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Experimental Study on Structural behaviour of reinforced concrete beams containing Sisal fibre and GGBS

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Abstract

The use of fibre reinforcement concrete provides the ductility and toughness required for higher strength. The single type of fibre with reinforcement in concrete improves the mechanical properties at certain level. This paper presents experimental work to investigate the strength and cracking characteristics of reinforced concrete beam with sisal fiber and partial replacement of cement by Ground Granulated Blast Furnace Slag (GGBS).It is an economical replacement of Ordinary Portland Cement (OPC) used in concrete, and it improves fresh and hardened properties of concrete. Sisal fiber is an agricultural product. It is used to increase the strength of concrete as a result of ability to arrest cracks and the fibers hold the matrix together even after extensive cracking. The cement in concrete replaced accordingly with the percentage of 2.5%, 5%, 7.5% and 10% by weight of GGBS and the sisal fiber added in various percentages such as 0.5% and 1% by weight of cement in M20 grade concrete. For the experimental work twelve beams each size of 1000x150x200 mm were casted and tested at 28 days. Beam were tested in flexure under two equal concentrated loads each applied at the one-third point of the beam with the help of hydraulic jack. Finally, the test results of slag and fibre blended reinforced concrete beams are compared with the conventional concrete beam. The results showed that the inclusion of Sisal fibre could improve the reduction in the shear capacity. In addition, combining GGBS and Sisal fibre contributed to developing sustainable concrete beams with high deformability, reduced self-weight and improved shear capacity, even it shows remarkable changes in flexural strength as compared with conventional concrete beam.

Keywords: Ground Granulated Blast Furnace Slag, sisal fiber, flexural strength, structural behavior.

1. Introduction

Concrete's versatility, durability, sustainability, and economy have made it the world's most widely used construction material since in early of 20th century. About four tons of concrete are produced per person per year worldwide. The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is normally made up of Portland cement and water and may contain supplementary cementing materials, such as fly ash or slag cement, and chemical admixtures. By utilizing the natural products and wastes is very much helpful to the environmental production. Sisal fiber (SF) is the natural fiber extracted from the tree leaves (Agave sisal ana tree), it is possible to use directly to concrete are in its chopped form. Cement replacement materials are special types of naturally occurring materials or industrial waste products that can be used in concrete mixes to partially replace some of the Portland cement. GGBS used as a direct replacement for Portland cement, on a one to one basis by weight. A replacement level for GGBS varies from 2.5 to 10%.

Flexural strength of beams retrofitted using cement matrix composite and conventional epoxy binder are compared. The matrix is made using cement, fly ash, admixtures and fibers. For this study, ten beams of cross section 100×135 mm and overall length of 1m are casted. Two of the beams served as control beams. The other eight beams are strengthened using EB technique. Group 1 having 2 beams strengthened with glass fibers and other 2 beams with sisal fibers using cement matrix composite. Group 2, having 2 beams strengthened with glass fibers and 2 beams with sisal fibers using sikadur lp 32 epoxy binder. Both the fibers are applied in the flexure zone in both above describe groups. Results are compared between retrofitted beams using cement matrix composite and conventional artificial binder which shows cement matrix composite is an effective alternate of the epoxy binder.(Abhishek Sharma at al)

Sisal is being used in concrete. Thereby, the mechanical properties such as compressive strength, split-tensile strength, and modulus of rupture of M40 grade concrete and by varying the dosage of fiber content from 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%, by volume of cement with optimum length of 35mm obtained from literature review, were found. The optimum dosage of sisal fiber was found to be 0.3%. The flexural behavior of reinforced concrete beams with 0.3% sisal fiber was compared with conventional concrete properties of M40 grade. The optimum percentage of sisal fiber for maximum strengths (compressive and split tensile) was found to be 0.3% for M40 grade of concrete. Modulus of rupture decreases with increase in percentage of sisal fiber. (Athiappan. K, 2014, at al)

The cement in concrete is replaced accordingly with the percentage of 10 %, 20% and 30% by weight of slag and 1% of sisal fiber is added by weight of cement. Concrete cubes are tested at the age of 7, 14, and 28 days of curing. Finally, the strength performance of slag blended fiber reinforced concrete is compared with the performance of conventional concrete. From the experimental investigations, it has been observed that, the optimum replacement of Ground Granulated Blast Furnace Slag Powder to cement is 20 % for M30 grade. The cement in concrete is replaced accordingly with the percentage of 10 %, 20% and 30% by weight of slag and 1% of sisal fiber is added by weight of cement. Concrete cubes are tested at the age of 7, 14, and 28 days of curing. Finally, the strength performance of slag blended fiber reinforced concrete is compared with the performance of conventional concrete. From the experimental investigations, it has been observed that, the optimum replacement of Ground Granulated Blast Furnace Slag Powder to cement is 20 % for M30 grade. (P. Sathish, 2015, at al)

