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Experimental Study on Flexural Strngth of RCC Beam Wrapped with Sisal Fiber

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ABSTRACT

Concrete framed structures are the most common- type of modern structure in the globe. When we say concrete in the building trade, we actually mean reinforced concrete. Its full name is reinforced cement concrete. RCC is concrete that contains steel bars, called reinforcement bars. This combination works very well, as concrete is very strong in compression and steel is very strong in tension. In an earthquake loading condition, the ground vigorously shakes the building both horizontally and vertically it causes the building to fall and also many of the concrete structure failed under seismic loading condition. Due to overcome this problem we proposed to use the composite concrete in building structure. There are several situations in which a civil structure would require strengthening or rehabilitation due to lack of strength, stiffness, ductility and durability. Our project aims to compare the mechanical properties of Sisal fiber in the improvement of load carrying capacity of concrete structure in different layers. Beams and columns may be strengthened in flexure through the use of sisal fiber bonded to their tension zone using epoxy as a common adhesive. Due to several advantages of sisal fiber wrapping over conventional techniques used for structural repair and strengthening. In our project is study about load carrying capacity of an RCC frame wrapped with sisal fiber. An experimental study is to predict the maximum load carrying capacity, deflection of the composite RCC structure. Finally, the results are compared with conventional framed structure, which is suitable for strength and rehabilitate the concrete structure.

Keywords: RCC, Beam, Wrapped, Sisal fiber.

1. INTRODUCTION

1.1 Concrete

Concrete is a composite material that consists of a cement paste within which various sizes of fine and coarse aggregates are embedded. It contains some amount of entrapped air and may contain purposely-entrained air by the use of air-entraining admixtures. Various types of chemical admixtures and/or finely divided mineral admixtures are frequently used in the production of concrete to improve or alter its properties or to obtain a more economical concrete.

Since the cement paste is a plastic material when the cement and water are first mixed, the mixture of the concrete making materials is also plastic when first mixed. Since cement paste gains the rigidity and hardness (due to chemical reactions taking between the cement and the water) as time passes, the plastic concrete mixture also gains rigidity and hardness in time. Therefore, by placing the plastic concrete mixture into a mould having the desired shape and dimensions, a rock like material having the desired shape and dimensions is obtained when the concrete hardness. The plastic state of the concrete starting from the time that the concrete making materials are mixed until the concrete gains rigidity is called “fresh concrete”; the state of the concrete starting from the time it gains rigidity is called “hardened concrete.

Concrete is a material that literally forms the basis of our modern society. Scarcely any aspect of our daily lives does not depend directly or indirectly on concrete. The popularity and wide use of concrete as a construction material derives from its advantages over other construction materials. Some of these advantages can be listed as follows:

- Concrete has the ability to be cast to any desired shape since it is in a plastic condition when the materials are mixed and hardens as time passes.
- Concrete is durable because it does not easily lose its quality as does steel, which corrodes, and as does timber, which decays with time.
- Concrete is economical: because of the abundance and relatively low price of the aggregates which constitute about three fourths of its volume,
- because semi-skilled workers can largely be employed and relatively unsophisticated equipment used in concrete work,
- Because of the low maintenance cost.
- Concrete is an efficient material as compared to metals and other construction materials. Aggregates, which constitute the greatest part of concrete volume, are abundant and cheap as mentioned.
- Concrete has satisfactorily high compressive strength.
- Concrete has fairly high fire resistance as compared to that of metals and timbers.
- Concrete has aesthetic properties since concrete elements of any shape and color can be produced easily by the use of admixtures

1.2 About Fiber

Fiber are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fiber produce greater impact, abrasion and shatter resistance in concrete. Generally, fiber do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural reinforcement. Indeed, some fiber actually reduce the strength of concrete. The amount of fiber added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fiber), termed volume fraction (Vf). Vf typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fiber with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio.

Natural fiber has special appeal in the field of civil engineering. The cost of natural fiber is expected to be price competitive. The advantages of natural fiber materials are strength, better durability, competitive cost, environmental compatibility and bio degradability. The use of natural fiber in concrete is recommended since several types of fiber are available locally and are plentiful for e.g. Straw, coconut coir, palm leaf, cotton, sisal, sugarcane, bamboo, jute, wood, etc.. Of all natural fiber, sisal is hard and tough fiber, polygonal to round in section has the greatest tearing strength and retains this property even in wet condition. Sisal is a bio degradable organic fiber material containing 46% lignin, 54% cellulose. Because its high content of lignin, sisal is much more advantageous than other natural fiber.

