STRUCTURAL BEHAVIOUR OF RCC BEAM BY PARTIAL REPLACEMENT OF CEMENT IN HIGH PERFORMANCE CONCRETE

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ABSTRACT

Ordinary Portland cement (OPC) is the mostly consumed cement in the construction industries due to its diversified applications. Unfortunately, during the production of Portland cement, it causes the emission of pollutants into the atmosphere. Similarly the accumulation of the fly ash and Granulated glass blast furnace slag have been increased to a larger extend day by day which in return affect the environment. Hence the paper deals with the usage of partial replacement of cement by fly ash (FA), and Ground Granulated Blast Slag (GGBS) to achieve high strength concrete mixes. This paper presents an experimental work carried out to study the effects of Ground Granulated Blast Furnace Slag (GGBS) and class F Fly ash on strength development of concrete and the optimum use of slag in concrete. Cement was partially replaced with percentages (10%, 20% 30%, 40%, 50% and 60%) of slag and 20% of Class F Fly ash by weight of cement. Specimens are casted. The Compressive Strength, Split Tensile Strength and Flexural Behaviour of the Specimens will be tested. Results of blended concrete are compared with that of normal concrete without GGBS and Fly ash.

Keyword: - *Permeable Concrete, Polymer Admixture, Compressive Strength, Flexural Strength, Split Tension Test, and Concrete Pavement etc….*

1.INTRODUCTION

1.1 GENERAL

Concrete is a heterogeneous mix of cement, aggregates and water in the proper proportions. Cement, when mixed with water undergoes a chemical reaction called hydration. The reaction involves each cement particle developing a type of growth on its surface which gradually spreads until it links with the growth from other cement particles. This link provides the bonding strength. The large solid coarse aggregate forms the basic structural members of the concrete. The voids between the aggregates are filled by subsequently smaller sized fine aggregates until the smallest void are filled up by the cement. The cement and water form a paste that binds the aggregate particles and solidly together is called concrete.

The production of cement is increasing annually by about 3%. The production of one tone of cement liberates about one tone of CO_2 to the atmosphere, as the result of de-carbonation of the limestone in the kiln during manufacture of cement. The contribution of Portland cement production worldwide to the greenhouse gas emission is estimated to be about 1.35 billion tone annually or about 7% of the total greenhouse gas emissions to the earth’s atmosphere.

Cement plays a vital role in the development of infrastructure viz., buildings, industrial structures, bridges and highways etc., leading to utilization of large quantity of cement. The demand for cement is quite high in developing countries owing to rapid infrastructural growth which results supply scarcity. To overcome from this crisis, partial replacement of cement with supplementary material is economic alternative.

The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Ground granulated blast furnace slag (GGBS), Silica fumes (SF), Fly ash (FA) are among the solid wastes generated by industry. Environmental friendly concrete is produced by reducing the amount of cement in concrete using alternate pozzolanic materials. A pozzolan is a powdered material which when added to the cement in a concrete mix reacts with the lime released by the hydration of the cement to concrete compounds which improve the strength or other properties of concrete. Some of the material that has been used to replace cement partially in concrete includes Rice Husk Ash, Ground granulated blast furnace slag, Fly Ash and silica fumes.

High performance concrete (HPC) may be defined as the concrete possesses high workability, high strength, low permeability and resistance to chloride attack. HPC is cement based concrete possessing the most desirable properties during fresh as well as hardened concrete stages. The low porosity of the HPCs results in their superior durability and strength characteristics. However, HPCs require high cement paste volume which often leads to high shrinkage and greater heat evolution due to hydration. In an attempt to solve these problems, mineral admixtures are often used as partial replacement for cement. Mineral admixtures act as pozzolanic materials as well as fine fillers, thereby the microstructure of hardened cement matrix becomes denser and stronger.

In this investigation, Fly ash and Ground granulated blast furnace slag was used as a mineral admixture which not only improved the properties of concrete but also resulted in a reduction in the cost of concrete, increases Durability, Sulfate Resistance, Workability, Reduces Segregation and Bleeding, Lowers Heat of Hydration.

Fly ash is an industrial waste and a material of pozzolanic characteristic occurring due to burning the pulverized coal in the thermal power plants. The fly ashes have pozzolanic activity because they contain surplus amount of silica, alumina and iron oxide. They have a structure with very fine particles and amorphous. Using the fly ash in the concrete generally increases the workability of the fresh concrete, decreases the bleeding, increases resistance of the concrete to the chemical effects, and decreases the costs. Ground Granulated Blast furnace slag (GGBS) is a by-product in the manufacture of pig iron. During the iron-manufacturing process the materials are heated in a blast furnace and quenching to form a molten slag. This molten slag is processed to produce a glassy, granular product is dried and ground into a fine powder i.e. less than 45 micron size. The composition of Mineral Admixture and Cement is given in Table 1.1

Table 1.1 Compositions of Mineral Admixture and Cement

SL.NO	Constituents	Percentage contents		
		Cement	GGBS	Fly ash
1	Lime (Cao)	60-67	30-45	1.0-3.0
2	Silica (SiO_2)	17-25	30-38	35-60
3	Alumina (Al_2O_3)	3.0-8.0	15-25	10-30
4	Iron Oxide (Fe_2O_3)	0.5-6.0	0.5-2.0	4-10
5	Magnesium Oxide (MgO)	0.1-4.0	4.0-17.0	0.2-5.0
6	Glass		85-98	20-30
7	Loss on Ignition (LOI)	1.4	1.2	0.3
8	Specific gravity	3.15	2.9	2.1-2.6

The performance of concrete is improved by adding GGBS and FLY ASH which also helps to improve the compressive strength and sulphate resistance, lowering the cost, also reduces creep, heat of hydration and drying shrinkage of concrete.

Considering the long term performance and stability of structures, there are number of investigations carried out with partial replacement of cement with Fly ash and Ground Granulated Blast furnace Slag (GGBS) and similarly the advent of super plasticizers provided an impetus for the development of very high strength concrete mixtures that found their way quickly into cast-in-place structures designed for long-term durability under severe environmental conditions., but this paper focuses on blending Fly ash and GGBS with cement as alternative cementious material with different aspect ratios such as Fly ash with 20% as constant and GGBS with 10%, 20% 30%, 40%, 50% and 60% percentage of replacement in cement to develop high performance concrete.

1.1.1 Classification of concrete

Concrete can be classified as per ACI code concretes are categorized as Normal Strength Concrete, High Strength concrete and Ultra High Strength Concrete as given in Table 1.2

Table 1.2 Group of concrete as per ACI code

SI. NO	Name of Group Of Concrete	Concrete strength (Cylinder strength fc)
1	Normal Strength Concrete(NSC)	21 Mpa to 42 Mpa
2	High Strength Concrete(HSC)	60 Mpa to 90 Mpa
3	Ultra High Strength Concrete(UHSC)	115 Mpa to 160Mpa

1.1.2 High Strength Concrete (HSC)

High strength concrete (HSC) is a specialized concrete designed to provide several benefits in the construction of concrete structures that cannot always be achieved routinely using conventional ingredients, normal mixing and curing practices. It includes concrete that provides either substantially improved resistance to Environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability. However, with the recent advancement in concrete technology and the availability of various types of mineral and chemical admixtures, and special super plasticizer leads to the production of high strength concrete commercially.

1.2 NEED FOR THE STUDY

The production of Cement leads to release of consequential amount of CO_2 in to the atmosphere which is responsible for global warming. Each ton of Cement will make the release of one ton of CO_2 into the environment. So, one of the applicable concrete technologies to improve the environmental aspects of concrete done by reducing the CO_2 emission and the economic aspects by making the high performance concrete is using industrial by-products known as cement replacements. Industrial byproducts materials lead to reduction of natural resource generate less CO_2 and make the concrete more durable, recyclable and environmental friendly product. The advanced concrete structures like tunnels in the metro rail projects other complicated dedicated thin structures well as in compiled and congested areas the application high strength concrete is must. Hence the addition of GGBS and Fly ash would increase the strength of the concrete. To have quality and cost effective the advanced concrete and the research on its technology is needed to meet out such demands.

