Experimental Study on Flexural Behavior of High-Strength Reinforced Concrete Beams

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Abstract: High performance concrete displays better properties when contrasted with traditional concrete. Usage of pozzolanic materials (Ground Granulated Blast Furnace Slag (GGBS), fly ash and silica fume and so forth) in concrete reductions the clinker creation. This paper presents the practicality of pozzolanic materials usage in new concrete, the blend of 60MPa compressive strength was embraced and with water-binder proportion as 0.31 according to standard methodology of ACI-211.4R.91. Level of cement in 10,20,30 and 40 was supplanted with GGBS. Silica fume was added at 2,4 and 6 rates to cement by weight as admixture. Compressive and split elastic qualities were resolved for HPC following 28 days of curing. Strengthened HPC radiates were standing and tried to check disappointment design following 28 days of curing under mid-point, 2-Point and Uniformly appropriated stacking. Flexure strength, redirection and break design were estimated. Better outcomes were seen at 20% GGBS replacement and at 6% silica fume addition for all samples.

Index Terms: HPC, Flexure strength, loading, Deflection and Crack Pattern.

I. INTRODUCTION

High performance concrete is in advantage altogether parts of solidarity and mechanical properties than those of ordinary concrete. With the expansion of silica fume in regular concrete makes it more able to perform. HPC has characterized compressive strength of 50MPa or above. HPC has been fundamentally utilized in extensions, burrows, thermal energy stations and tall structures for its solidarity, durability and high modulus of versatility. It has additionally been utilized in energy assimilation limit, parking structures, farming applications, Shotcrete fix and retrofitting occupations. HPC are made with painstakingly chose excellent fixings and enhanced blended plans, grouping, blending, putting ought to be made reasonable to fulfill most noteworthy industry guidelines. Commonly, such concretes will have a low water-cover proportion of 0.20 to 0.45. Super plasticizers assume an indispensable part in the creation of High-execution concrete. Admixture is a fundamental piece of HPC blend. The conduct of Alccofine based superior concrete, upgrade the mechanical properties of concrete [1]. Alccofine was utilized as a mineral admixture in concrete blend to build the underlying strength of the concrete than the conventional concrete [2]. The reused aggregates (RCA) of 4-16 mm sizes and class F fly debris were utilized in concrete [3]. To accomplish compressive strength of concrete, the water cement proportion of 0.25, 0.3 and 0.35 were utilized [4]. The trial examination on HPC, 12.5mm greatest size aggregates were utilized to find out usefulness and the mechanical properties of the M80 and M100 grades and to discover incomplete replacements of silica fume [5]. To improve compressive strength up to 15% replacement of silica fume with cement in High performance concrete. [6]. The halfway replacement levels of fly debris (class F) and allcofine on compressive strength and durability properties of concrete [7]. The exploratory investigation was done on the use of GGBS in the High performance concrete [8]. The rules were followed for the determination of the blend extents of High-strength concrete with mix of cement and fly debris [9]. The test examination was finished with High-amount of Fly debris [10]. In this paper to consider, five distinct combinations are plan for examination of proficiency of silica fume, GGBS and synergistic impacts of these pozzolanic materials on split ductile and compressive strength of concrete in contrasting and control blend or examples.

II. MATERIALS

A. Cement

Cement is the significant designing material after the elimination of lime in the development business. OPC 53 evaluation cement is ordinarily used to project the uncommon kind of concrete constructions. The estimation of explicit gravity of cement is 3.12. The principle explanation for considering 53grade cement is a direct result of its particular surface region and fineness makes the interaction of hydration productive and gives sufficient strength. Prior to choosing the evaluation of cement trail combination which gives the thickness of 556Kg/m3is received by shifting the cement sand and cement content.

B. Coarse aggregates

The important parameters of coarse aggregates are its texture, shape and the optimum size. The aggregate strength was an important role in the case of high-performance concrete. The nominal size of the aggregates used were 20mm,10mm and crushed aggregates. The properties are shown in Table I.

Table I: Coarse aggregates

Specific gravity	Bulk density	Water absorption
2.67	1535 kg/m³	0.48

C. Fine aggregates

The main role of the fine aggregates (sand) is to provide workability and good finishing characteristics of concrete. River sand with a fineness modulus is about 3.0 is taken as coarse aggregate has been found to be satisfactory for production high compressive strength and good workability. For special strength of 50MPa or greater, FM should be between 2.8 and 3.1.

