first yield, the load at which the steel yields was calculated and then from (P-□) curve, □$_y$ was obtained. The cumulative ductility factor are shown in fig.5.

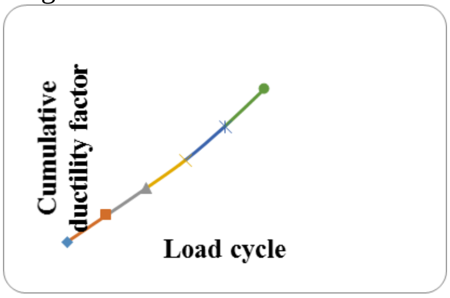

Figure.5. Cumulative ductility factor Vs Load cycle

4. CONCLUSIONS

From the experimental and analytical work presented in this investigation, the following may be concluded.

- Higher strength developed at optimum mix is due to the pozzolanic reaction in the concrete and filler effects inhibited by Metakaolin and GGBS.
- The compressive strength increases with addition of GGBS upto certain limit. The average compressive strength of HPC is 9%, 21% and 10% higher than the conventional concrete and is obtained in Mix1, Mix2 and Mix3 respectively.
- The average split tensile strength of HPC is13%, 21% and 10% higher than the conventional concrete and is obtained in Mix1, Mix2 and Mix3 respectively.
- The average flexural strength of HPC is 8%, 15% and 9% higher than the conventional concrete and is obtained in Mix1, Mix2 and Mix3 respectively.
- The maximum Compressive, split tensile and flexural strength are obtained when cement is partially replaced with 10% GGBS + 10% Metakaolin and natural sand is replaced with 30% quarry sand.
- The RC Beam for MIX2 shows the maximum ultimate load of 70kN which is 19.5% higher than the conventional beam. Higher ultimate load may be due to high pozzolanic reaction of Metakaolin and stronger interfacial transition zone due to addition of GGBS.
- Hence, GGBS and quarry sand wastes can be effectively used in cement concrete replacements thereby paving way for sustainable environment.

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