1.3 SCOPE

The construction industry relies heavily on cement as the principal binder in concrete. The high cost of cement coupled with the harmful gas emitted during its production has led to the use of agricultural and industrial by products such as rice husk ash, fly-ash and ground granulated blast furnace slag (GGBS) among others as partial replacement alternatives.

There have been enormous amount of waste have been left over due to various man made resources and various chemical waste created because of the usage of many modern products by the humans and demand of the same and thus it poses a threat to the environment authorities, besides storing in the form of dumping them in grounds. In this study, it is planned to replace cement with fly ash & GGBS as a blend to develop the high performance concrete.

1.4 OBJECTIVE

The objective of the project is to minimize the cost of construction material and also save our environment for our future generation by leaving the non-renewable resource materials like limestone, sand, granite, etc., so using the waste materials as a raw material for construction. The aim of this research was to study on the potential for using waste materials such as Fly ash and GGBS by mixing it with ordinary Portland cement to maximize the strength gain. The tests described in the project were performed to establish the physical and mechanical properties of recycled waste with the cement materials.

To determine the optimum percentage of GGBS to be used in each of the mixes for achieve high strength .To develop a mix proportions for control and blended concrete having percentage of replacement 20% of fly ash as constant and varying GGBS by 10%, 20%, 30 %, 40%, 50%, 60% and also to determine the mechanical properties such as compressive strength and Split Tensile strength test on cylinder and also flexural strength test on RC beam.

2. Materials Used

2.1 **CEMENT**

Cement is a binder, a substance that sets and hardens independently, and can bind other materials together. Ordinary Portland cement of grade–53 conforming to Indian standard IS: 12269-1987 has been used in the present study. Cement is a material, generally in powder form, that can be made into a paste usually by the addition of water and, when molded or poured, will set into a solid mass. It is a bluish-gray powder obtained by finely grinding the clinker made by strongly heating an intimate mixture of calcareous and argillaceous minerals.

2.2 Fine aggregate

Fine aggregate / sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. Sand that is available in nearby locality has been used as fine aggregate. Other foreign matter present in the sand has been separated before use. River sand available in Chennai was used as fine aggregate.

2.3 Coarse aggregate

Coarse aggregate are the crushed stone is used for making concrete.. Coarse aggregates are usually those particles which are retained on I.S. 4.75mm sieve.The aggregates should be absolutely clean, free from organic matter and other impurities. In this project 12 mm coarse are used. Coarse aggregate has been sieved through IS: 150- micron sieve to remove dirt and other foreign materials.

2.4 Fly ash (class F-type)

Pulverized fuel ash (commonly called fly ash) is a by-product of electricity production in coal-fired power stations. It consists of oxides of silica, alumina, iron, calcium and various minor constituents. Due to the high temperature of formation, these are mainly in a glassy phase and the particles, particularly those less than about 45 μm, are mainly spherical. In this project class F fly ash is used which shown in Figure 3.2.

Figure 2.1 Fly ash

2.5 Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases which shown in Figure 3.3. Ground granulated blast furnace slag is off-white in Color and substantially lighter than Portland cement. It contains aluminum oxide and silica oxide, it is suitable for making high strength concrete with partial replacement of fly ash and cement.

Figure 2.2 Ground granulated blast furnace slag

2.6 Super Plasticizer

Plasticizers help us to increase the workability of concrete without addition of extra quantity of water. Use of super plasticizers becomes essential for designing mix to achieve HPC to increase workability. Super plasticizer used in this study was Glenium B-233 which is shown in Figure 3.4

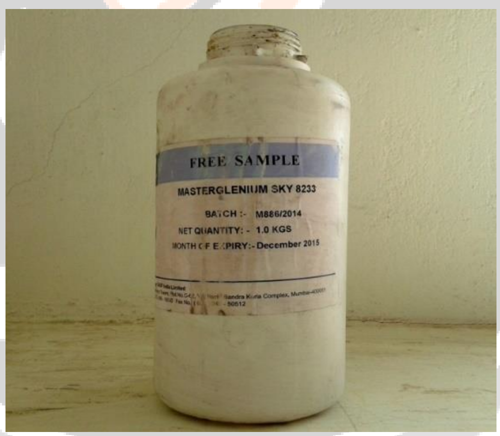

Figure 2.3 Super plasticizer (Glenium B-233)

2.7 Steel (Fe 415)

Steel reinforcements are used, generally, in the form of bars of circular cross section in concrete structure. They are like a skeleton in human body. Plain concrete without steel or any other reinforcement is strong in compression but weak in tension. Steel is one of the best forms of reinforcements, to take care of those stresses and to strengthen concrete to bear all kinds of loads. Grade Fe 415 is being used most commonly nowadays because of higher yield stress and bond strength resulting in saving of steel quantity. Bars range in diameter from 6 to 50 mm. Steel reinforcements used in this study was Fe 415.

3. METHODOLOGY

In this chapter, the brief description of the methodology and the sequence of the works to be carried out in this complete duration of project (phase-I and phase-II) are presented. In order to fulfill the objectives the methodology has been adopted. The flow chart for Methodology is given in Figure 3.1

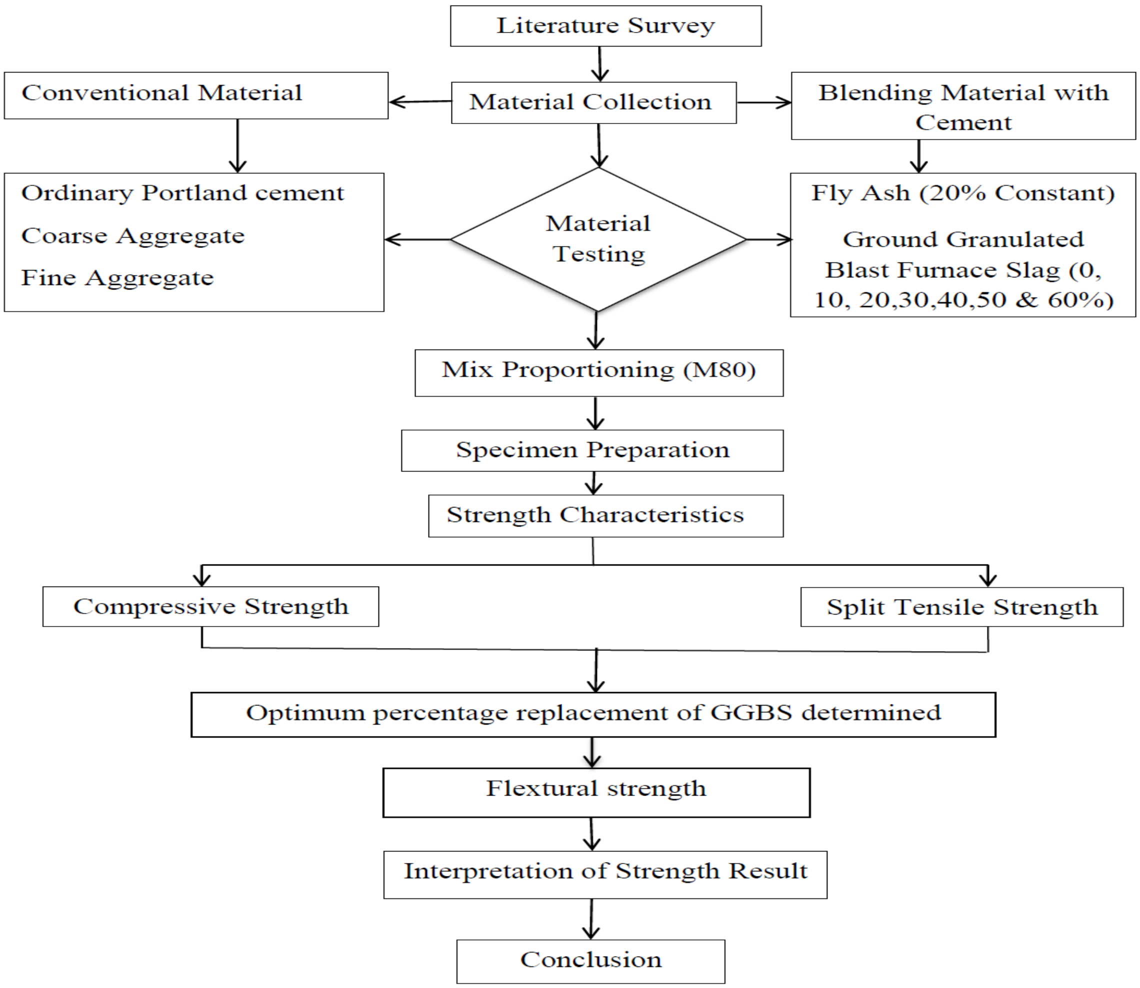

Figure 3.1 Methodology

The replacement waste that is to be used for the project is available locally. The percentage of replacement of cement by fly ash have been decided as 20% as constant and varying Ground Granulated Blast furnace slag (GGBS) as 10%, 20%, 30 %, 40%, 50%, 60%.The w/c ratio for the various replacement of OPC has to be investigated.