Experimental investigation included testing of eight reinforced concrete beams with and without GGBS. Portland cement was replaced with 40% GGBS and Glenium B-233 was used as superplastisizer for the casting of beams. The results of laboratory investigation on the structural behavior of reinforced concrete beams with GGBS are presented. Data presented include the load-deflection characteristics, cracking behavior, strain characteristics and moment- curvature of the reinforced concrete beams with and without GGBS when tested at 28 days and 56 days. The investigation revealed that the flexural behavior of reinforced GGBS concrete beams is comparable to that of reinforced concrete beams. The ultimate moment capacity of GGBS was less than the controlled beam when tested at 28 days, but it increases by 21% at 56 days. (S.P.Sangeetha 2014, at al)

2. Materials Used

2.1. Cement

The Cement used in this experimental work is Birla Super 53 grade ordinary Portland cement. All properties of OPC were evaluated referring IS: 12269:1987. The cement utilized for casting was fresh and as per standards. The properties of the material are presented in Table 1.

Table 1: Test result on cement

Property	Observed value
Fineness %	3%
Initial setting time	40 min
Final setting time	240min
Specific Gravity	3.10

2.2. Fine Aggregate

Now a day's natural sand is not freely available for the construction purpose due to the scarcity of natural sand, M-Sand is used as a substitute for natural sand. Good quality of M-sand as per the IS 383-1970 code conforming to ZONE I and passing through 4.75 mm sieve was used. The properties of the material are presented in Table 2.

Table 2: Test result on Fine aggregates

Properties	Results
Specific gravity	2.56
Fineness modulus	4.66
Moisture content	1.40
Water absorption	16%
Bulking sand	4%

2.3. Coarse Aggregate

Machine crushed angular granite stone of 20 mm nominal size from the local source was used as Coarse aggregate. It was free from impurities such as dust, clay particles and organic matter etc. The physical properties of coarse aggregate were investigated in accordance with IS 2386 -1963. The properties of the materials are presented in Table 3.

Table 3: Test result on Coarse aggregates

Properties	**Results**
Specific gravity	2.68
Water absorption	0.67
Crushing strength	30%
Impact value	25%

2.4. Sisal Fiber

Sisal fiber is a species of Agava. It is botanically known as Agave sisalana. The material is chosen to improve the various strength properties of the structure to obtain sustainability and better quality structure. Short discrete vegetable fiber (sisal) was examined for its suitability for incorporation in cement concrete. The physical property of this fiber has shown no deterioration in a concrete medium. Leaves are dried, brushed and baled to form fiber.

Fig:1 Sisal fibre

2.5. Ground Granulated Blast Furnace Slag (GGBS)

GGBS is a waste product in the manufacture of iron by blast furnace method. The molten slag is lighter and floats on the top of the molten iron. The process of granulating the slag involves cooling the molten slag through high-pressure water jets. This rapid cooling of slag results in formation of granular particles generally not larger than 5 mm in diameter. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching, optimizes the cementitious properties and produces granules similar to a coarse sand. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS (ground granulated blast furnace slag). Grinding of the granulated slag is carried out in a rotating ball mill.

3. METHODOLOGY

The aim of the study was to determine the behavior of sisal fiber in reinforced concrete beam with partial replacement of cement by GGBS. The concrete mix design was proposed using Indian Standard for control concrete. Concrete mix design is a process by which the proportions of the various raw materials of concrete are determined with an aim to achieve a certain strength and durability, as economically as possible. Based on the simplified mix design procedure, a concrete mix of proportions with characteristic target mean compressive strength of 20 Mpa was designed. The concrete mix was designed as per IS 10262:2009 for M20grade of concrete.

3.1. Specimen Preparation

To investigate the effect of using GGBS (Ground Granulated Blast Furnace Slag) with sisal fiber in concrete twelve specimens of Rectangular reinforced concrete beams were casted. There are two specimens are conventional beams and another beam are added with sisal fiber and GGBS in reinforced concrete beams. The details of mix proportions are given in table 4.