D. Silica fume

Silica fume is a byproduct of ferrosilicon alloys. The addition of silica fume is reducing the permeability of concrete. It is an effective pozzolanic material Although the slump decreases, the mix remains highly cohesive.

E. Ground Granulated Blast Furnace Slag

GGBS is used as a direct replacement in the basic weight of cement. Replacement levels for GGBS varies from 30% to 80%. In most instances of GGBS use 40% to 50%.

F. Water

The acceptability of water for high-strength concrete is not required major content. Water is lubricating the concrete mix.

G. Chemical Admixtures

High-range water-retarders are needed to ensure the concrete is easy to place and finishing. Super plasticizer is used to check the early setting problem. The combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

III. EXPERIMENTAL WORK

The experimental work was carried out by conducting compressive strength test on cubes(150×150×150mm) and split tensile strength of cylinders (150mm diameter, H=300mm) respectively by using binders with various proportions of GGBS and silica fume. The experimental work consists of casting and testing of total 64 cubes and 48 cylinders. All specimens were cast with M60 grade concrete. Figure 1 provide information related to casted cubes and cylinders.

Figure 1: Cube & cylinder Specimens

After performing various tests on cubes and cylinders, Categories 1, 2 and 3 are mentioned for the various mixtures with different percentage in GGBS and Silica fume. It is found that optimum value is obtained for the samples of 80% cement, 20% GGBS and 6% silica fume is the most - effective combination to give optimum results.

A. Mix Design Method

The methodology of formulate an High performance mix design is based ACI 211.4R-93 following phases,

a) Water requirement and air content of conventional concrete based on using a sand under 35% of voids.
The target strength $F_{ck}= f_{ck}+1.65(s)$
F_{ck}= target compressive strength
f_{ck}= characteristics compressive strength
s= assumed standard derivation is 5N/mm²
b) Strength required is depends on the maximum size of aggregates.
c) Selection of optimum dry rodded unit weight of coarse aggregates content. Based on ASTM C 29.
d) Water quantity and air content is depends on the Mix grade of concrete.
e) The recommended maximum water-cement ratio, to achieve different compressive strengths at 7 days, 28 days for a mix made with high-range water-reduction (HRWR).
f) The amount of cement content can be determined by dividing water quantity by water-binder ratio.

B. Mix Proportion

The recommended trial mixtures are conducted (workability) the mixture of each percentage of chemical admixture. The mix proportions (M60 grade) are shown in Table.

Table II: Mix proportions

Cement	Fine aggregates	Coarse aggregates	w/c	Chemical admixtures
556 Kg/m^3	630 Kg/m^3	1100 Kg/m^3	0.31	2.78 Kg/m^3

The amount of silica fume and GGBS that is to be taken in three categories and Table 3 show the details of concrete weights of different proportions for M60:

1) In this case taken silica fume as a constant value of 2% and the replacement of GGBS by considering percentage 10%,20%,30% and 40%.
2) Taken silica fume 4% of constant value and the replacement of GGBS by considering percentage 10%,20%,30% and 40%.
3) In this case take 6% of silica fume constant value and the replacement of GGBS by considering percentage 10%,20%,30% and 40%.

Table III: Details of concrete Mix Proportions for M60

Mix Id	Cement	Sand	CA	SF	GGBS
100C0S0G	556	630	1100	0	0
90C2S10G	500.4	630	1100	11.12	55.6
80C2S20G	444.8	630	1100	11.12	111.2
70C2S30G	389.2	630	1100	11.12	166.8

60C2S40G	333.6	630	1100	11.12	222.4
90C4S10G	500.4	630	1100	22.24	55.6
80C4S20G	444.8	630	1100	22.24	111.2
70C4S30G	389.2	630	1100	22.24	166.8
60C4S40G	333.6	630	1100	22.24	222.4
90C6S10G	500.4	630	1100	33.36	55.6
80C6S20G	444.8	630	1100	33.36	111.2
70C6S30G	389.2	630	1100	33.36	166.8
60C6S40G	333.6	630	1100	33.36	222.4

Note: In all proportions amount of Super plasticizer (2.78), water quantity (175) is same and all quantities are in Kg/m^3.