To determine the optimum percentage of GGBS to be used in each of the mixes for achieve high strength. The casted specimens at various ages (i.e.) at 7 days and 28 days have to be subjected to various experimental tests. The mechanical properties such as compressive strength and Split Tensile strength test on cylinder and also flexural strength test on RC beam at various ages have to be found out.

4. TESTING OF SPECIMEN

4.1.1 Specific Gravity Test for Fine Aggregate

Weight of empty pycnometer (W_1) = 678

Weight of pycnometer + fine aggregate (W_2)= 1357

Weight of pycnometer + F.A + water (W_3) = 1843

Weight of pycnometer + water (W_4) = 1418

Specific gravity (G) = $\frac{(w2-w1)}{(w2-w1)-(w3-w4)}$

$= \frac{(1357-678)}{(1357-678) - (1843-1418)}$

= 2.6732

4.1.2 Water Absorption for Fine Aggregate

Weight of fine aggregate taken = 1000 gm

Weight of pan = 765 gm

Weight of oven dried aggregate + Pan = 1763 gm

Weight of oven dried aggregate (A) = 1763-765

= 998 gm

Weight of surface dried aggregate (S) = 1015 gm

Water absorption = $\frac{(S-A)\times 100}{A}$

$= \frac{(1015-998) \times 100}{998}$

= 1.7034 %

4.1.2 Dry Bulk Density for Fine aggregate

Empty weight of cylinder = 12.95 Kg

Weight of loosely packed FA = 22.25 Kg

Volume of cylinder = $\pi/4 \times (0.15)^2 (0.3)$

= 5.3014×10^{-4} m^3

Weight of fully compacted aggregate (W) = 9.3 Kg

Bulk density of fine aggregate = $\frac{w}{v}$

$= \frac{9.3}{5.3014\times10^{-3}}$

= 1754.25 Kg/m^3

4.1.3 Fineness Modulus for Fine aggregate

Weight of fine aggregate taken = 1000gm

The grading of fine aggregate is given in Table 3.1

Table 4.1 Grading of fine aggregate

S. No	Sieve Size (mm)	Weight Retained (g)	% of weight retained	Cumulative % retained	% finer
1	4.75	67	6.7	6.7	93.3
2	2.36	74	7.4	14.1	85.9
3	1.18	143	14.3	28.4	71.6
4	600µ	315	31.5	59.9	40.1
5	300 µ	293	29.3	89.2	10.8
6	150 µ	98	9.8	99	1
7	pan	10	1	100	0

Fineness Modulus = $\frac{\text{Percentage finer}}{100}$

= $\frac{302.7}{100}$

= 3.027

4.1.4 Specific Gravity and Water Absorption Test of Coarse aggregate

Weight calculated aggregate suspended in Water with the basket (W_1) = 2.520 Kg

Weight of water suspended in water (W_2) = 1.37 Kg

Weight of saturated aggregate in water (W_s) = (W_1-W_2)

= 1.15 Kg

Weight of saturated surface dry aggregate in air (W_3) = 1.865 Kg

Weight of water equal to the volume of aggregate (W_3-W_s) = 0.715 Kg

Weight of oven dried aggregate (W_4) = 1.861 kg

Specific gravity = $\frac{W4}{(W3-Ws)}$

= $\frac{1.861}{1.865-1.15}$

= 2.6027

Water absorption = $\frac{(W3-W4)\times 100}{W4}$

= $\frac{1.865-1.861}{1.861}$

= 0.2149 %

4.1.5 Dry Bulk Density for Coarse aggregate

Empty weight of cylinder = 12.95 Kg

Weight of loosely packed CA = 20.10 Kg

Volume of cylinder = $\pi/4 \times (0.15)^2 (0.3)$

= 5.3014×10^{-4} m^3

Weight of fully compacted aggregate (W) = 8.65 Kg

Bulk density of fine aggregate = $\frac{W}{v}$

= $\frac{8.65}{5.3014\times10^{-3}}$

= 1630.814 Kg/m^3

4.1.6 Fineness Modulus test for Coarse aggregate

Weight of Coarse Aggregate taken = 2000 gm.

The grading of coarse aggregate is given in Table 3.2

Table 4.2 Grading of Coarse aggregate

S. No	Sieve size	Weight retained	% of weight retained	Cumulative % retained
1	10	137	6.85	6.85
2	9.5	100	5	11.85
3	6.3	1480	74	85.85
4	4.75	130	6.5	92.35
5	2.36	130	6.5	98.85
6	1.18	20	1	99.85
7	600µ	0	0	99.85
8	300µ	0	0	99.85
9	150µ	0	0	99.85

Fineness Modulus = Cumulative % retained / 100
= 695.15/ 100
= 6.9515

TRIAL MIX

According to the following seven trials of mix design cylinders were casted, cured and compressive and split tensile strength test has been found after 7 & 28 days. The mix proportion for different trials has shown in Table 3.3 and the specimen details has been showed in Table 3.4

Table 4.3 Mix Proportion for M80 concrete grade

Specimen ID	Cement kg/m^3	Fly ash kg/m^3	GGBS kg/m^3	F.A kg/m^3	C.A kg/m^3	Water kg/m^3	HRWR(1.75%) kg/m^3
S1	535.53	133.88	0	445.41	1105.09	171	3.05
S2	481.97	133.88	53.55	445.41	1105.09	171	3.05
S3	428.44	133.88	107.106	445.41	1105.09	171	3.05
S4	374.88	133.88	160.659	445.41	1105.09	171	3.05
S5	321.33	133.88	214.212	445.41	1105.09	171	3.05
S6	267.78	133.88	267.76	445.41	1105.09	171	3.05
S7	214.23	133.88	321.31	445.41	1105.09	171	3.05

GGBS - Ground Granulated Blast Furnace Slag.
F.A - Fine Aggregate
C.A - Coarse Aggregate
HRWR - High Range Water Reducer (GLENIUM B233)

Table 4.4 Specimen details

Specimen ID	Description
S1	Cement 80% + Fly Ash 20% + GGBS 0%
S2	Cement 70% + Fly Ash 20% + GGBS 10%
S3	Cement 60% + Fly Ash 20% + GGBS 20%
S4	Cement 50% + Fly Ash 20% + GGBS 30%
S5	Cement 40% + Fly Ash 20% + GGBS 40%
S6	Cement 30% + Fly Ash 20% + GGBS 50%
S7	Cement 20% + Fly Ash 20% + GGBS 60%

4.2 EXPERIMENTAL PROGRAM

4.2.1 Specimen Preparation

A total of 42 cylinders (80mm diameter and 100mm height) for compression test and 14 cylinders (80mm diameter and 100mm height) and 4 RCC beam (1200 x 100 x 200mm) were cast in the present investigation. The coarse aggregates were first poured into the mixer before half of the fine aggregates were added. The binder was completely poured in, followed by the rest of sand. The machine was then allowed to run for about one minute to ensure dry mixing of the ingredients before the calculated water was added. Immediately after the addition of the water, chemical admixture at the level of 1.75 % of water was added to improve the workability of the mix.