Table 4: Mix proportions of concrete

Mix	GGBS%	Sisal fibre %
CC	0	0
GS1	2.5	0.5
GS2	5	0.5
GS3	7.5	0.5
GS4	10	0.5
GS5	2.5	1
GS6	5	1

3.2. Experimental set-up

The tests were carried out in a loading frame of 40T capacity. All the specimens were white washed in order to assist marking of cracks. Strain gauges of 20 mm were fixed under the reinforcement beam to measure the deflections at several locations and one at mid span, one directly below the loading points and two near the end supports as shown in Figure 2.Strain gauges readings were captured for every load interval until failure of the beam occurred. The beams were subjected to two-point loads under a load control mode. The developments of cracks were observed and the crack widths were measured using a hand-held microscope with an optical magnification of X50 and a sensitivity of 0.02 mm. As the application of load increases, the deflection value also increases. Cracks starts to appear in the beam as a result of application of load as showed in fig 3.

Fig 2: Strain gauge set up

Fig 3: Crack pattern of the beam

4. Result and Discussion

Vertical flexural cracks were observed in the constant-moment region and final failure occurred due to crushing of the compression concrete with significant amount of ultimate deflection. Crack formations were marked on the beam at every load interval at the tension steel level. It was noticed that the first crack always appears close to the mid span of the beam. The crack widths at service loads for GGBS concrete beams ranged between 0.16mm to 0.2mm

4.1. Load-deflection curves

Load-deflection Behaviour The experimental load-deflection behaviour of sisal fibre and GGBS based RC beams are presented in Fig. 4(a)-(g). It can be observed that in cases of all beams the slopes of the load-deflection of beams are fairly linear before the first flexural crack is formed. The gradient of the load- deflection curve of maximum number of beams are similar which may be reasoned that, it depends on the flexural strength of beams which are made with the same mix proportion.

