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Experimental Investigation on Structural Members Using M-Sand Based High Performance Concrete

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ABSTRACT

In obvious, the primary goal is to consider the behaviour of flexural beam which has been created from High Performance Concrete by utilizing mineral admixtures, such as fly ash. In numerous creating nations like India broad reinforced construction works are utilized from the low cost construction materials. In this paper, M50 grade concrete with glass fiber, glenium, M sand and fly ash is utilized. The specimens are tried under compression and split tension. The results are tabulated and compared using graphs. By testing at the specimens, the ideal blend was found and decided for casting beam of length 1.5m. Absolutely 8 beams are cast for testing, 2 with control mix, 2 with M-sand, 2 with glass fibre and finally 2 with optimized mix. The beams are testing under flexure and Load deflection curve are plotted. At long last the paper demonstrates that the effectiveness of M-sand and glass fiber based concrete under flexure. The ideal substitution of blending 0.4% glass fiber and 60% of M sand accomplishes better execution of concrete beam.

Key words: Beam, glass fiber, fly ash, Ordinary Portland Cement (OPC), M sand and load deflection.

1. INTRODUCTION

High Performance Concrete can be stated as concrete which contains unique efficiency and consistency requirements. It need not always necessarily be appraised regularly using conventional materials and normal mixing, placing and curing practices [1]. Concrete has a disadvantage of failing in a brittle manner whereas fibers can make failure mode more ductile by increasing the tensile strength of concrete [2]. Fly ash, the waste product from the thermal power plants when produced in large amount poses severe environmental problems. [3]. Fiber reinforced polymer resins, as is known today, was first commenced in 1940s [4]. Reinforced concrete when subjected to high temperatures due to fire loses compressive strength of concrete and reduces its stiffness due to gradual deterioration of the hardened cement paste and the destruction of the bond between the cement paste and the aggregates [5]. Glass, an amorphous material is obtained by super cooling of molten mass produced by the combination of metallic oxides in a chemical reaction with silica [6]. The Mixing of discrete glass fibers in concrete results in the improvement of its properties when they are subjected to ambient temperatures. The resulting material which is obtained may be considered as a new composite material with improved tensile strength and cracking resistance. It is able to enhance the resistance of RC beams subjected to fire besides increasing the flexural and shear capacities of the RC beams [7]. When rock is crushed and sized in quarry generally produces coarse aggregate and road construction materials. M sand is defined is a purpose made crushed fine aggregate produced from suitable source materials. Manufactured sand is produced by variety of crushing equipments that includes cone crushers, impact crushers; roll crushers, road rollers etc. [8]. The most commonly used fine aggregate is natural river sand or quarry dust where fine and coarse aggregate constitute about 75% of total volume [9].

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Fibers are put to use in self-compacting concrete, natural or artificial lightweight aggregate concrete and expanded polystyrene concrete [10]. Due to the advantages of these materials, their combined use is supposed to yield a durable, cost-effective and sustainable construction system. With the increasing demand for the rehabilitation of existing RC structures and the construction of new infrastructure, is accompanied by the mounting fly-ash production mainly in China, India and Australia [11-13]. Concrete with steel fibers has been widely employed in the building industry for quite some time in applications like industrial and airport pavements, reinforcement of projected concrete, and precast elements with reduced thickness, among many others [14]. Their use is based on extensive studies of the mechanical behavior of this particular type of concrete under tensile stresses, fatigue or even impact [15, 16]. It remarkably shows the linear behavior between the moment and the deflection, until a load stage of approximately 85-90% is achieved from the value of the ultimate bending moment [17].The material characteristics being were very much dependent on the production procedures, the experimental tests had to consider cementations matrix with different plain mortar productions. They had several types of glass fibers reinforced with carbon or glass strands or with steel elements [18].

2. RECENT RESEARCH WORKS: A BRIEF REVIEW

In 2016 Shasha Wang *et al.* [19] had proposed the experimental and numerical studies on the performance of seven high-performance fiber-reinforced cement-based composites against high velocity projectile impact (HVPI). The materials had been investigated and involved four fiber reinforced high-strength concretes (FRHSCs) with 28-day compressive strengths ranging from about 60 to 140 MPa, two strain hardening cement-based composites (SHCCs), and a fiber-reinforced high-strength mortar (FRHSM). The result explained about the higher compressive strength and greater toughness of cement-based composites, as well as the presence of strong coarse aggregate and fibers, contribute positively to the impact resistance of composites. In addition, it had been found that the penetration depth of the composites subjected to HVPI were reduced with an increase in the elastic modulus, as well as with the "effective hardness index" calculated based on the hardness and proportion of the coarse aggregate and mortar matrix.