C. Casting Beams

By taking the optimum values obtained after testing under casted with variation in percentage of materials and constant super plasticizer. The beams are casted with dimension (230mm×300mm and length= 1300mm).

Figure 2: Reinforcement of beam details

Figure 3 shows the casted beam with 10mm diameter reinforced steel bars.

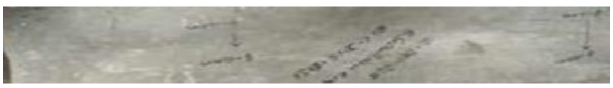


Figure 3: Casted beam

IV. RESULTS AND DISCUSSIONS

A. Compressive strength

The compressive strength of concrete with OrdinaryPortland cement, silica fume and GGBS concrete at the age of 7days and 28days are conducted. The maximum 28days cubecompressive strength of M60 grade with replacement in combination of 20% GGBS and 6% silica fume was 78MPa. Table IV is Compressive strength results of Plain concrete forM60.

Table IV: Compressive strength of Plain concrete

Mix Id	7 days	28 days
100C0S0G	44.25 N/mm²	66.73 N/mm²

Figure 4 show the compressive strength of Plain concrete for M60.

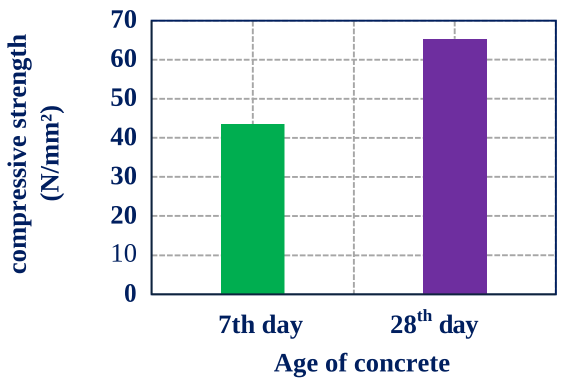


Figure 4: Compressive strength of concrete.

Table V shows the Compressive strength of concrete for partial replacement of GGBS and constant add 2% of Silica fume for M60.

Table V: Compressive strength of concrete

Mix Id	7 days	28 days
90C2S10G	57.26 N/mm²	65.15 N/mm²
80C2S20G	58.66 N/mm²	72.5 N/mm²
70C2S30G	60.57 N/mm²	69.56 N/mm²
60C2S40G	59.36 N/mm²	63.44 N/mm²

Figure 5 show the Compressive strength of concrete for partial replacement of GGBS and constant 2% of silica fume for M60.

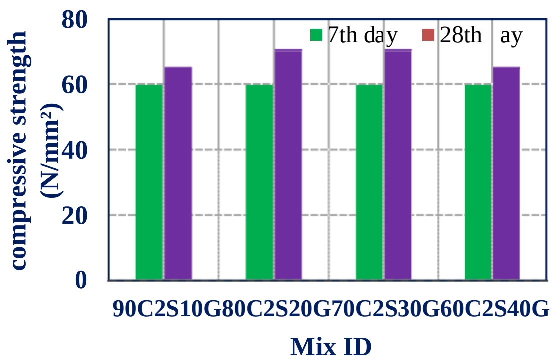


Figure 5: 2% Silica fume for M60

Table VI show the Compressive strength of concrete for partial replacement of GGBS and constant 4% of silica fume for M60.

Table VI: Compressive strength of concrete

Mix Id	7 days	28 days
90C4S10G	57.45 N/mm²	66.86 N/mm²
80C4S20G	61.28 N/mm²	74.43 N/mm²
70C4S30G	59 N/mm²	69.72 N/mm²
60C4S40G	58.55 N/mm²	62.12 N/mm²

Figure 6 shows compressive strength of concrete for partial replacement of GGBS and constant 4% of silica fume for M60