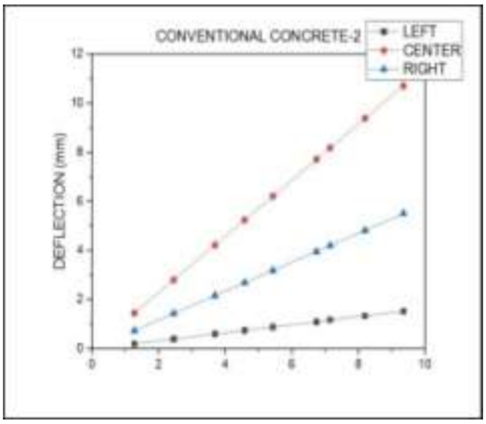

Fig 4(a): Conventional beam

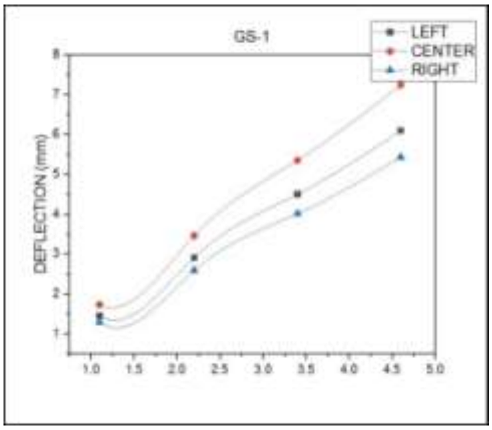

Fig 4(b): GS-1

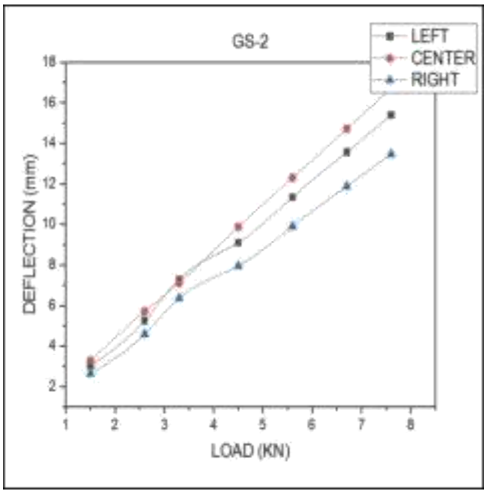

Fig 4(c): GS-2

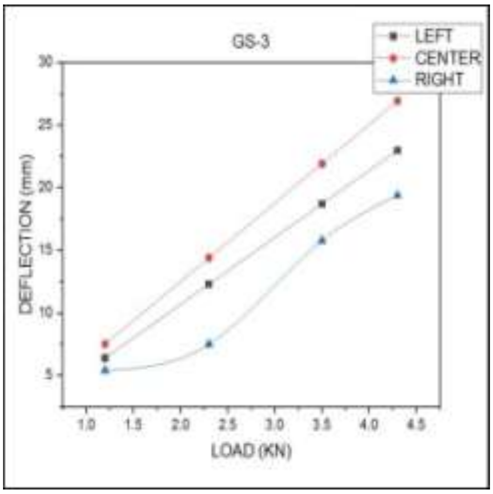

Fig 4(d): GS-3

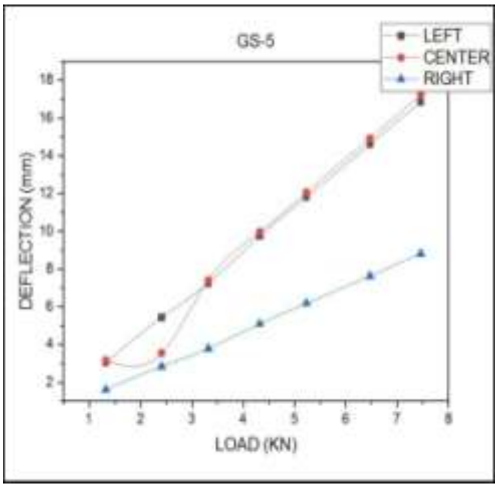

Fig 4(e): GS-4

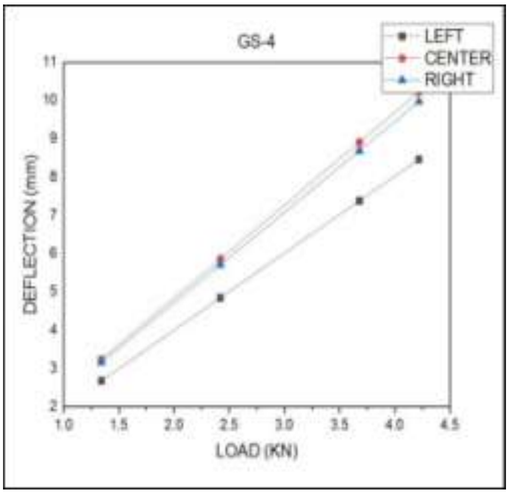

Fig 4(f): GS-5

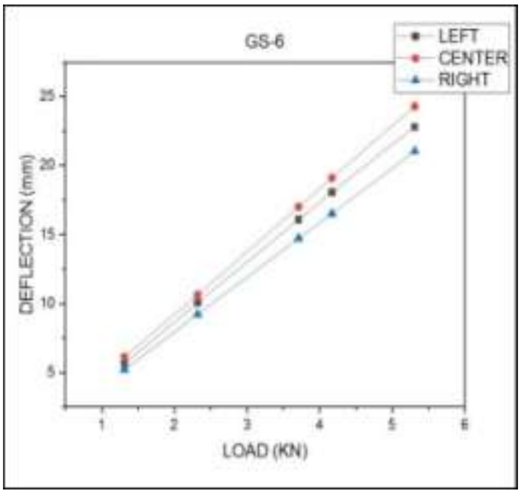

Fig 4(g): GS-6

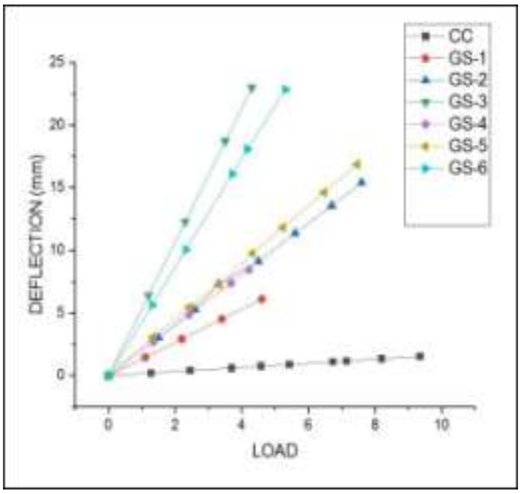

Fig 4(h): Deflection at left side

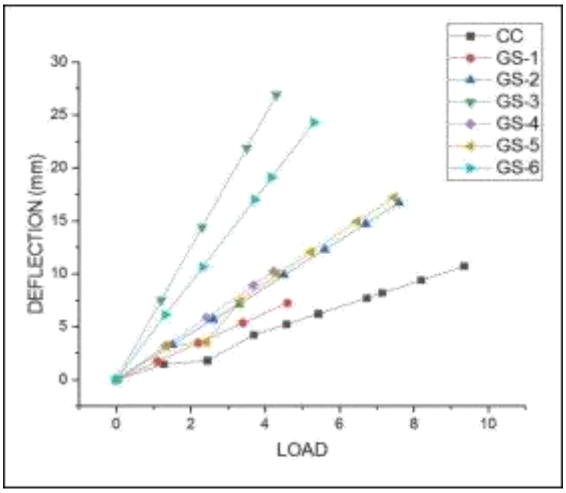

Fig 4(i): Deflection at mid span

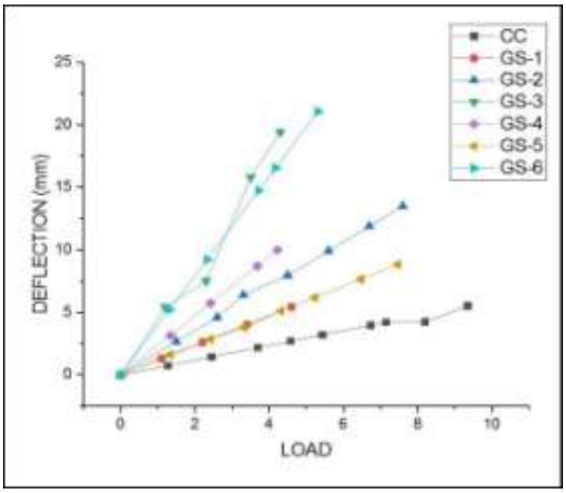

Fig 4(j): Deflection at right side

4.2. *Flexural Behaviour of RCC Beams*

The beam specimens show remarkable increases in the flexural strength with addition of controlled mixing of Sisal fibre and GGBS. Adding 5% of GGBS and 0.5% of sisal fibre shows maximum flexural strength compared with other mix samples.