In 2016 Kenneth Awinda *et al.* [20] had proposed the Geometrical size effect on the flexural strength of the ultra high performance fiber reinforced concrete had been investigated by experimental test data and numerical simulation. Comparison of the simulation results to existing about an experimental test results indicated that the Cohesive Crack Model (CCM) with a bilinear traction separation curve can provide predictions of both the load–deflection curves and peak load of 100 and 150 mm deep UHPFRC test specimens to 6% with a little size effect observed on the flexural strength. However, for the 50 mm deep beams a difference of 25% had been observed between model predictions of the peak load and experiment test data possibly due to a surface layer size effect.

In 2016 Mahdi Rafieizonooz *et al.* [21] had proposed the Concrete specimens were prepared incorporating 0, 20, 50, 75 and 100% of bottom ash replacing sand and 20% of coal fly ash by mass, as a substitute for Ordinary Portland cement. Fresh and hardened state properties of the experimental specimens were determined. Results showed that concrete workability reduced when bottom ash content increased replacing sand. On the other hand, at the early age of 28 d, no significant effect had been observed in compressive, flexural and tensile strengths of all concrete samples. After curing at 91 and 180 d ages, compressive strength of both the experimental and control concrete samples increased significantly but remained almost similar. However, flexural and splitting tensile strengths of the experimental mix containing 75% bottom ash and 20% fly ash exceeded much more than the control sample.

In 2015 Sung-Won Yoo *et al.* [22] have proposed the High-volume fly ash (HVFA) concrete representation as a promising solution for the construction industry .This helped to deal with the issues related to the global emissions of greenhouse gases. Though numerous studies were dedicated on the material properties of HVFA concrete, it is necessary to study the flexural behavior and performance of structures using HVFA concrete in order to promote further field applications. Therefore, in this study, the results of a series of tests conducted on reinforced concrete beam specimens with various fly ash replacement ratios of 0%, 35% and 50%, various tensile steel ratios and concrete compressive strengths to evaluate their flexural behavior is presented. Based upon the experimental results, an analysis model was proposed which helped to predict the behavior of the reinforced concrete beams. By the comparison with the test data the analytic results that predict accurately the behavior of the beams for all the considered replacement ratios in fly ash is verified.

In 2015 Mahdi Arezoumandi *et al*. [23] have proposed the three mixes with 0% (conventional concrete), 50%, and 70% replacement of Portland cement. This was on the basis of a Class C fly ash investigated in the study. Three beams (simply supported four-point loading condition) as well as three pull-out specimens (based on RILEM recommendations) were tested for each mix. On the basis of the evaluation of the test results based on different codes as well as a bond database of conventional concrete specimens, the comparisons indicate that with increasing replacement level of fly ash in concrete the bond strength of reinforcing steel in concrete increases.

In 2013 Carmine Lima *et al.* [24] had proposed the result of the wide experimental campaign carried out on concretes made using recycled concrete aggregates (RCAs) and fly-ash (FA) in partial substitution of natural aggregates (NAs) and cement (C) are presented and discussed herein. Particularly, concretes characterized by variable water-binder ratios and produced with different percentages of RCA and variable the content of FA has been tested. Test results have allowed estimating the time evolution of the compressive strength, as well as the tensile strength at 28 days, along with some relevant physical properties, such as permeability and resistance to chloride ion penetration. The feasibility of producing structural concrete made with even significant amounts of the aforementioned recycled constituents and industrial by-products clearly emerges from the experimental results.

The remainder of this paper is organized as follows. Section 3 provides theoretical analysis and the experimental works and procedures, section 4 provides result and discussion finally the section 5 illustrates the conclusion.

3. THEORETICAL ANALYSIS

The aspiration of the work is the assessment of the compressive stress (CS), split tensile stress (STS) and deflection (D) of the High Strength Concrete (HSC) beams. Here concrete mix Ordinary Portland cement (OPC) is supplanted by fly ash, fine aggregate is supplanted by manufactured sand (M sand) of 0 to 100% and coarse aggregate, glass fiber (G-Fiber) with weight extending from 0% to 0.8% added to make M50 grade concrete. To build the workability of the concrete glenium materials included concrete mix, the exploratory investigation process utilizes just low cost material. With weight variation in mixing materials solidified in concrete and cube specimens casted for testing at 7 and 28 days. In the result area flexure beam is designed by using the optimum mix and the load vs deflection curve is plotted.

Objective

- To find the optimum mix by conducting compressive and split tensile test in concrete with replacement of cement by flyash as 10%, replacement of river sand by M-sand as 0%, 20%, 40%, 60%, 80% & 100% and addition of glass fibre as 0%, 0.2%, 0.4%, 0.6% & 0.8%.
- To find the flexural behaviour of reinforced concrete beams made of 8 optimized mixes.