After about three minutes of complete mixing the machine was switched off. The concrete was placed inside already prepared oiled molds on the table vibrator. Placement of the concrete was carried out in three layers and the table vibrator was used to ensure adequate compaction of the concrete after each layer was placed. On completion of casting, the concrete filled molds were then transferred to the laboratory floor to set and harden for 24 hours which shown in Figure 3.5

4.2.2 Curing of specimen

After 24 hours, demoulding of the specimens were carried out, the specimens were given identification marks and transformed to the curing tank for 7 and 28 days as shown in Figure. 3.6

Figure 4.2.1 Casted Specimen

Figure 4.2.2 Curing of Specimen

4.2.3 Beam design

STEP 1: Data

Span of the beam (L) = 1200 mm

Concrete Grade (f_{CK}) = 80 N/mm^2

Steel grade (f_Y) = 415 N/mm^2

Breadth of the beam (b) = 100 mm

Depth of the beam (D) = 200 mm

Diameter of the steel (Ø) = 12 mm

Clear cover (C/C) = 15 mm

Effective depth of the beam (d_e) = D - C/C - (Ø/2)

= 200 – 15 – (12/2)

= 179 mm

STEP 2: Steel area calculation

Area of steel (A_{st}) = $\pi/4 \times (Ø)^2 \times n$

No of bars used (n) = 2

Area of steel (A_{st}) = $\pi/4 \times (12)^2 \times 2$

= 226.19 mm^2

STEP 3: Moment calculation

Ultimate Moment (M_u) = $0.87\ f_y\ A_{st}\ d \left[1 - \left(\frac{Ast\ fy}{b\ d\ fCK}\right)\right]$

= $0.87 \times 415 \times 226.19 \times 179 \left[1 - \left(\frac{226.19 \times 415}{100 \times 179 \times 80}\right)\right]$

= 13.66 KNM

STEP 5: Load calculation

Ultimate Moment (M_u) = $\frac{Wu\ l}{4}$ (for mid-point loading)

13.66×10^6 = $\frac{Wu \times 1000}{4}$

Ultimate load (W_u) = 54.64 KN

STEP 6: Check for Shear stress

Shear force V_u = $\frac{Wu\ l}{2}$

= $\frac{54.64 \times 1000}{2}$

= 27.32 KN

Nominal shear stress (τ_v) = $\frac{Vu}{b\ d}$

= $\frac{27.32 \times 10^3}{100 \times 179}$

= 1.53 N/mm^2

Percentage of tension reinforcement (P_t) = $\frac{Ast}{b\ d} \times 100$

= $\frac{226.19}{100 \times 200} \times 100$

= 1.13

Referring Table 19 0f IS 456- 2000, by interpolating the value of τ_c becomes

Shear strength of concrete (τ_c) = 0.71 N/mm^2

Referring Clause 40.2.1.1 0f IS 456- 2000, the value of k becomes

Shear strength factor (k) = 1.30

$k\,\tau_c = 1.30 \times 0.71$

$= 0.92$

$\tau_v > k\,\tau_c$

Hence provide nominal shear reinforcement using 8mm diameter two legged stirrups at a spacing of 125 mm center to center

STEP 7: Check for deflection control

Percentage of tension reinforcement (P_t) = 1.13

Referring Figure 4 0f IS 456- 2000, the value of k_t becomes

Modification factor (k_t) = 0.9

$$\left(\frac{L}{d}\right)_{max} = \left(\frac{L}{d}\right)_{basic} \times k_t \times k_c \times k_f$$

$$= 20 \times 0.9 \times 1 \times 1$$

$$= 18$$

$$\left(\frac{L}{d}\right)_{actual} = \frac{1200}{179}$$

$$= 6.7$$

$$\left(\frac{L}{d}\right)_{actual} < \left(\frac{L}{d}\right)_{max}$$

Hence deflection control is satisfactory

4.2.4 Beam Specimen details

The beam specimens were 100mm wide and 200mm deep in cross-section. They were 1200mm in length and simply-supported over an effective span mm. The clear cover of the beam was 15mm. The geometry of the beam specimens is shown in Figure 3.7

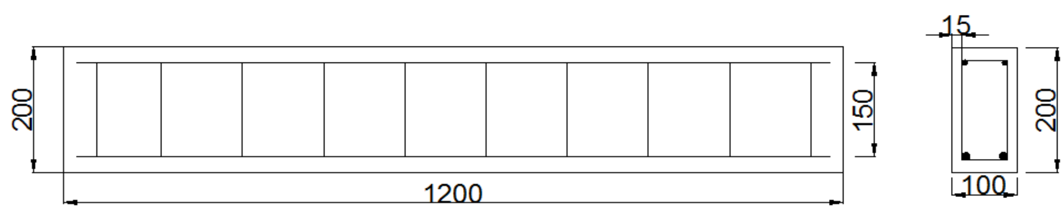

Figure 4.2.3 Geometry of beam specimen (All dimensions are in mm)

High yield strength deformed steel bars of diameter 12mm and 8mm were used as the longitudinal reinforcement in the specimens. The reinforcement details are given in the Table 3.5 for both compression steel and tension steel. Two legged vertical stirrups of 8mm diameter at a spacing of 125mm center to center were provided as shear reinforcement. After 28-days curing then beam is tested. The reinforcement and casted beam specimen is shown in Figure 3.8, 3.9.

Figure 4.2.4 Beam Reinforcement

Figure 4.2.5 Casted Beam specimens

Table 4.1 Reinforcement details for beam specimens.

Specimen ID	No of beams	Area of steel (mm^2)	
		A_{SC}	A_{ST}
S1	2	100	226
S5	2	100	226

4.2.5 Flexural Behaviour of Reinforced Concrete Beams

The test setup for the flexural test is shown in Figure 3.10. The test specimen was mounted in loading frame of 50 ton capacity. The supports of the beam rested on a roller which rest on the I section. The load was applied on center of the beam.

Dial gauges were used for measuring the deflections under the load points and at mid span for measuring the deflection. The dial gauge readings were recorded at different loads. The load was applied gradually until the first crack was observed. Subsequently, the load was applied. The Behaviour of the beam was observed carefully. The crack development and propagation were monitored and marked during the progress of the test. The crack widths were measured. The deflections were recorded for respective load increments until failure. The failure mode of the beams was also recorded.

Figure 4.2.6 Test setup for flexural test

5. RESULTS AND DISCUSSION

5.1 COMPRESSIVE STRENGTH

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen divided by the area of cross section in uniaxial compression under a given rate of loading. Compressive strength is the most important parameter in structural design. Three standard cylinders were produced for each mix. All the cylinders were tested in surface dried condition for each mix combination, cylinders were tested at the age of 7 and 28 days using compression testing machine of 100 ton capacity.The cylindrical specimen and the tested specimen are shown in Figure 4.1 and 4.2. The Compressive strength results are shown in Table 4.1 and bar chart shown in Figure 4.3.The loading was continued till the specimen reaches its ultimate load. The load shall be applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The ultimate load divided by the cross sectional area of the specimen is equal to the ultimate compressive strength. The compressive strength of the concrete is calculated by using the formula

$$\text{Compressive strength} = P/A \text{ (MPa)}$$

Where,

P = Load (KN)

A = Area of cylinder (mm^2) = $\left(\frac{\pi}{4}\right) * \mathbf{d^2}$

d = diameter of cylinder (mm) = 80

Figure 5.1 Cylindrical Specimens

Figure 5.2 Tested Specimens

Table 5.1 Result of Compressive Strength Test

S.NO.	Specimen ID	7 days			28 days		
		Load (KN)	Strength (MPa)	Average Strength (MPa)	Load (KN)	Strength (MPa)	Average Strength (MPa)
1	S1	290.21	57.74	56.48	400.51	79.68	81.51
		283.44	56.39		409.67	81.50	