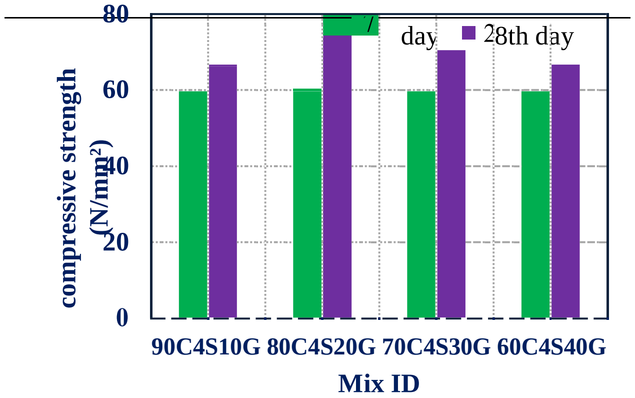


Figure 6: 4% of silica fume for M60

Table VII show the Compressive strength of concrete for partial replacement of GGBS and constant 6% of silica fume for M60.

Table VII: Compressive strength of concrete

Mix Id	7 days	28 days
90C6S10G	58.67 N/mm²	72.15 N/mm²
80C6S20G	63.44 N/mm²	79.22 N/mm²
70C6S30G	62.37 N/mm²	71.44 N/mm²
60C6S40G	59.54 N/mm²	67.34 N/mm²

Figure 7 show the Compressive strength of concrete for partial replacement of GGBS and constant 4% of silica fume for M60

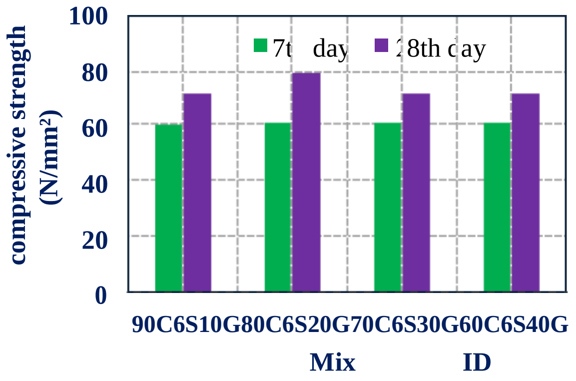


Figure7: 6% of silica fume for M60

B. Split tensile strength

The Split tensile strength test was carried out conforming to IS 5816:1999 to obtained split tensile strength for M60 grade of concrete. The split tensile strength of concrete with GGBS and silica fume at the time span of 7days, 28days are conducted. The maximum 28days cylinder split tensile

Table VIII: Split tensile strength of concrete

Mix Id	7 days	28 days
100C0S0G	4.32 N/mm²	4.6 N/mm²

Figure 8 shows the Split tensile strength of Plain concrete for M60 in a bar chart representation for 7 and 28 days.

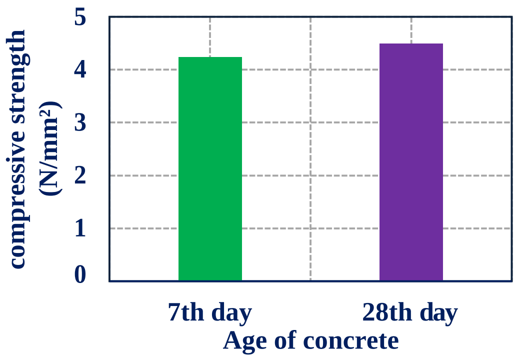


Figure 8: Split tensile strength of Plain concrete

Below Table shows the Split tensile strength of concrete for Partial replacement of GGBS and constant 2% of silica fume for M60

Table IX: Split tensile strength of concrete

Mix Id	7 days	28 days
90C2S10G	3.49N/mm²	3.84 N/mm²
80C2S20G	3.85 N/mm²	4.45 N/mm²
70C2S30G	4.221 N/mm²	4.324 N/mm²
60C2S40G	3.768 N/mm²	4.424 N/mm²

Figure 9 show the Split tensile strength of concrete for different percentages of GGBS and constant 2% of silica fume for M60.