3.1. Materials and properties

This reinforced concrete mixing proportion is 1:1.24:1.89. Different materials such as OPC 53 grade, fly ash, M sand, glass fiber, water and glenium are utilized to prepare the concrete.

3.1.1. Ordinary Portland cement (53 grade)

OPC is a binder, a substance used in construction that sets and hardens and can bind other materials together. Portland cement is the basic ingredient of concrete, mortar and most non specialty grout. If the 28 days strength of cement is not less than 53 N/mm^2, it is called 53 grade cement. Specific gravity of the cement is 3.15, initial and final setting times of the cement are 50 minutes and 450 minutes respectively.

3.1.2. Manufactured sand (M Sand)

Manufactured sand is the sand produced from crushing of granite stones in required grading to be used for constuction purpose as a replacement of river sand. The size of manufactured sand is less than 4.75 mm. specific gravity, fineness modulus and water absorption of M-sand is 2.84, 2.75 & 5.6%. M-sand helps the concrete structures withstand extreme environmental conditions and prevents the corrosion of reinforcement steel by reducing permeability, moisture ingress, freeze-thaw effect increasing the durability of concrete structures.

3.1.3. Fly ash

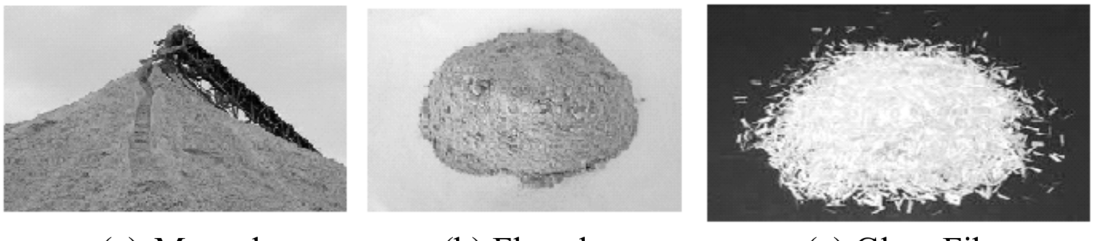
Fly ash is a byproduct from burning pulverized coal in electric power generating plants. Fly ash is also known as "pulverized fuel ash". The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Class C fly ash generally contains more than 20% lime (CaO). The chemical composition is mainly composed of the oxides of silicon (SiO_2) – 52%, aluminium(Al_2O_3)-33.9% ,iron (Fe_2O_3) - 4%, and calcium(CaO) - 1.2%, whereas Mg, K, Na, Ti & S are also present in a lesser amount. Fineness of flyash depends on the operating conditions of coal crushers and the grinding process of the coal itself. It helps to improve workability of fresh concrete. Fly ash was gathered from Thoothukudi Thermal Power Plant, Tamil Nadu, and India. The specific gravity of the fly ash comes to 2.18.

3.1.4. Glass fibers

Glass fiber is a material that comprises of numerous extremely fine filaments of glass as shown in figure 1(c).Glass fiber is generally utilized as a protecting material and is likewise utilized as a reinforcing agent for some polymer items. This structures an extremely solid and light fiber- reinforced polymer (FRP) composite material called glass- reinforced plastic (GRP), prevalently known as "fiberglass". Glass fiber has certain practically identical properties to different filaments, such as polymers and carbon fiber.

3.1.5. Glenium

Glenium 7500 high-extend water-diminishing admixture depends on the up and coming era of polycarboxylate innovation found in the majority of the Glenium 7000 arrangement items. GLENIUM 7500 admixture goes about as a successful operator in producing concrete mixtures with various levels of workability including applications that require self-consolidatingconcrete (SCC).



(a) M sand (b) Fly ash (c) Glass Fiber

Figure 1: Materials

3.1.6. Fine aggregate

According to the Indian Standards fine aggregate is a type of silica (SiO_2) having a molecular size less than 4.75mm. The minimum molecular size of fine aggregate is 0.075mm and is shaped by disintegrations of sand stones because of different weathering activities. Fine aggregate prevents shrinkage of the mortar and cement. The specific gravity and fineness modulus of fine aggregate were found to be 2.67 and 2.3.

3.1.7. Coarse Aggregate

Coarse aggregate comprises most part of natural occurring materials, for example, rock, or that which results from the damaged guardian rock, to incorporate common rock, slags, extended dirts and shales (lightweight totals) and other endorsed idle materials having comparable attributes, that are hard, solid, strong particles, adjusting to the particular prerequisites of this Section. According to the Indian Standards, crushed angular aggregate when passed through 20 mm IS sieve entirely retains on 10 mm IS sieve. The specific gravity and fineness modulus of coarse aggregate was 2.60 and 5.95.

