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INVESTIGATION ON THE FLEXURAL BEHAVIOUR OF BAMBOO REINFORCED CONCRETE BEAMS

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ABSTRACT

Construction industry is the main consumer of energy and materials in most countries. Concrete is the most consumed construction material in the entire world. Concrete is found to have excellent compressive strength but poor in tensile strength. To take care of the tensile strength steel is commonly used reinforcing material. Due to the increasing cost, unavailability and other drawbacks of the steel enforced to use an alternative material as reinforcement. The use of bamboo which is fast growing and ecologically friendly material for structural applications is being considered as quite appropriate. The tensile strength of bamboo is quite high and can reach up to 125 MPa. The use of bamboo as a structural element may contribute to the reduction of material-based energy use of a structure. To investigate the feasibility of using bamboo as a reinforcing material in reinforced-concrete members, flexural Strength were carried out on reinforced-concrete beams in which all rebars, including the main rebar and the stirrups, were replaced with bamboo. In this present study nine beams each of size 150x150 x750 mm were cast to study the flexural strength. Beams 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. From these experimental works, it was concluded that bamboo can be usedin non-structural element in low cost construction.

***Keywords**: Bamboo, Concrete, Flexure Test, Reinforcement, Steel, Structural Elements, Tensile Strength.*

INTRODUCTION

Bamboo has a long and well-established tradition as a building material throughout the world's tropical and sub-tropical regions. It is widely used for many forms of construction, in particular for housing in rural areas. Bamboo is a renewable and versatile resource, characterized by high strength and low weight, and is easily worked using simple tools. It is widely recognized as one of the most important non-timber forest resources due to the high socio-economic benefits from bamboo based products. It is estimated that there are 1200 species growing in about 14.5 million hectares area. Most of them grow in Asia, Africa and Latin America. Bamboo is the world's fastest growing woody plant. It grows approximately 7.5 to 40cm a day, with world record being

1.2m in 24 hours in Japan. Bamboo grows three times faster than most other species. Commercially important species of bamboo usually mature in four or five years' time, after which multiple harvests are possible every second year, for up to 120 years in some species and indefinitely in others. Bamboo also excels in biomass production, giving 40 tons or more per hectare annually in managed stands. It accounts for around one-quarter of biomass produced in tropical regions and one-fifth in subtropical regions. It has been used successfully to rehabilitate soil ravage by brick making in India, and abandoned tin-mine sites in Malaysia. It shelters top soil from the on slaught of tropical down pours, preserves many exposed areas, providing micro-climate for forest regeneration and watershed protection It is often introduced into the banks or streams or in other vulnerable areas, for rapid control of soil erosion; one bamboo plants closely matted roots can bind up to six cubic meters of soil.

From the early times, bamboo is used as a construction material. The bamboo is used in both technical as well as non-technical ways. Our ancestors used Bamboo in the construction of the houses. The Bamboo was used as the struts, post, roof etc., in the construction of the houses. Nowadays concrete are used as the basic material for the construction works. The concrete is good in compression but weak in the tensile strength. So steel is used as reinforcement in the concrete to achieve the tensile strength. Problems encountered with the commonly used construction material like steel are high in cost, corrosion etc. Due to the advantages characteristics of Bamboo, in the last few years, studies have been made on the use of bamboo as structural material and reinforcement in concrete. The main obstacle for the application of Bamboo as a reinforcement is the lack of sufficient information about its interaction with concrete, strength and durability.

OBJECTIVE OF THE STUDY

Bamboo has historically been used as a building material due to its inherent properties, being regenerating, biodegradable, with high tensile strength, and light weight. It does not require sophisticated fuel/energy guzzling procedures for processing. However, despite its innumerable qualities one does not get to see bamboo houses. The conventional brick,RCC, framed structures have emerged as the prime solution for mass housing, even though they are not affordable by the majority of the sections in society. The irony is that while on one hand there is acute housing shortage, homelessness, poverty, growth and worsening conditions of slums in urban areas, on the other hand, valuable research on alternative cheaper and easy to construct solutions, do not disseminate to the level of practical application in the field. The Research Objective is to investigate

1. To Study the feasibility of the Bamboo as reinforcement in the cement concrete flexural element that is beam.
2. To Compare Reinforced concrete beam with bamboo reinforced beam and Plain Concrete Beam

SCOPE OF THE STUDY

The focus of this paper is to present a concise summary of the information about the range of material choices, which are locally available for producing concrete structural elements, reinforced with bamboo. Finally, some recommendations for future studies are proposed with the hope that the newly developed material could contribute, on a large scale, to sustainable development

LITERATURE REVIEW

An exhaustive survey of the available literature was conducted to assess the present status of the work carried out on bamboo reinforced concrete elements. Some of the researches carried out by the past researchers are given below

Tara Sen, and H. N. Jagannatha Reddy(2011) carried out an attempt is made to study the possibilities of reusing the sisal fibres, bamboo fibres, coir fibres and jute fibres which not only has various applications but also helps to solve the problem of waste disposal atleast to a small extent. They concluded that Bamboo segments are used as reinforcement of concrete beams, circular columns and pillars in quadratic form of concrete, double–layer spatial and plane truss bamboo structure and special joints between the bamboo elements, which can be easily used for plane and double-layer spatial structures. Bamboo frame structures commonly used by local people for improvement of the concrete permanent bamboo shutter slabs and reinforced concrete beams and columns.