Fiber can be added to cement-based matrices as primary or secondary reinforcement. Fiber work as primary reinforcement in thin products in which conventional reinforcing bars cannot be used. In these applications, the fiber act to increase both the strength and the toughness of the composite. In components such as slabs and pavements, fiber are added to control cracking induced by humidity or temperature variations and in these applications, they work as secondary reinforcement. Vegetable fiber, including sisal, coconut, jute, bamboo and wood fiber, are prospective reinforcing materials and their use until now has been more empirical than technical. They have been tried as reinforcement for cement matrices in developing countries mainly to produce low-cost thin elements for use in housing schemes.

Vegetable fiber require only a low degree of industrialization for their processing and in comparison, with an equivalent weight of the most common synthetic reinforcing fiber, the energy required for their production is small and hence the cost of fabricating these composites is also low (Aziz et al., 1984). In addition, the use of a random mixture of vegetable fiber in cement matrices leads to a technique that requires only a small number of trained personnel in the construction industry. The use of such fiber in concrete provides an exciting challenge to the construction industry for housing, for providing roofing sheets and to contribute to the rapid development of a country's infrastructure. Vegetable fiber cement composites thus pose the challenge and the solution for combining unconventional building materials with traditional construction methods.

The use of sisal, a natural fiber with enhanced mechanical performance, as reinforcement in a cement-based matrix has shown to be a promising opportunity. The cement matrices can consist of paste, mortar or concrete. Most of the studies on sisal fiber concrete involve the use of ordinary Portland cement. However, high alumina cement, cement with additives such as fly ash, slag, silica fume have also been used to improve the durability of the composites.

1.3 Natural Fiber Reinforced Concrete

Fiber can be added to cement-based matrices as primary or secondary reinforcement. Fiber work as primary reinforcement in thin products in which conventional reinforcing bars cannot be used. In these applications, the fiber act to increase both the strength and the toughness of the composite. In components such as slabs and pavements, fiber are added to control cracking induced by humidity or temperature variations and in these applications, they work as secondary reinforcement. The use of fiber in concrete provides an exciting challenge to the construction industry for housing, for providing roofing sheets.

1.4 Advantages of Fiber Reinforced Concrete

- Fiber reinforced concrete has started to find its place in many areas of civil infrastructure applications, where the need for repairing, increased durability arises also avoid the corrosion at the maximum.
- The advantages of natural fiber materials are strength, durability, reduce cost of environmental compatibility and bio degradability. It is a hard and tough fiber. In components such as slabs and pavements, fiber is added to control cracking induced by temperature variation.
- Fiber reinforced concrete is better suited to minimize cavitation erosion damage in structures such as sluice-ways, navigational locks and bridge piers where high velocity flows are encountered also avoid catastrophic failures in bridges.
- Also, in the earth quake prone areas the use of fiber reinforced concrete would certainly minimize the human casualties and to contribute to the rapid development of a country's infrastructure. Natural fiber has special appeal in the field of Civil Engineering.

1.5 Need of Sisal Fiber Reinforced Concrete

In the fulfilment of this need, many challenges remain in path to generate environmentally friendly structure products. These Fiber have advantage of easily available, economical extraction, no hazard to environment and good tensile strength etc. Natural Fiber such as sisal, jute, coconut etc. have been use as reinforcement of resource matrices in form of short and long fiber but there is no proper study of exact behaviour of reinforced with these Fiber. Fiber work as primary reinforcement in thin products like door panels, partitions etc. In which reinforcing steel bars are not used. In these applications, the Fiber act to increase the strength of structure.

1.6 Applications of Sisal Fiber

- It is also used as cement reinforcement.
- In developing countries, sisal fibers are used as reinforcement in houses.
- Sisal is also used in housing schemes. Sisal house is panelized system for building emergency shelters. It uses pre-made panels that are connected to form a shed like structure. These are used as emergency shelters and later can be disassembled and reused or converted into permanent houses.
- Sisal-based bricks, roofing tiles, insulation material and fiberboard.