Table 1
Mix proportion Details

Materials	*Proportion*
Cement	550 kg /m^3
(w/c)	0.32
Fly ash	10 % by weight of cement
M sand	0 %, 20%, 40%, 60%, 80%, 100% by weight of sand
Glass fiber	0%, 0.2%, 0.4%, 0.6%, 0.8% by weight of cement
Glenium	0.4% by weight of cement
Fine aggregate	684 kg /m^3
Coarse aggregate	1042 kg /m^3

Table 2
Mix proportion

Sl.No	*Concrete mixture quantity (kg/m^3)*						
	OPC	*Flyash*	*FA*	*CA (20mm)*	*CA (12.5mm)*	*M-sand*	*Fiber*
1	495	55	684	625	417	0	0
2	495	55	684	625	417	0	1.1
3	495	55	684	625	417	0	2.2
4	495	55	684	625	417	0	3.3
5	495	55	684	625	417	0	4.4
6	495	55	547.2	625	417	136.8	0
7	495	55	574.2	625	417	136.8	1.1
8	495	55	547.2	625	417	136.8	2.2
9	495	55	547.2	625	417	136.8	3.3
10	495	55	547.2	625	417	136.8	4.4
11	495	55	410.4	625	417	273.6	0
12	495	55	410.4	625	417	273.6	1.1
13	495	55	410.4	625	417	273.6	2.2
14	495	55	410.4	625	417	273.6	3.3

contd. table 2

Sl.No	Concrete mixture quantity (kg/m^3)						
	OPC	Flyash	FA	CA (20mm)	CA (12.5mm)	M-sand	Fiber
15	495	55	410.4	625	417	273.6	4.4
16	495	55	273.6	625	417	410.4	0
17	495	55	273.6	625	417	410.4	1.1
18	495	55	273.6	625	417	410.4	2.2
19	495	55	273.6	625	417	410.4	3.3
20	495	55	273.6	625	417	410.4	4.4
21	495	55	136.8	625	417	547.2	0
22	495	55	136.8	625	417	547.2	1.1
23	495	55	136.8	625	417	547.2	2.2
24	495	55	136.8	625	417	547.2	3.3
25	495	55	136.8	625	417	547.2	4.4
26	495	55	0	625	417	684	0
27	495	55	0	625	417	684	1.1
28	495	55	0	625	417	684	2.2
29	495	55	0	625	417	684	3.3
30	495	55	0	625	417	684	4.4

Table 1 shows mix proportion details and table 2 shows that the 30 mixes for several materials namely OPC, fly ash, fine aggregate, coarse aggregate, super plasticizer, M sand and fiber.

3.2. Experimental Works and Procedures

3.2.1. Compressive Strength Test

Each cubes of size 150mm x 150mm x 150mm was tried in immersion condition, subsequent to wiping out the surface dampness. For every blend mix, three cubes were tried at 7 days and 28 days using compression testing machine of 2000 kN limit according to IS:516-1959. The results are tabulated at the results and discussion section below.

Figure 2: Compression Testing

3.2.2. Split Tensile Strength

Split tensile strength test was done at 7 and 28 days for the concrete cylinder specimens of size 100 mm diameter and 200 mm height, using compression testing machine of 2000 kN limit according to IS:5816-1970. Three specimens are cast for each mix. The results are tabulated and the graphs are plotted.

3.3. Design of Flexure beam model

Table 3
Flexure beam design

Grade of Concrete	M50
Grade of steel	Fe 415
Length of Beam	1.50m
Effective span Length	1.40m
Breadth of beam	150mm
Depth of Beam	200mm
Loading Method	Two Point Load (Equal Distance (L/3))
End Condition	Simply Supported Beam

The length of the reinforced concrete beam was 1.5m and the cross sectional area was 150 mm x 200 mm. The effective length of the beam is 1.4m. Cover depth provided as 25mm. All beams were singly reinforced with two 12 mm dia steel bars as longitudinal tensile reinforcement at the bottom of the specimen and the effective depth of 170mm. Two straight 10mm dia bars at the top were used for fixing stirrups. The Reinforcement details of the beam are given below.