		278.08	55.32		418.98	83.35	
2	S2	250.10	49.75	50.69	360.45	71.71	72.01
		255.75	50.88		365.90	72.79	
		258.65	51.46		359.54	71.53	
3	S3	260.31	51.79	51.63	370.81	73.77	75.35
		263.95	52.51		385.40	76.67	
		254.26	50.58		380.09	75.62	
4	S4	275.35	54.78	53.88	380.54	75.71	76.76
		264.15	52.55		385.18	76.63	
		273	54.31		391.76	77.94	
5	S5	295.60	58.81	57.73	425.65	84.68	83.59
		284.54	56.61		420.87	83.73	
		290.45	57.78		414.02	82.37	
6	S6	255.10	50.75	49	320	63.66	64.80
		244.58	48.66		325.91	64.84	
		239.23	47.59		331.31	65.91	
7	S7	229.17	45.59	46.69	310	61.67	61.50
		239.58	47.66		305.65	60.81	
		235.41	46.83		311.75	62.02	

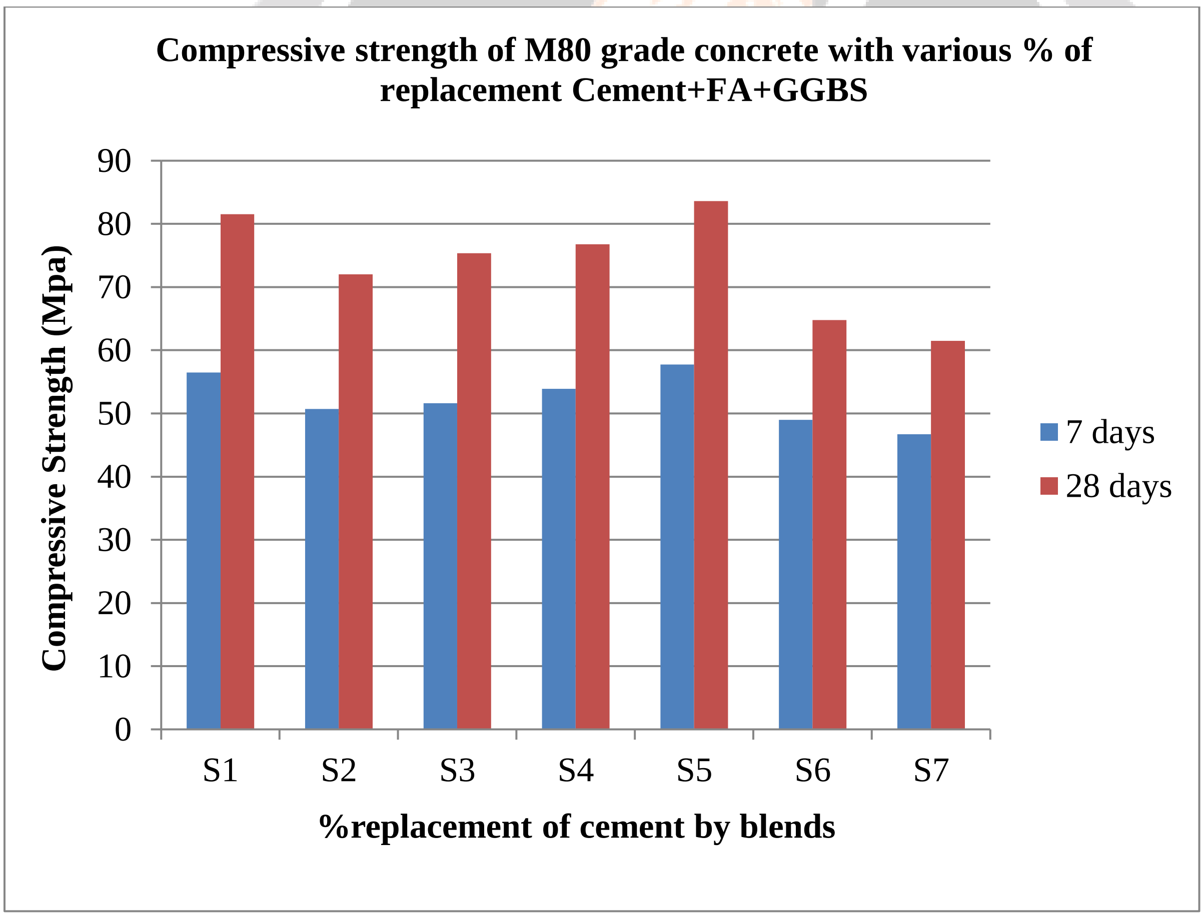

Figure 5.2 Compressive strength of Cylinder.

5.1.1 Discussion for Compressive strength

In view to the compressive strength of the specimens the strength of the mix can be clearly seen. In the results given above the compressive strength of the specimen without any replacement (S1) and the specimen with 40% replacement of blends (S5) are found to be similar such that there is good agreement that the same strength can be achieved with blends. For more than 40% replacement of blends there is a drop in the compressive strength making the 40% as optimum. However the tensile strength and flexure of the concrete should be checked to judge the mix to be used in the field.

5.2 SPLIT TENSILE STRENGTH

Tensile strength tests are used to assess the cracking resistance of concrete and bond strength to reinforcing bars. The cylinders were tested in saturated surface dried condition. Cylinders were tested at the age of 28 days using compression testing machine of 100 ton capacity. Placing and splitting of cylinders are shown in Figure 4.4.Split tensile strength results are shown in Table 4.2 and its bar chart shown in Figure 4.5. The loading was continued till the specimen reaches its ultimate load. The split tensile strength is calculated by using the formula given in IS 5816:1999 is

$$f_t = 2P/ \pi dL_s$$

Where,

P = Tensile load (KN)

d = diameter of the cylinder = 80 mm

L_s = length of the cylinder = 150mm

Figure 5.3 Placing and Splitting of Cylinder

Table 5.2 Result of Split Tensile Strength test

S.NO	Specimen ID	Load (KN)	Tensile strength (MPa)	Average Tensile strength (MPa)
1	S1	120.10	6.37	6.33
		118.54	6.29	

2	S2	116.83	6.19	6.20
		117.10	6.21	
3	S3	117.69	6.24	6.23
		117.19	6.22	
4	S4	117.04	6.21	6.24
		118.21	6.27	
5	S5	122	6.47	6.43
		120.29	6.38	
6	S6	116.32	6.17	6.19
		117.22	6.22	
7	S7	113.45	6.02	6.05
		114.44	6.07	