1.7 Objectives of the Study

The main objectives of this study are,

- To study the mechanical properties of conventional concrete structure and compare with sisal fiber wrapped concrete structure. To determine the bond strength between sisal fiber concrete.
- To determine the flexural strength of sisal fiber reinforced concrete beam with sisal fiber.
- To compare the flexural behaviour of sisal fiber reinforced concrete beams with conventional concrete structure.

1.8 Need for Study

- Natural fiber as reinforcement in composites have been studied by many researchers only for non-structural members.
- Natural fiber are good alternative at lower cost and promote sustainable development. Earthquakes have caused mass destruction of buildings because of non-engineered constructions.

- These observations emphasize the need for new techniques for economical and safe housing in earthquake prone rural areas.
- Natural fiber reinforced concrete structures can be one solution. Sisal is a complete biodegradable and highly renewable resource of energy.
- A sisal fiber is exceptionally durable and requires low maintenance with minimum wear and tear. Sisal is one of the promising natural fiber.
- Hence sisal fiber reinforced concrete (SFRC) and sisal fiber rope is investigated for their potential in low-cost housing in under- developed and developing countries.

2. METHODOLOGY

Figure 1 shows the methodology of the study.

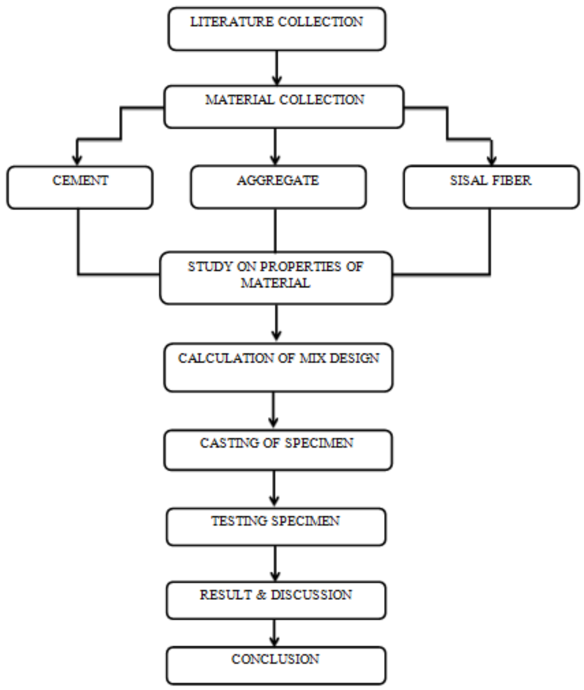

Figure 1 Methodology

3. MATERIAL COLLECTIONS

3.1 Cement

- Cement is a generic term that can apply to all binders. There is a wide variety of cements that are used to some extent in the construction and building industries, or to solve special problems. The chemical composition of these cements can be quite diverse, but by far the greatest amount of concrete used today is made with Portland cements.
- Portland cement is a hydraulic binder produced by pulverizing a small amount of gypsum along with the Portland cement clinker that is obtained by burning an appropriate combination of calcareous and clayey materials. The mixture of cement and water is called “cement paste”. The function of the cement paste in a concrete is to cover the surfaces of the aggregate particles, to fill the spaces between the particles and produce a compact mass by binding the aggregates particles
- The cement used was ordinary Portland cement 53 (OPC 53). All properties of cement were determined by referring IS 12269 - 1987. Cement is the important building material in today’s construction world. 53 grade Ordinary Portland Cement (OPC) conforming to IS: 8112-1989. Table 1 gives the properties of cement used.

3.2 Fine Aggregate

The sand which was locally available and passing through 4.75mm IS sieve is used. Locally available river sand conforming to Grading zone I of IS: 383 –1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.Fine aggregate is defined as material that will pass a No. 4 sieve and will, for the most part, be retained on a No. 200 sieve. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

3.3 Coarse Aggregate

Aggregates generally occupy 70 to 80 percent of the volume of concrete and can therefore be expected to have an important influence on its properties. They are granular materials, derived for the most part from natural rock (crushed stone or natural gravels) and sands, although synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in lightweight concretes. In addition to their use as economical filler, aggregates generally provide concrete with better dimensional stability and wear resistance. Aggregate classifications are made principally for the purpose of easier identification of particular aggregate lots, or to become familiar with the different types of aggregates. There are numerous ways of classifying aggregates. These classifications are made according to source of aggregate, specific gravity or unit weight of aggregate, size of aggregate particles, shape of aggregates, surface texture of aggregates, mode of preparation of aggregates, geological origin of aggregates, and mineral composition of aggregates and reactivity of aggregates. Aggregates are not generally classified by mineralogy; the simplest and most useful classifications are on the basis of source and specific gravity.