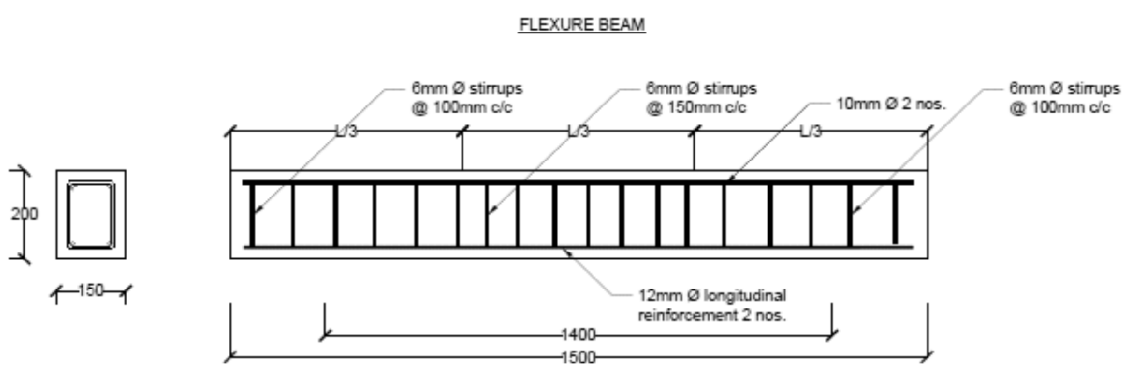


Figure 3: Reinforcement detailing of Flexure Beam

The specimens were also designed to resist shear stresses at the yield of the tensile reinforcement to obtain pure flexure failure at the centre of the beam. For this purpose, 6mm dia stirrups of 100mm c/c were used from the supports to one third of the span for each side. This beam designed with breadth and depth as 150mm and 200 mm for two point load condition with simply supported beam as ending condition.

4. RESULT AND DISCUSSION

This section was talks about the compressive strength and split tensile strength of hardened concrete and the deflection in reinforced concrete beams in 7 and 28 days of testing. Hardened concrete test results of 30 mix proportions is used to analyze the stress in a specific rate of including fly ash and glass fiber (G-Fiber) to get optimal strength value. At that point the load Vs deflections are assessed in 7 and 28 days with various specimens.

4.1. Stress Analysis in Hardened Concrete

The compressive stress and split tensile stress analysis for 7 and 28 days have been shown in graphs below.