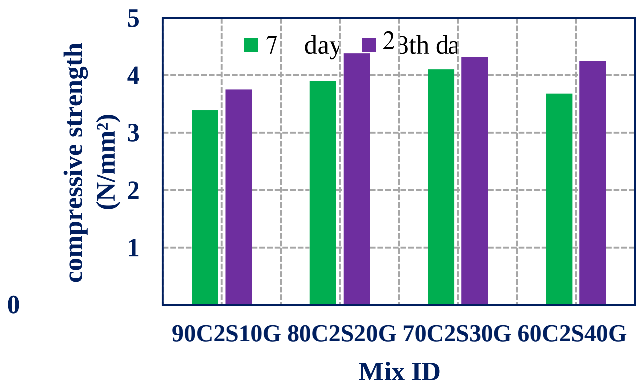


Figure 9: 2% of silica fume for M60

Table X show the Split tensile strength of concrete for different percentages of GGBS and constant 4% of silica fume for M60.

Table X: Split tensile strength of concrete

Mix Id	7 days	28 days
90C4S10G	4.57 N/mm²	5.073 N/mm²
80C4S20G	4.42 N/mm²	4.641 N/mm²
70C4S30G	4.113 N/mm²	4.41 N/mm²
60C4S40G	4.113 N/mm²	4.773 N/mm²

Figure 10 show the Split tensile strength of concrete for different percentages of GGBS and constant 4% of silica fume for M60.

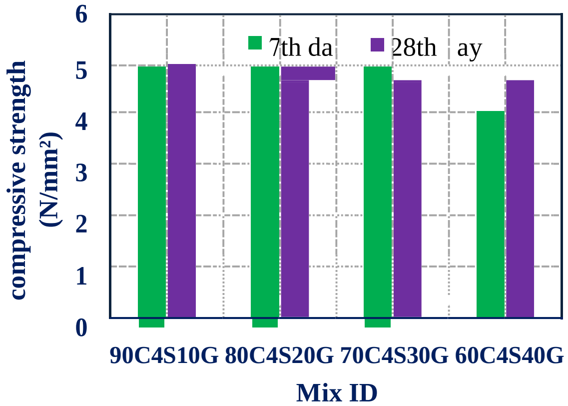


Figure 10: 4% of silica fume for M60

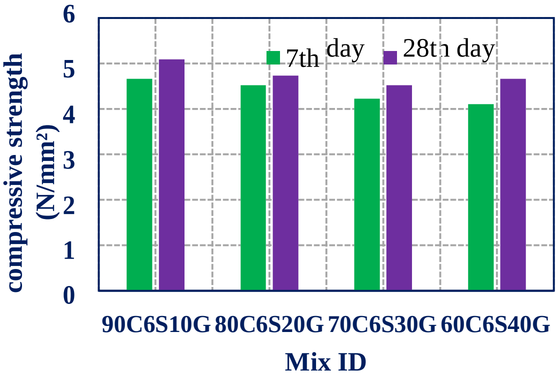
Table XI show the Split tensile strength of concrete for different percentages of GGBS and constant 6% of silica fume for M60

Table XI: Split tensile strength of concrete

Mix Id	7 days	28 days
90C6S10G	4.66 N/mm²	5.163 N/mm²
80C6S20G	4.95 N/mm²	5.3 N/mm²
70C6S30G	4.385 N/mm²	4.95 N/mm²
60C6S40G	4.244 N/mm²	4.81 N/mm²

Figure 11 show the Split tensile strength of concrete for different percentages of GGBS and constant 6% of silica fume for M60.

Figure 11: 6% of silica fume for M60



C. Testing

After the curing time, the beam specimens were cleaned to remove dirt. Then whitewashed were applied to facilitate easy detection of cracks. The beam specimens were tested under loading frame having a capacity of 1500 KN and hydraulic jack of 500 KN capacity subjected to 1-point, 2- point and UD Loadings. After the initial crack load the load increases.

D. Failure Mode and Crack Pattern

Beyond the peak load, the no. of cracks stabilized and the cracks at the mid span. At failure load, the beams deflected significantly. The failure pattern of the beam specimens was found to be similar for the High performance reinforced concrete beams. The failure in all cases was initiated by yielding of the tensile steel followed by the crushing of concrete in the compressive face. Figure 12 shows the crack pattern of 1-point loading beam with average ultimate load is 165kN and crack width is 2mm.

Figure 12: 1-point loading

Figure 13 show the load-deflection curve obtained for 1-point loading beam.