3.4 Water

Water is a key ingredient in the manufacture of concrete. It is also material on its own right. Understanding its properties is helpful in gaining and understanding of its effects on concrete and other building materials. Although water is an important ingredient of concrete little needs to be written about water quality, since it has little to do with the quality of the concrete. However mixing water can cause problems by introducing impurities that have detrimental effects on concrete quality. Although satisfactory strength development is of primary concern, impurities contained in the mix water may also affect setting times, drying shrinkage, or durability, or they may cause efflorescence.

4. PROPERTIES OF MATERIAL

4.1 Physical Properties of Cement

Table 1 shows the physical properties of cement.

Table 1: Physical Properties of Cement

S.NO	PROPERTY OF CEMENT	VALUE
1	Fines of cement	7.5%
2	Grade of cement	53 Grade(OPC)
3	Specific gravity of cement	3.15
4	Initial setting time	30min
5	Final setting time	60min
6	Normal consistency	35%

4.2 Property f Fine Aggregate

Table 2 shows the property of fine aggregate.

Table 2: Property of Fine Aggregate

S.NO	PROPERTIES	VALUE
1	Specific Gravity	2.65
2	Fineness Modulus	2.25
3	Water absorption	1.5%

4.3 Property Of Coarse Aggregate

Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability. Table 3 shows the property of coarse aggregate.

Table 3: Property of Coarse Aggregate

S.NO	PROPERTIY	VALUES
1	Specific Gravity	2.68
2	Size Of Aggregates	20mm
3	Fineness Modulus	5.96
4	Water absorption	2.0%
5	Impact Test	15.2%

4.4 Sisal Fiber

Sisal fiber (Agave sisal fiberana) is an agave that yields a stiff fiber traditionally used in making twine rope and also dartboards. The term may refer either to the plant or the fiber, depending on context. It is sometimes incorrectly referred to as sisal fiber hemp because hemp was for centuries a major source for fiber, so other fiber were sometimes named after it.The plant's origin is uncertain; while traditionally it was deemed to be a native of Yucatan; there are no records of botanical collections from there. Gentry hypothesized a Chiapas origin, on the strength of traditional local usage. In the 19th century, sisal fiber cultivation spread to Florida, the Caribbean islands and Brazil, as well as to countries in Africa, notably Tanzania and Kenya, and Asia. The first commercial plantings in Brazil were made in the late 1930s and the first sisal fiber exports from there were made in 1948. It was not until the 1960s that Brazilian production accelerated and the first of many spinning mills was established. Today Brazil is the major world producer of sisal fiber. There are both positive and negative environmental impacts from sisal fiber growing. Traditionally used for rope and twine, sisal fiber has many uses, including paper, cloth, wall coverings and carpets and here for get a good value of flexural strength for concrete. Figure 2 shows the sisal fiber.

Figure 2 Sisalfiber

4.4.1 Properties of Sisal Fiber

Fiber have been used to construct tough bricks, external wall plastering and crockery, but only in last two decade have the principles of fiber reinforcement structural element is to be scientifically research. The fiber beyond the cracks and it provide post-cracking ductility. A large diversity of fiber usages with cement-based element. They include metal fiber, mineral fiber, polymer fiber and vegetable fiber. The RCC beam mould cast paste or mortar steel reinforced concrete. Most of researches fiber reinforced concrete mould is casted by using ordinary Portland cement. Which are structurally safe and durable? Sisal fiber is attain from leaves of a plant which is name as “Agave sisalana”, which is originate from Brazil, Mexico and it is cultivated now in India. Name of sisal fiber came from Harbour town Yucatan, Mexico. Sisal fiber plants easy to cultivation, it gives short renewing time and easy to grow in all type of environments. 200 leaves yield from one sisal plant each leaves gives 4 to 5% of dry sisal fiber as comparison its weight. Hence the normal leaves weight of sisal plant is around 500grm. Fiber is extracting from a leaf by scraping and a diameter of sisal fiber varied from 0.2 to 0.3 mm. Table 4 shows the mechanical properties of sisal fiber.