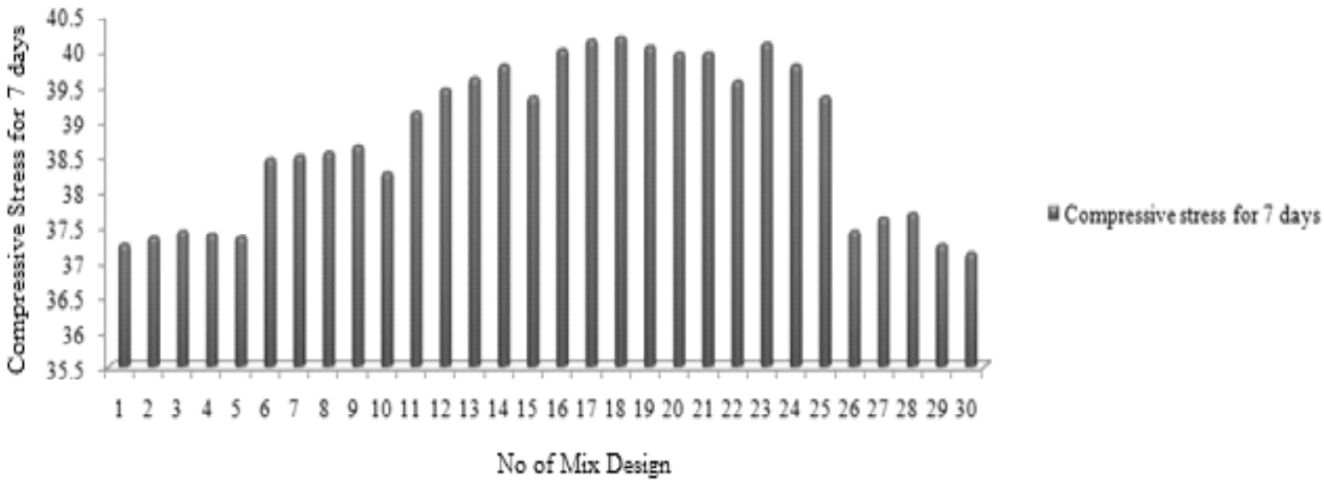


Figure 4: Compressive stress results for 7 days

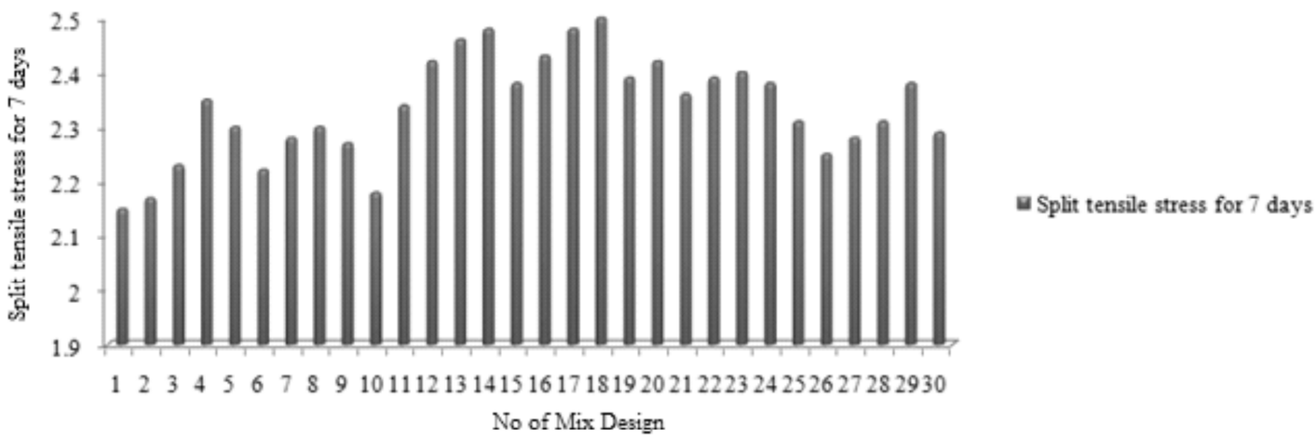


Figure 5: Split tensile stress results for 7 days

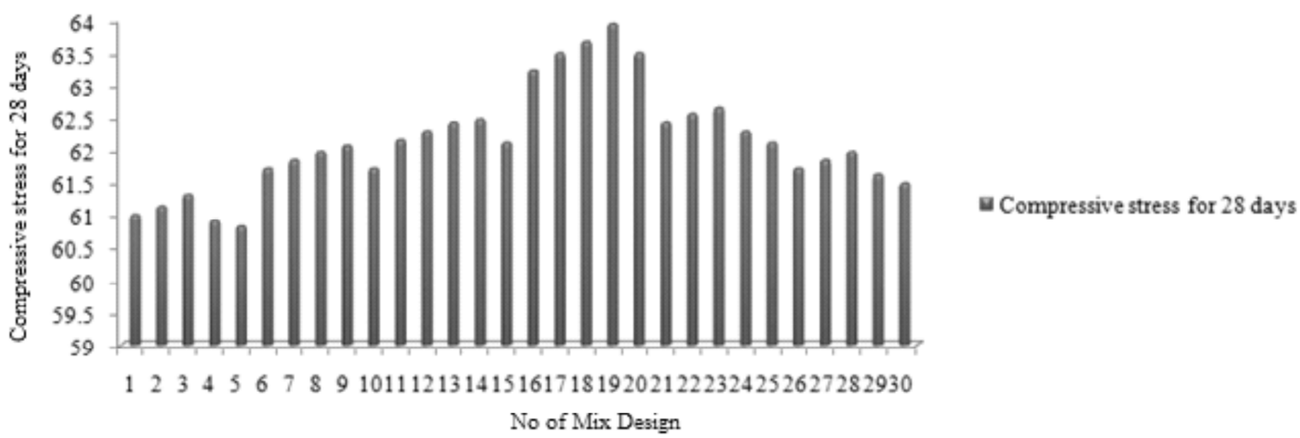


Figure 6: Compressive stress results for 28 days

From the above graphs, it was found that maximum strength was obtained at mix 18 which was blended with 60% M-sand and 0.4% glass fiber.

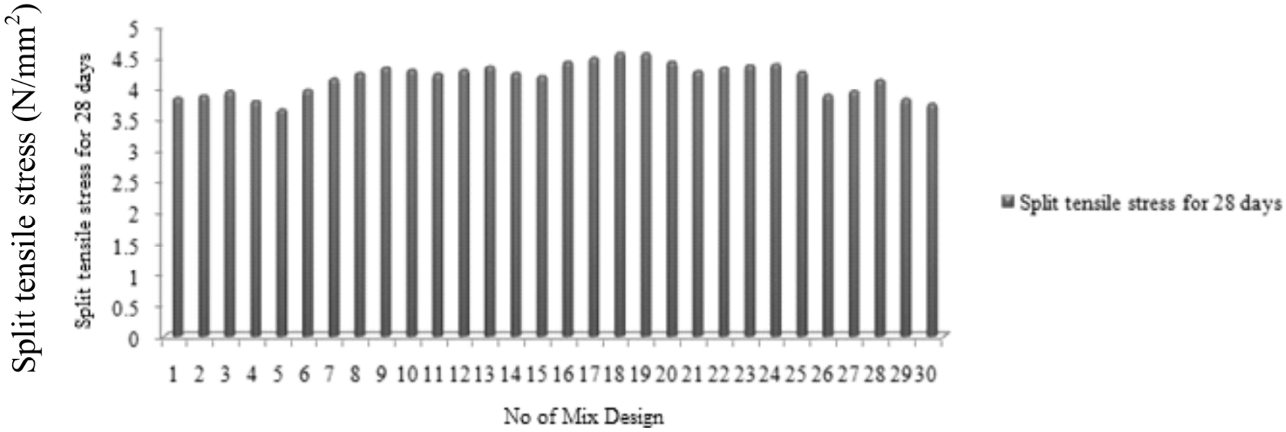


Figure 7: Split tensile stress results for 28 days

4.2. Testing and Results of Reinforced Concrete Beams

Totally eight beams were casted. Among the 8 beams, two with control mix, two with M-sand, two with glass fiber and two with optimum mix.