Amit Singh et.al., (2016) investigated the experimental study on plain cement concrete (PCC) beam, bamboo reinforced concrete (BRC) beam, treated bamboo reinforced concrete (TBRC) beam and steel reinforced concrete (SRC). Beams were casted for and were tested on flexural testing machine. From the results it was concluded that, bamboo reinforced concrete beams (treated and untreated) showed a significant improvement in their flexural strength as compared to plain cement concrete beam. Hence, it can be recommended to use bamboo reinforced concrete beam for light load bearing structures like beam and slab for small panel. Also, it may be used for temporary structure.

Dr. Shakeel Ahmad et.al. (2014) carried out the experimental programme on Concrete cubes reinforced with 1% bamboo fibre by volume and been tested in compression testing machine and stress -strain curve has been plotted. The results have been compared with plain concrete cubes. Concrete beams reinforced with bamboo sticks at top and at top and bottom both have been cast and tested in flexure (pure bending). Four point bending test has been conducted and load deflection curve has been plotted. The results are compared with same dimension beam without any reinforcement.

M. M. Rahman, et.al. (2011) discussed the tensile property of bamboo and evaluation of the use of bamboo as reinforcing bar in concrete with replace of steel is done. Singly and double bamboo reinforced beams of 750 mm length having 150 mm width and depth are compared with plain concrete beam to carry out the test. From the study it was concluded that for singly bamboo reinforced concrete beam, the load carrying capacity increased about 2 times and that for doubly bamboo reinforced concrete beam about 2.5 times than that of plain concrete beam having same dimensions. The maximum deflection of singly reinforced beam and doubly reinforced beam are about 4.5 and 8 times respectively than that of plain concrete.

I.K. Khan (2014) investigated experimental study on eight slabs each of size 1000x1000x50 mm, out of which six slabs were reinforced with bamboo sticks and remaining two slabs were reinforced with steel bars. Out of six bamboo reinforced slabs, every two slabs were provided with bamboo stick of triangular, circular and square cross section. All the slabs were tested under single concentrated load applied at the centre of slab with all sides of slab as simply supported. The load was applied and gradually increased till failure with the help of hydraulic jack. During test load and corresponding deflection were recorded at the centre and diagonally near the four corners of each slab with the help of dial gauges. From the result it was concluded that the load carrying capacity of the bamboo reinforced slab using square cross-section was higher than other bamboo reinforced slabs reinforced with bamboo stick of triangular and circular cross section. The load at first crack and ultimate load in bamboo reinforced slab with square cross section was 30% less than that of mild steel concrete slab. Deflection of bamboo reinforced slabs with square cross section was less among bamboo reinforced slabs with triangular and circular cross sections.
Chandra et. al., (2013) Discussed about the earlier research through literature available on the use of bamboo as reinforcement in concrete. They concluded that bamboo can replace steel for modest housing for the urban poor who live close to bamboo growing regions.

B.Benitta PaulinMary and Dr. D.Tensing (2013) discussed, a review of the research carried out on bamboo reinforced concrete is given with emphasis on experimental work. From the analysis results it was proved that bamboo has high tensile strength and it can be used as a replacing material for steel reinforcement because of its low cost. Constructions made with bamboo can be very durable if it is well immunized and well selected trying to have the best quality of the material.

Anurag Nayak et., al., (2013) presented the paper deals with cost-wise comparison of steel reinforcement with bamboo reinforcement. To study the effect of replacement of steel reinforcement by bamboo reinforcement, designs have been conducted on one way slab of size 3000 x 7000 sq.-mm with providing beam of 7000 mm length and 250 x 250 sq-mm. In that paper the designs are done on the basis of shearing and bending. It is clear from results that this bamboo

reinforcement technique is absolutely cheaper than steel reinforcement technique especially for single story structure.

AdomAsamoah Mark and Afrifa Owusu Russell (2011) aimed at exploring ways of making the use of bamboo reinforced concrete beams simple, efficient and cost effective for rural construction with Ghana as a case study. It is a comparative study of bamboo reinforced concrete beams with shear links made of different materials. It is therefore recommended that bamboo reinforced concrete beams are reinforced with steel stirrups to improve on its load carrying behaviour.

Guo Chen et., al., (2013) carried out experimental studies on glue-laminated bamboo trusses. Six full-scale model trusses with two types of configuration and sizes were tested to failure under gradually increased vertical load. The failure of the model trusses was caused by lateral buckling of the top chords. Tests show that the modern glue-laminated bamboo trusses have adequate stiffness and strength.