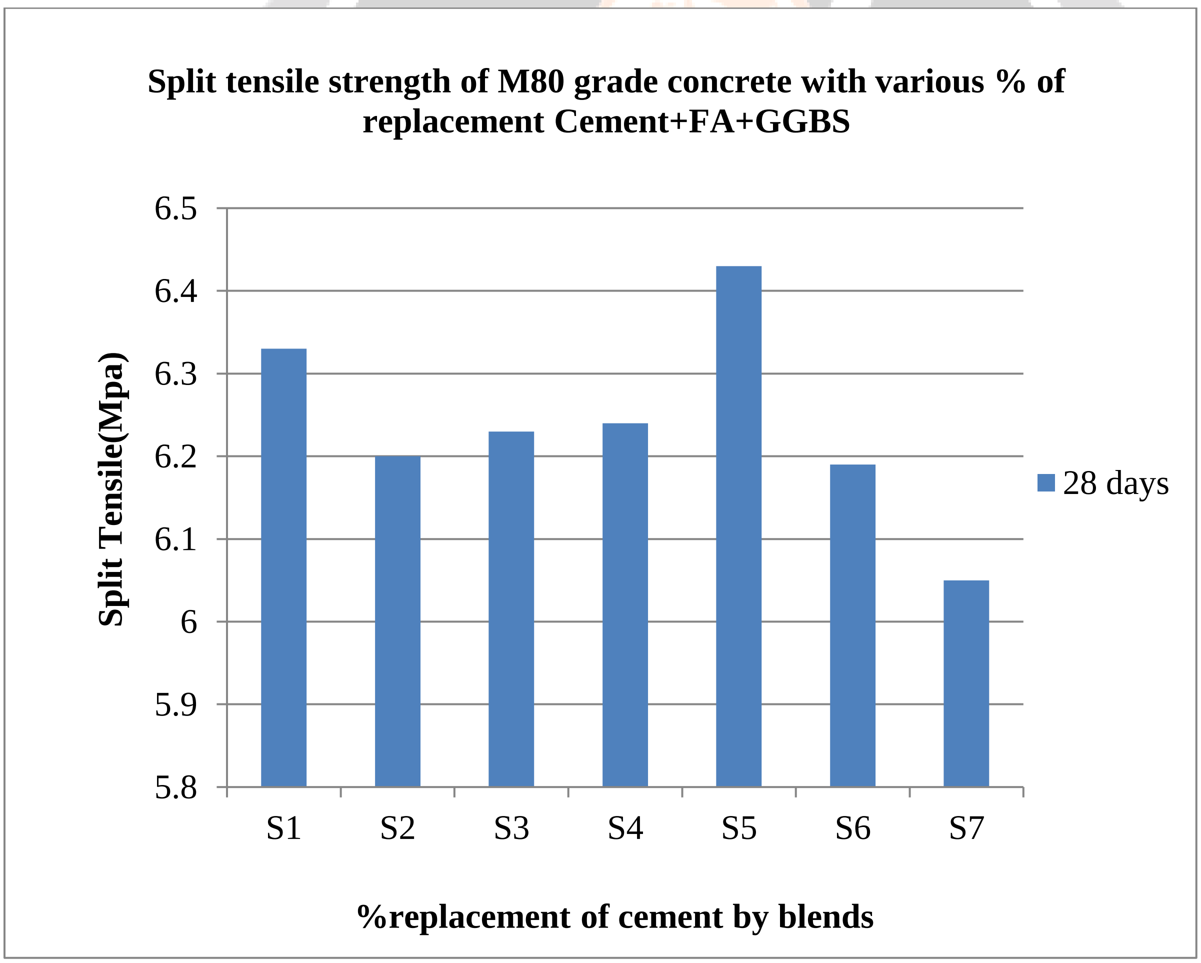

Figure. 5.4 Split Tensile Strength of cylinders

5.2.1 Discussion for split tensile strength

In reference to the compressive strength results the results of tension test was expected to be at the optimum level. The 28 days cured cylinders were tested for tension and the specimen S1 and S5 has the similar test results proving that optimum percentage is 40% of replacement by blends.

5.3 FLEXTURAL STRENGTH ON RCC BEAM

The experimental load-deflection curves of the RCC beam with 40% GGBS and without GGBS are tested at 28 days are shown in Figure respectively. The Summary of beam test results for reinforced OPC concrete beams and 40% GGBS concrete beams are shown in Table 4.3 respectively. During the test, vertical flexural cracks are observed. The measurement including deflection and load are recorded at different intervals of load until the beam fails. It was noticed that the first crack always appear close to the mid span of the beam. The failure patterns of the beam are shown in Figure respectively. Load vs Deflection values are shown in annexure 2 to 5..Similiarly load vs deflection curves are shown in Figure 4.6 to 4.9.Failure of beam specimen for S1 beam and S2 beam are shown in Figure 4.10 and 4.11. Comparison of Flexural Behaviour of beam S1 and S5 are shown in 4.1

Table 5.4 Summary of beam test results

S.NO	SPECIMEN ID	ULTIMATE STAGE		MODE OF FAILURE
		LOAD (KN)	DEFLECTION (mm)	
1	S1	68.9	6.32	Flexure
2	S1(a)	70.56	7.24	Flexure
3	S5	73.92	10.18	Flexure
4	S5(a)	76.94	11.20	Flexure