Figure 8: Flexure beam test setup

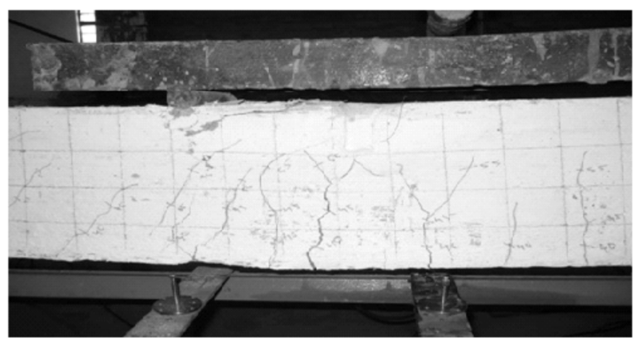


Figure 9: Crack pattern

The crack patterns and flexure beam test setup has been shown in figure 8 and 9. The flexural test results are tabulated in Table 4.

Table 4
Flexural Test Results for Beam Specimen

Specimen details	*% of M-Sand*	*% of glass fiber*	*First crack load (KN)*	*Ultimate load (KN)*	*Deflection at ultimate load (mm)*
S1	0	0	62	80	25
S2	0	0	68	85	19
S3	60	0.4	76	91	23
S4	60	0.4	71	89	21
S5	0	0.4	68	85	22
S6	0	0.4	70	86	21
S7	60	0	72	88	18
S8	60	0	70	87	25

4.3. Load vs Deflection (P-Δ) Curves

Load versus Deflection curves for the beam specimens tested for Flexure are Shown in figures 10 and 11.

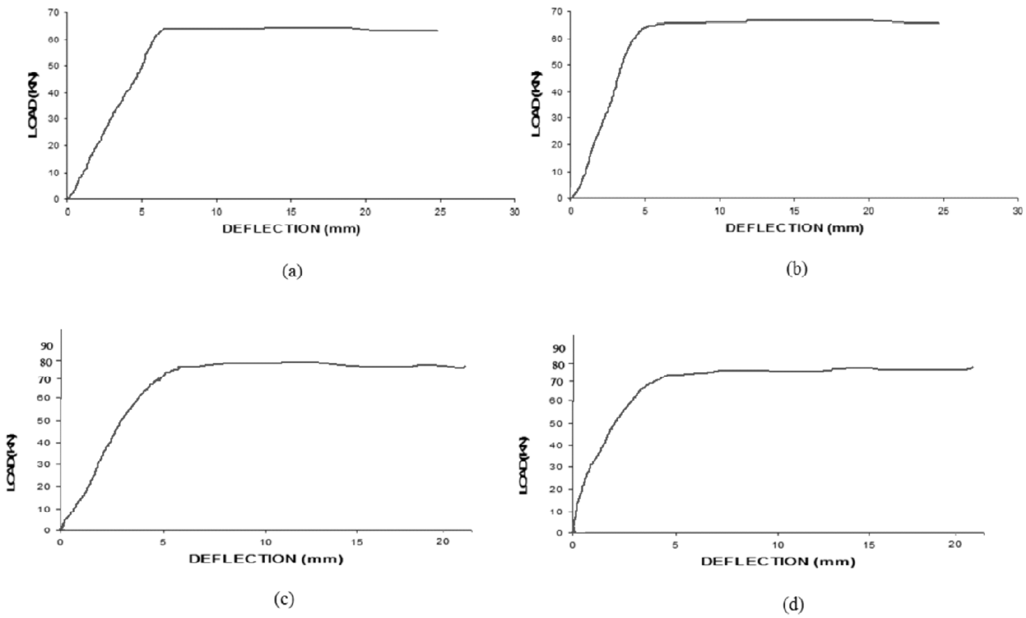


Figure 10: P-Δ Curve for (a) S1, (b) S2, (c) S3 and (d) S4

In the above figure load vs deflection of S1, S2, S3 and S4 is shown. In S1 the load varies 0 to 70 and deflection varies 0 to 30, the curve drawn for load 62 KN and deflection 25mm. In S2 the load ranges from 0 to 70 and deflection ranges from 0 to 30 then the curve strained for load 68 KN and deflection 19mm. In S3 the load differ from 0 to 90 and deflection differ from 0 to 20 then the curve strained for load 76 KN and deflection 23mm. Finally in S4 the load change from 0 to 90 and deflection change from 0 to 20 then the curve had drawn for load 71 KN and deflection 21mm.