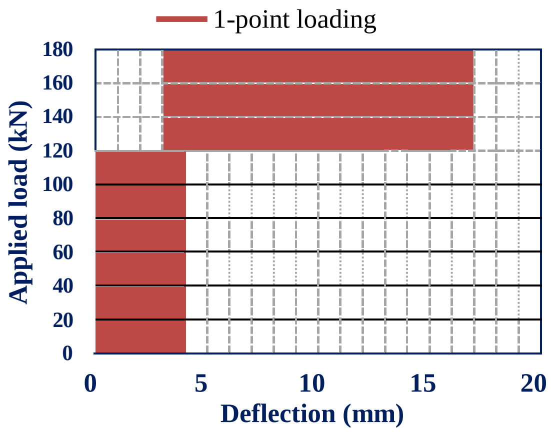


Figure 13: Load-deflection curve

Figure 14 shows the crack pattern of 2-point loading beam with average ultimate load is 320kN and crack width is 1.2mm.

Figure 14: 2-point loading

Figure 15 shows the load-deflection curve obtained for 2-point loading beam.

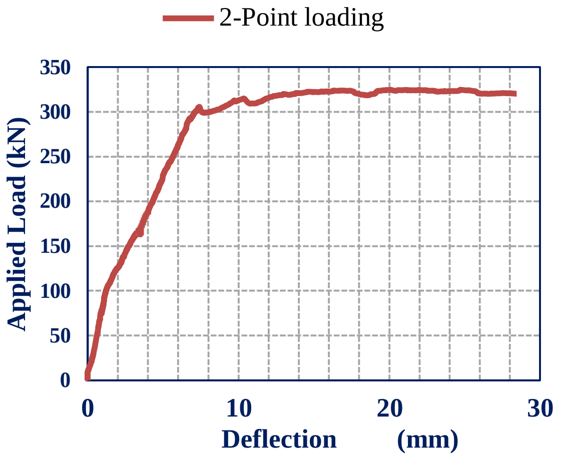


Figure15: Load-Deflection Curve

Figure 16 shows the crack pattern of uniformly distribution loading (u.d.l) beam with average ultimate load is 165kN and crack width is 1mm.

Figure 16: Uniformly distribution loading

Figure 17 shows the load-deflection curve obtained for uniformly distribution loading beam.

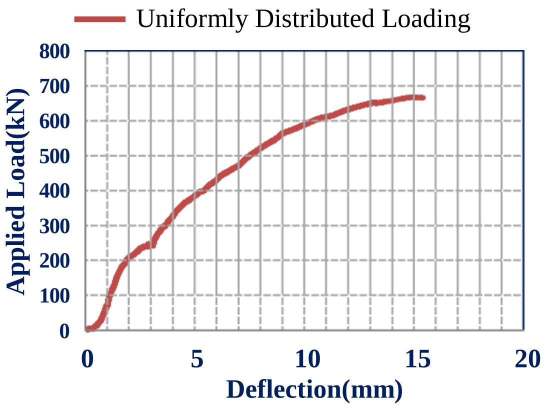


Figure 17: Load-deflection curve

V. CONCLUSION

Based on experimental investigations the following conclusions were made are:

1. M60 mix design procedure for High performance concrete using Silica Fume and super plasticizer is formulated by ACI methods of mix design and available literatures on High performance concrete.
2. It was identified that at 28 days, compressive strength of M60 grade of concrete increased by 20% in strength and split tensile strength was increased by 17.77% of strength for combination of 20% GGBS and adding 6% silica fume as admixture when compared to that of controlled concrete.
3. Beyond 30 to 40% replacement of GGBS, compressive strength and split tensile were decreased.
4. As the replacement percentage increases workability of concrete also reduced
5. The addition of silica fume is improving the bond strength of concrete however it is decreasing the permeability of concrete.
6. The compression failure pattern of concrete is due to crushing of coarse aggregates and not due to bond failure.
7. From the test results of cubes and cylinders, the percentage of water absorption of the high performance concrete mixes containing silica fume was lower, when compared to controlled mixes.
8. By taking three types of loading conditions, such as 1-point, 2-point & udl loads. The flexural behavior of the High-performance concrete can be analyzed from the observation of 1- point load consists of flexural crack pattern. Similarly, 2-point and uniformly distributed load will get the flexural crack pattern and true shear.

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