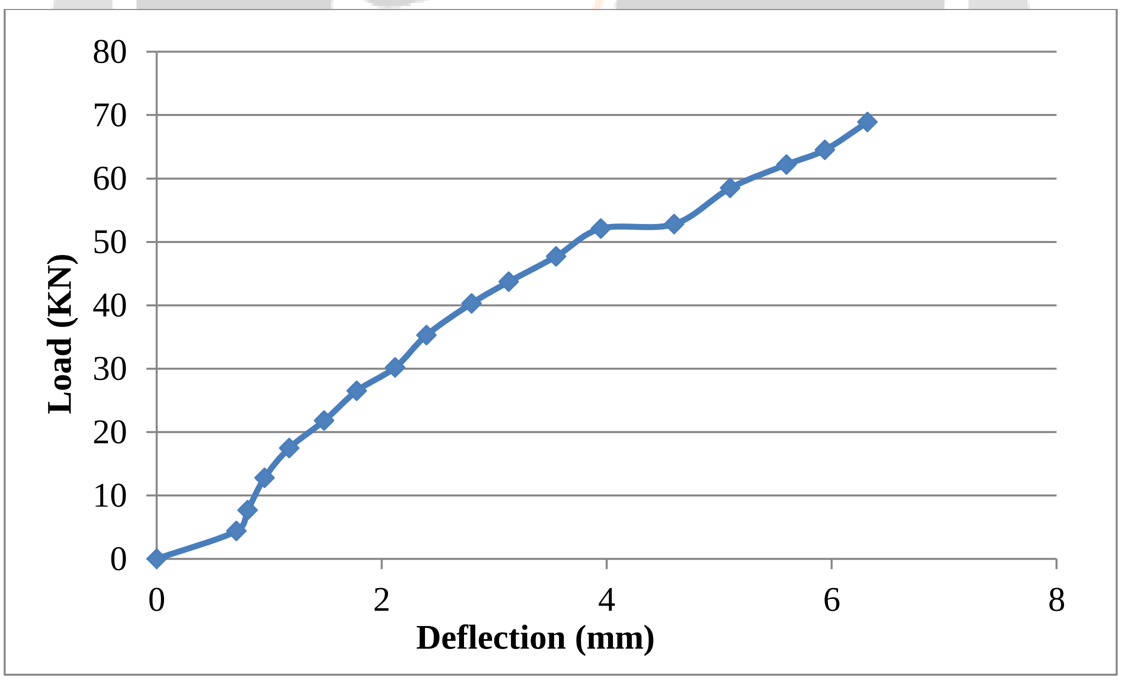

Figure 5.5 Load Vs Mid span deflection for S1 beam

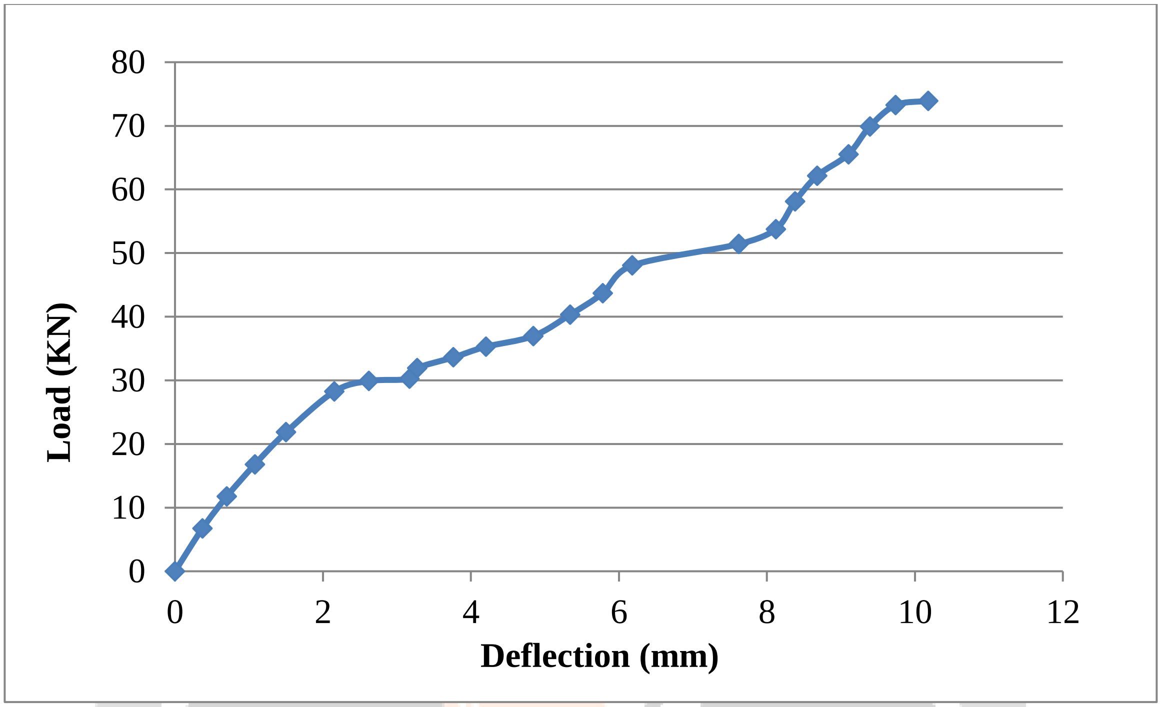

Figure 5.6 Load Vs Mid span deflection for S5 beam

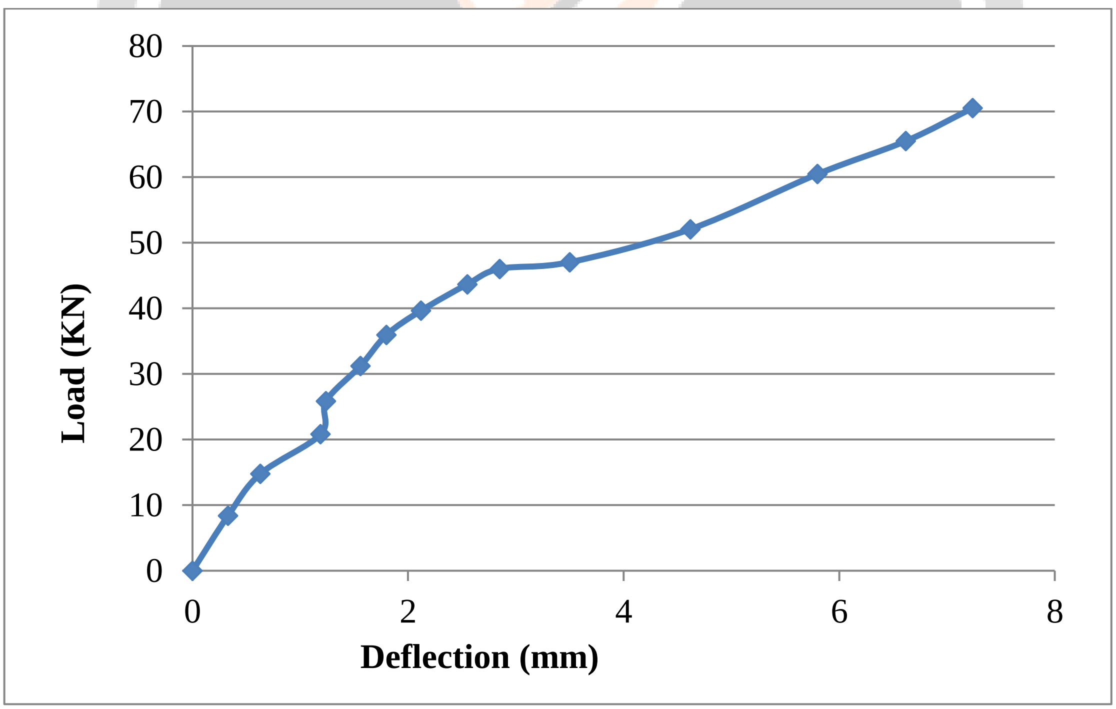

Figure 5.7 Load Vs Mid span deflection for S1 (a) beam

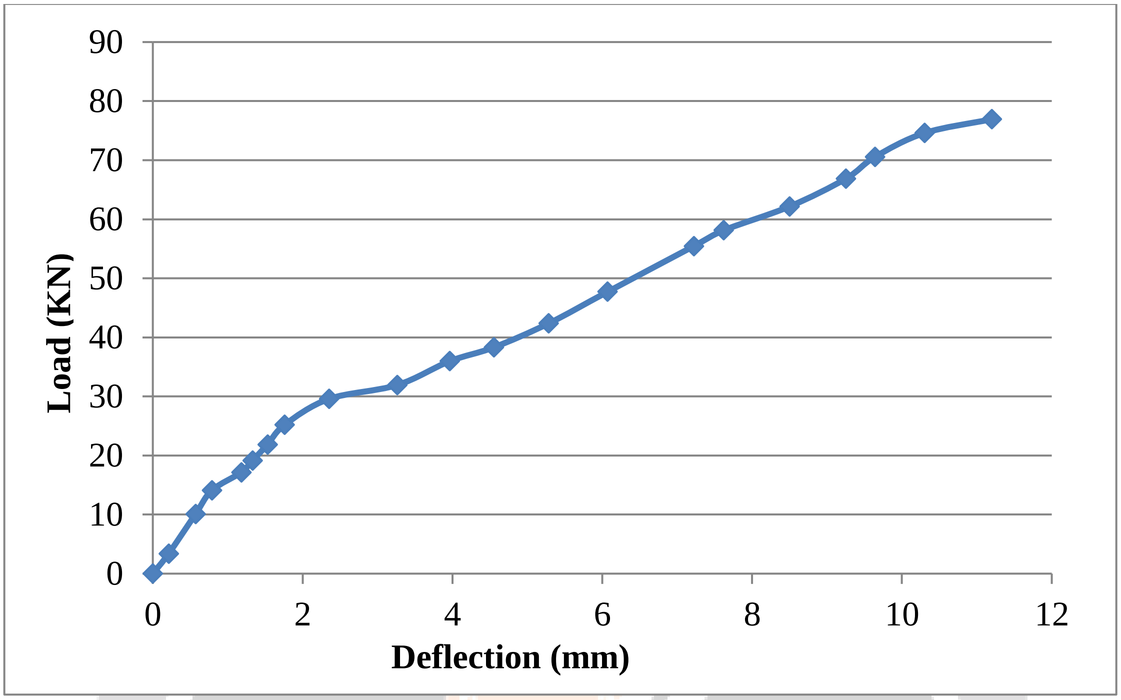

Figure 5.8 Load Vs Mid span deflection for S5 (a) beam

Figure 5.9 Failure of beam specimen S1

Figure 5.10 Failure of beam specimen S5

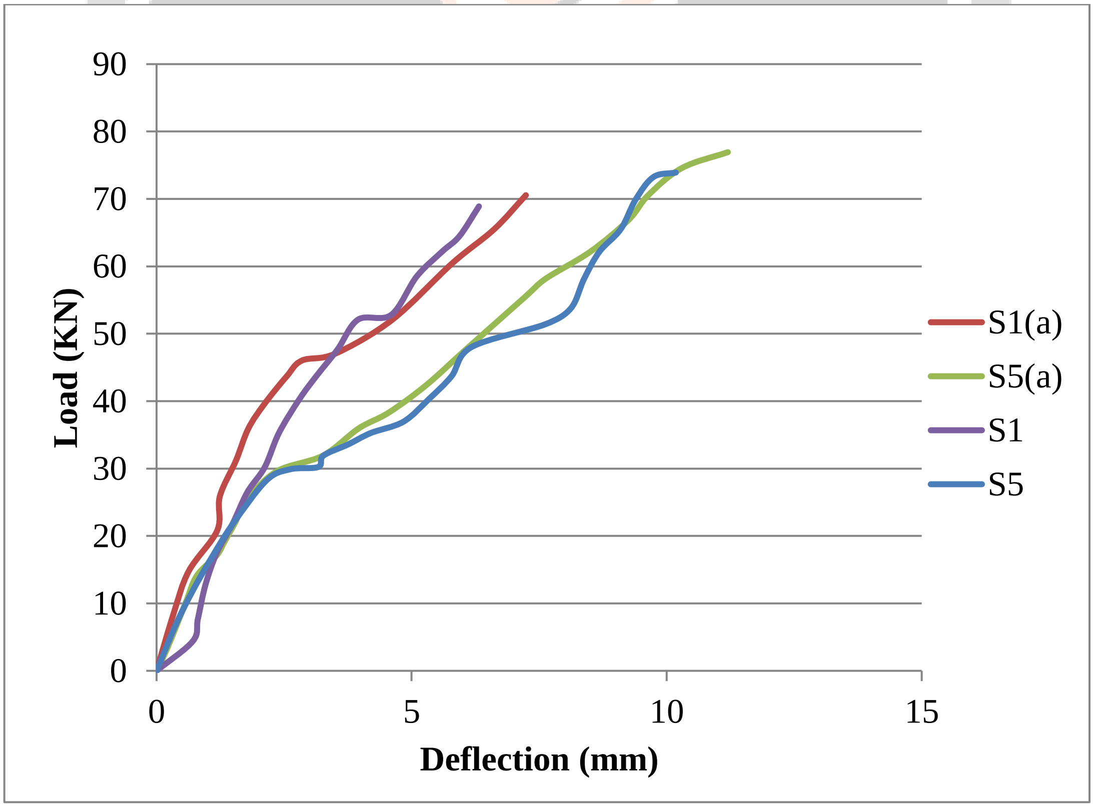

Figure 5.11 Comparison of Flexural Behaviour of beams

5.3.1 Discussion for flexural strength on rcc beam

The flexural behavior of the beams S1 and S5 are recorded and compared by the above chart. It is seen that both the specimens gave the similar behavior and the specimen S5 is found to fail at load little much higher than the conventional specimen S1. The deflection of the specimen S5 is somewhat higher compared to the specimen S1 but the failure occurs above the expected point proving that S5 has more serviceable nature.

6. Conclusion and Scope for Future Work

6.1: GENERAL

Combination of FA/slag used as partial replacement of cement at different levels produced concrete with high strength and acceptable performance of concrete.

Therefore, overall major conclusions regarding their mechanical properties extracted from the test result presented in this thesis and may be summarized as follows. However these conclusions are offered within the limitation of the test condition and procedures, as well as the limited duration of the study period. The compressive strength test, split tension test were conducted by incorporating proper design mix according to codes. The optimum replacement of the blend is found and the flexural behavior of the optimum mix is compared with the conventional concrete beams.

6.2 CONCLUSIONS

1. The compressive strength of the blended concrete is more similar to the conventional concrete. The mix with the blends will have a better option to be replaced instead of cement partially.
2. The split tension also proves to be similar to that of the conventional concrete strength such that 40% replacement will be optimum usage of the blends.
3. The deflection, crack patterns and failure modes observed for S1 beams were found to be similar to the S5 beam. The beams failed initially by yielding of the tensile steel followed by the crushing of concrete in the compression face.
4. The comparison made for the blended and conventional beam specimen showed a better performance of the blended mix by failing at a load little greater than the conventional mix.
5. Although the results obtained are more or less similar to the conventional concrete specimens the project has a positive outcome that 40% of cement can be saved by using low cost unused materials.

7. REFERENCE:

1. ACI 211.4R-93, Guide for selecting proportions for high-strength concrete with Portland cement and fly ash.
2. Anand Kumar B.G, (2012), 'Effective Utilization of Fly Ash and Supplementary Cementitious Materials in Construction *Industry' International Journal of Advanced Technology in Civil Engineering.* Volume 1, Issue-2, pp.2231 –5721.
3. Atul Dubey, Chandak R, Yadav R K,(2012), 'Effect Of Blast Furnace Slag Powder On Compressive Strength Of Concrete', *International Journal Of Scientific & Engineering Research* Volume 3, Issue 8, pp.2229-5518.
4. Deepa A Sinhan (2012), 'Comparative mechanical properties of different ternary blended concrete', *Paripex - Indian Journal Of Research* Volume : 1 Issue : 10 pp.2250-1991