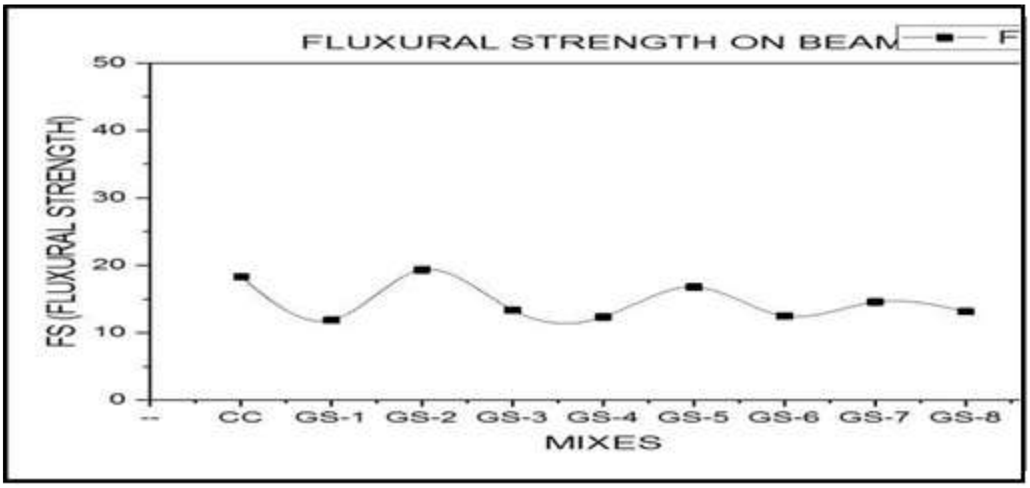

Fig 5: flexural strength of beams

5. Conclusion

On the basis of experiments conducted on eight beam specimens the following conclusions are drawn:

1. The flexural strength of conventional concrete beam is worked out to be 50% of flexural Strength of fibre reinforced concrete beam
2. In conventional concrete beams, cracks developed at the point of loading i.e., at L/3 distance from the edges whereas in fiber reinforced beam the crack is observed only in the center of the beam.
3. The deflection curve of conventional beam increases constantly with respect to application of load, whereas in fiber reinforced beam initially there is a gradual increase, and after a certain load, there is a steep increase in the deflection value.

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