Table 4: Mechanical Properties of Sisal fiber

Properties	Value
Density	1.33 g/cm3
Tensile Strength	$600\text{-}700 \times 10^6 N/m^2$
Modulus of elasticity	38 Gpa
Elongation at failure	2-3%
Moisture absorption	11%

Table 5 shows the chemical composition of sisal fiber.

Table 5: Chemical Composition of Sisal Fiber

Chemicals	Percentage
Cellulose	65%
Hemicelluloses	12%
Lignin	9.9%
Waxes	2%
Total	100%

5. MIX DESIGN

5.1 Mix Design of Concrete

The control mix was designed to make M30 grade of concrete as per BIS 10262-2009. The procedure adopted is described in the following section.

5.1.1 Stipulations for Proportioning

- Grade of Designation = M 30
- Type of cement = OPC 53 Grade
- Maximum nominal size of aggregate = 20 mm
- Minimum cement content = 320 kg/m^3
- Maximum water cement ratio = 0.45
- Workability = 100 mm
- Exposure conditions = Sever

- Method of concrete placing = Hand Placing
- Degree of supervision = Good
- Type of aggregate = Angler

5.1.2 Test Data for Materials

- Cement usedOPC 53
- Specific gravity of cement = 3.15
- Specific gravity of Fine aggregate =2.65
- Specific gravity of Coarse aggregate =2.68
- Water absorption of Fine aggregate =1.5%
- Water absorption of Coarse aggregate =2.0%

6. EXPERIMENTAL SETUP

6.1 Compressive Strength

Compression tests are used to determine how a product or material reacts when it is compressed, squashed, crushed or flattened by measuring fundamental parameters that determine the specimen behaviour under a compressive load. Compression test is conducted at the end of the 7th and 28th day of casting the specimens. The load was applied without any shock and continuously until the failure of the specimens. The maximum load is applied to the specimens until the failure is recorded.
Fc= load/ Cross sectional area

6.2 Flexural Strength

Before applying the FRCM system, the specimens were flipped upside down to make the application process easier. To apply the FRCM, the surface of the beam was roughened then dampened with water, but without having any standing water at the surface. An initial layer of mortar was applied, approximately 3 mm thick. Then, the first FRCM mesh was laid down, embedded in the mortar and totally covered by another layer of mortar. This procedure was repeated for each layer of both the main bottom FRCM strengthening and the U-wraps. Figure 7 shows illustrations for the different steps. The applied strengthening was then wet-cured for 3 days.

6.3 T-Section – Cyclic Load Test (With SFRP)

Test Setup: The specimens were fixed on universal testing machine such that the both ends of column were fixed by UTM. The projections of beam length 300 mm on either side of the column were fixed by proving ring attached with hydraulic jacks. Only one end beam was loaded by means of hydraulic jack and readings are taken from proving ring. Other end of the beam also has same arrangement but only for supporting purpose.
Packing plates were placed on either side of the column. The hydraulic jack and proving ring were seated vertically. A dial gauge was placed on top of the application of load on the beam for measuring deflections. The least count of dial gauge is 0.01mm.

7. RESULTS & DISCUSSION

7.1 Compressive Strength of Concrete Cube

All the casted specimens were demoulded and tested in saturated dry surface condition, after wiping out the surface moisture. For each specimen tested were carried out at the age of 7 days, 14 days and 28 days. The maximum load applied to the specimen until the failure took place is recorded. The ultimate load divided by the cross-sectional area of the specimen is equal to the ultimate compressive strength of the cube. The specimen attains the maximum load and strength at the age of 28 days is 30.3 N/mm^2 respectively. Table 6 shows the compressive strength of concrete cube.

Table 6: Compressive strength of concrete cube

Grade	Curing Days	Opt.mix			
		M1	M2	M3	Avg
M30	7	12.6	12.4	12.4	12.46
	14	22.6	22.4	22.8	22.6
	28	30.4	30.2	30.4	30.3

Figure 3 shows the graph for compressive strength on cube.