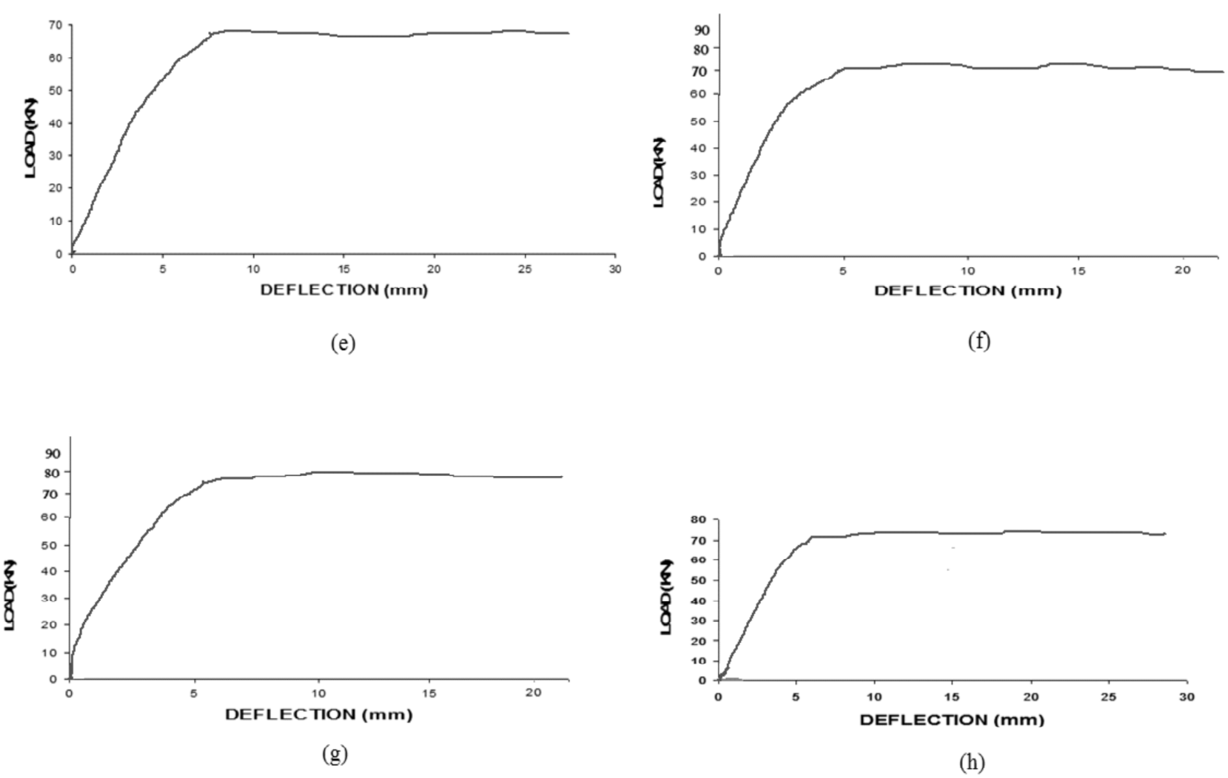


Figure 11: P-Δ Curve for (e) S5, (f) S6, (g) S7 and (h) S8

Above figure shown that the load versus deflection of S5, S6, S7 and S8. In S5 the load varies from 0 to 70 and deflection varies from 0 to 30, the curve drawn for load 68 KN and deflection 22mm. In S6 the load differ from 0 to 90 and deflection differ from 0 to 20 then the curve strained for load 70 KN and deflection 21mm. In S7 the load differ 0 to 90 and deflection differ 0 to 20 then the curve strained for load 72 KN and deflection 18mm. Finally in S8 the load change 0 to 80 and deflection change 0 to 30 then the curve had drawn for load 70 KN and deflection 25mm. From the flexural test S3 and S4 is better than other specimens.

5. CONCLUSION

In this segment the behaviour of flexural beam is developed by high performance concrete. The compressive strength of concrete is high, when the substitution of M-sand as 60% and addition of glass fiber as 0.4%. The cylindrical specimens got ideal strength when blended with 10% Fly ash and 60% M-sand. The primary point of the addition of fly ash was for economy and for enhancing the strength of hardened concrete. The RCC Flexural beams behaved on well under flexural loading and Load-deflection curves are plotted. The specimens got good strength when compared to designed loads. The specimens S3 and S4 are performed better when compared with other flexural beam specimens. The crack pattern and deflection are observed and given by tables and diagrams.

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