5. Detlef Heinz, Tobias Gerlicher, and Liudvikas Urbonas (2013), 'Ultra-High Performance Concrete Mixes with Reduced Portland Cement Content', *Journal of Sustainable Architecture and Civil Engineering* pp.2029-9990.

6. Dordi C M , Vyasa Rao A N and Manu Santhanam (2013), 'Microfine Gound Granulated Blast Furnace Slag For High Performance Concrete' *Third international conference on sustainable construction materials and technologies.*

7. IS 456-2000, Code of practice for plain and reinforced concrete, Bureu of Indian standards, New Delhi.

8. Kamran Muzaffar Khan (2004), 'Effect Of Blending Of Portland Cement With Ground Granulated Blast Furnace Slag On The Properties Of Concrete', *29th Conference On Our World In Concrete & Structures*, pp. 25-26

9. Karim M.R., Zain M.F.M., Jamil M and Lai. F.C. (2011). 'An Experimental Study on Utilization of Slag and Fly Ash as an Alternative Cementitious Binder' *Journal of Asian Scientific Research* pp. 620-625.

10. Merin K Abraham , Elson John and Bybin Paul (2014) 'A Study On The Influence Of Mineral Admixtures In Cementitious System Containing Chemical Admixtures', *International Journal Of Engineering Research And Development* Volume 10, Issue 3 Pp.76-82.

11. Natalie Peterson Becknell And William Micah Hale (2011),'Effect Of Slag Grade And Cement Source On The Properties Of Concrete', *International Journal Of Concrete Structures And Materials* Vol.5, No.2, Pp.119~123.

12. Oner.A and S. Akyuz (2007),'An Experimental Study On Optimum Usage Of Ggbs for the Compressive Strength Of Concrete', *Cement & Concrete Composites* pp. 505–514

13. Peter J. A., Neelamegam M., Dattatreya J.K., Rajamane N.P. and Gopalakrishnan .S (1999), 'Utilisation of flyash as cement replacement Material to produce high performance concrete' *Fly Ash Utilization for Value Added Products* pp. 38-49.

14. Poon C.S., Lam L and Wong Y.L (2000), 'A study on high strength concrete prepared with large volumes of low calcium fly ash', *Cement and Concrete Research*., pp. 447-455.

15. Pratap V, Bhasker, and Teja S S R (2014) 'Triple Blending Of Cement Concrete With Fly Ash And Ground Granulated Blast Furnace Slag', Ijear, *International Journal Of Education And Applied Research.* Vol. 4

16. Sangeetha S P and Joanna P S (2014) 'Flexural Behaviour Of Reinforced Concrete Beams With Ggbs', *International journal of civil engineering and technology* Volume 5, Issue 3 pp. 124-131.

17. Shariq M. Prasad J. and Ahuja A.K. (2008), 'Strength Development Of Cement Mortar And Concrete Incorporating Ggbfs', *Asian Journal Of Civil Engineering (Building And Housing)*., Vol. 9, No. 1 pp. 61-74.

18. Soutsos, S.J. Barnett, Bungey, and Millard S G (2007), 'Fast Track Construction with High-Strength Concrete Mixes Containing Ground Granulated Blast Furnace Slag', *ACI materials journal*, pp.303-311

19. Suvarna Latha K, Seshagiri Rao M V, Srinivasa Reddy. V, (2012) 'Estimation Of Ggbs And Hvfa Strength Efficiencies In Concrete With Age', *International Journal Of Engineering And Advanced Technology (Ijeat)*, Volume-2, Issue-2, pp. 2249 – 8958.

20. Swaroop A.H.L, Venkateswararao K, and Kodandaramarao P (2013), 'Durability Studies On Concrete With Fly Ash & Ggbs' *International Journal Of Engineering Research And Applications (Ijera)*, pp. 2248-9622

21. Vidivelli B, and Jayaranjini A (2014), 'Comparative Study on High Performance Concrete with Different Admixtures', *International Journal Of Modern Engineering Research (Ijmer)*