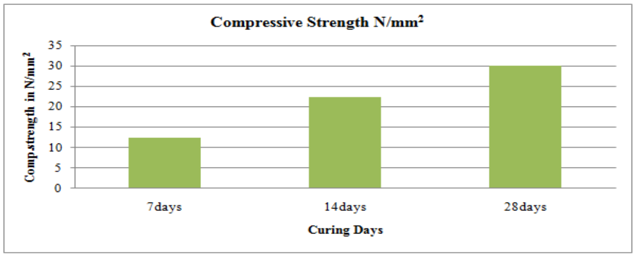

Figure 3 Graph for Compressive strength on cube

7.2 Split Tensile Strength on Cylinder

To find out the tensile strength of the cylinder, the tests are carried out at the age of 7 days, 14 days and 28 days. The size of the concrete cylinder specimens is about 150 mm diameter and 300 mm height as per IS: 5816-1970 code book for tensile test with the grade of M40. The strength of cylinder attain maximum tensile load is 2.79 N/mm^2 strength at 28 days. The results are tabulated in table 8.2 and the graph for Split tensile strength on prism as shown in Figure 7.

Table 7: Split tensile strength of concrete prism

Grade	Curing Days	Opt.mix			
		M1	M2	M3	Avg
M30	7	2.06	2.12	2.17	2.11
	14	2.32	2.42	2.48	2.40
	28	2.74	2.80	2.83	2.79

Figure 4 shows graph for split tensile strength on prim.

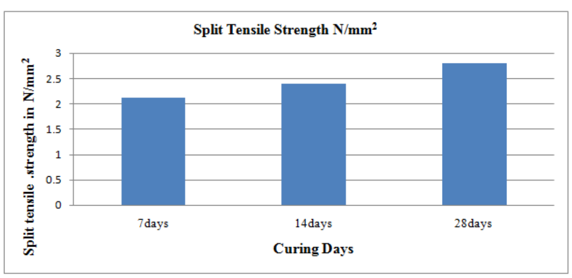

Figure 4 Graph for Split tensile strength on prism

7.3 Flexural Strength on Beam

Flexural test of beam is carried out at the age of 7 days, 14 days and 28days with the size of 150 mm x 150 mm x 700 mm specimen by using universal testing machine. The flexural strength is finding out by applying two-point load condition. Maximum strength of beam attains 9.1 N/mm², 10.3 N/mm², and 12.1 N/mm² for 7, 14 and 28 days respectively. Table 8 shows the flexural strength of beam.

Table 8: Flexural Strength of beam

Control mix	Days	CC	Flexural strength in N/mm²		
			SFRP thickness		
			2mm	3mm	4mm
M_{30}	7	6.8	8.1	8.6	9.1
	14	7.6	8.8	9.8	10.3
	28	10.6	11.2	11.8	12.1

Figure 5 shows theGraph for CC V_S 2mm thickness OC(OPTIMIZED CONCRETE)

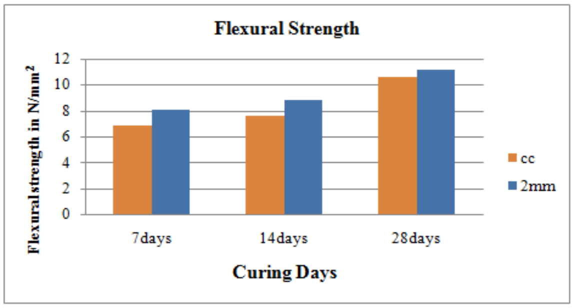

Figure 5 Graph for CC V_S 2mm thickness OC(OPTIMIZED CONCRETE)

Figure 6 shows the Graph for CC V_S 3mm thicknesses OC (OPTIMIZED CONCRETE)

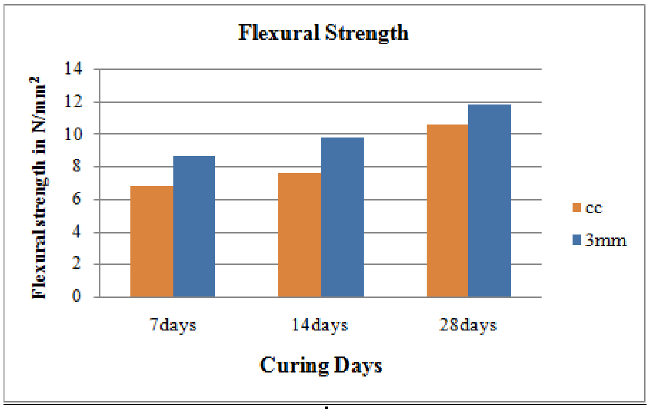

Figure 6 Graph for CC V_S 3mm thicknesses OC (OPTIMIZED CONCRETE)

Figure 7 shows the Graph for CC V_S 4mm thicknesses OC (OPTIMIZED CONCRETE)

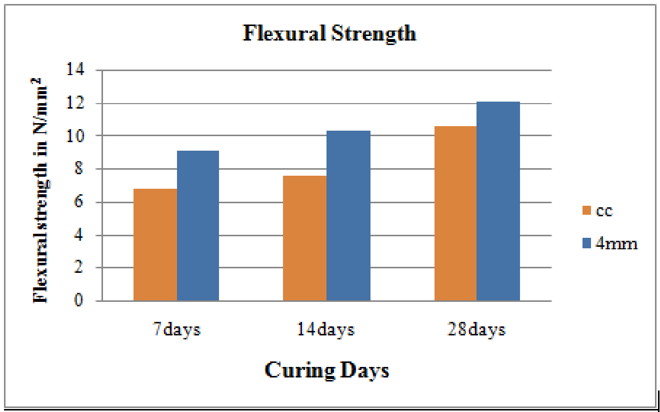

Figure 7 Graph for CC V_S 4mm thicknesses OC(OPTIMIZED CONCRETE)

7.4 Cyclic Load Test

The specimen was tested in a loading frame. A hydraulic jack was used to apply the axial load for column. To record the load precisely a proving ring was used. The load is applied forward cyclic and deflection measured from every 2KN.

Thedeflection was measured at the beam free end tip. Loading is applied gradually such as 2,4, 6, 8,10,12 KNrespectively forforward direction. Figure 8 shows the cyclic load graphs for T section.

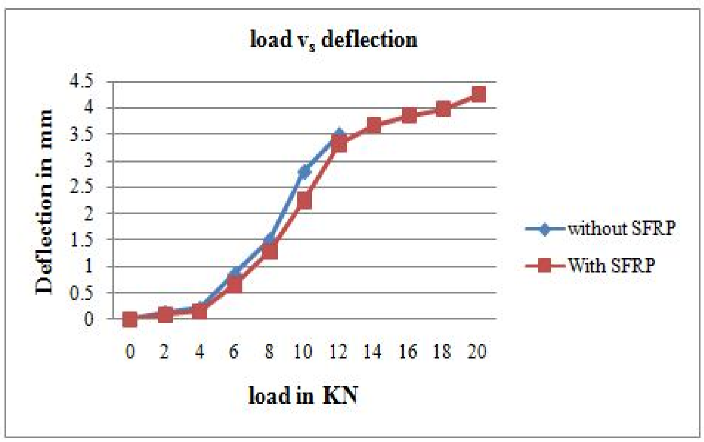

Figure 8 Cyclic load graphs for T section

Table 9 shows the cyclic load value of the specimen.

Table 9: Cyclic load value of the specimen

S.NO	Load in 'KN'	Deflection in mm	
		Without SFRP	With SFRP
1	0	0	0
2	2	0.12	0.08
3	4	0.20	0.14
4	6	0.85	0.65
5	8	1.50	1.28
6	10	2.80	2.25
7	12	3.50	3.32
8	14	-	3.68
9	16	-	3.85
10	18	-	3.98
11	20	-	4.25

The SFRP specimen, the first crack formed in the beam portion at a load of 6 kN. Bond failure of the wrap was noticed on the tension side of the beam at a load of 8 kN. and on the tension side of the compression side of the beam at a load of 14 kN. The application of the load was stopped when the deflection at the free end of the beam reached 3.50 mm. The load corresponding to this deflection was 12 kN.

8. CONCLUSION

Based on the experimental investigations carried out on the control and Sisal fiberwrapped beam-column joint specimens, the following conclusions are drawn

- The load deformation characteristics were high for SFRP retrofitted specimens over the control specimens. This resulted in a substantial increase in the energy absorption characteristics of the specimens that were retrofitted with SFRP.
- The energy absorption capacity of the SFRP wrapped specimenswas in the range 15% over the control beam-column joint specimens.
- The case of the wrapped specimens, the failure was noticed in the beam portion only and the column was intact.
- Generally SFRP as a strengthening material led to increased ultimate capacity and decreased ductility compared to those of control joints specimen.

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