Jigar K. Sevalia et., al., (2013), evaluated the feasibility of the use of Bamboo as reinforcement in concrete members. In that study the Bamboo was used as a reinforcing material without any treatment and stirrups. In order to check flexural strength of Bamboo Reinforced cement concrete, beam specimens are casted with dimension 130*130*750 mm. From the experimental result it was found that Modulus of Elasticity of the Doubly Reinforced Beam is more than twice of Modulus of Elasticity of the Singly Reinforced Beam

Dr. Patel Pratima A. et., al., (2013) tested & evaluated physical and mechanical properties like compressive strength, tensile strength, Flexural test, Bonding strength, water absorption, density etc. of the selected bamboo species in material testing laboratory. Purpose of the experiments on bamboo strips is for validation and justification of these results confirm the application of bamboo as reinforcement element. Slabs were cast with and without bamboo reinforcement. The study concluded that the flexural test on slab panel is as below with bamboo reinforcement is as below the slab withoutbamboo reinforcement. . The ultimate deflection and elasticity of slab panel is also denoted in table

Arpit Sethia and Vijay Baradiya (2014) performed bending test on Plain, Steel & Bamboo reinforced members. For example, a total of 4beam (150x150x700mm) were casted using design mix (M25) as per IS code. These beam included 1 beam of steel reinforcement, 1beam of plain concrete, and 4beam of untreated bamboo reinforcement. The result concluded that For bamboo reinforced concrete beam, the load carrying capacity increased about 3 times that of plain concrete beam having same dimensions. The maximum deflection of bamboo reinforced concrete beam is about 1.5 that of plain concrete. This thesis concludes that it is possible to use bamboo as reinforcing for masonry structure. Though the tensile strength is about 1/3rd that of steel, this is

sufficient for masonry structure and provides a more economical and environment- friendly alternative that is accessible to every section of the society.

Nirav B. Siddhpura et., al., (2014) studied the usefulness of Bamboo as a structural member in flexural element. Various surface coatings on the Bamboo are given and the reinforcement cage has been prepared using the Bamboo stirrups. The flexure test was performed on the beam elements. To check the flexural strength of the beam reinforced with the Bamboo, Cement concrete flexural elements of the dimension 130*130*750 mm were prepared. The Bamboo strip used as reinforcement was 710 mm long. When water comes in contact with the surface of the Bamboo, it swells. In order to prevent the swelling of the Bamboo waterproofing of the Bamboo was done by chemical Araldite, Epoxy Resin and Coal Tar treatments. From the study it was concluded that Beam elements reinforced with Bamboo having coal tar as a surface coating has showed highest value of Modulus of Elasticity

Humberto C. Lima Jr. (2008) presented an experimental investigation made to evaluate bamboo durability to be used as concrete reinforcement. The durability was evaluated by changing the tensile strength and Young's Modulus of bamboo. Five hundred specimens were extracted from a Dencrocalamus giganteus bamboo culms and part of them was set into concrete prisms. A set up was developed to expose the specimens to wetting and drying cycles. Each exposure to wetting and drying lasted 24 h. The specimens without concrete were submitted to a calcium hydroxide solution and the samples with concrete were immersed in tap water. Tensile strength and Young's Modulus were measured after 7, 15, 30, 45 and 60 cycles. Results did not show any significant variation on these mechanical properties, attesting the durability of bamboo in these aggressive tests.

MATERIALS USED

Cement, water and Aggregates

Concrete is prepared by mixing various constituents like cement, aggregates, water etc. which are economically available. Ordinary Portland cement of 43 grade conforming to IS 8112 was used throughout the work. The fine aggregate used in this investigation was clean river sand, whose maximum size is 4.75 mm, conforming to grading zone II. Machine crushed blue granite stone angular in shape was used as coarse aggregate. The properties of the materials are presented in Table 1.

METHODOLOGY

Experimental Programme

The aim of the experiment was to assess the feasibility of the Bamboo as reinforcement in the cement concrete flexural element that is beam. The concrete mix design was proposed using Indian Standard for control concrete. The grade was M35. The Proportion of materials shown in Table 2.

Specimen Preparation

To investigate the feasibility of using bamboo as a reinforcing material in reinforced-concrete members, flexural Strength were carried out on reinforced-concrete beams in which all rebars, including the main rebar and the stirrups, were replaced with bamboo. In this present study ninebeams each of size 750x150x150 mm were cast to study the flexural strength, out of which 3 beams used as a Plain concrete beam. Doubly reinforced concrete was casted. Reinforcement is provided on both sides of the beam with a nominal cover of 30mm. Steel stirrups is used in both steel and bamboo reinforced beams as shown in Fig.1 and Fig.2.Bamboo selected for reinforcement had an average diameter of 12mm. Three steel reinforced beams and three bamboo reinforced beams were casted. Plain concrete beam nominated as PCB, Bamboo reinforced concrete beam nominated as BRCB and Reinforced Concrete Beam noted as RCB. The details of each beam given in table 3.

RESULTS AND DISCUSSIONS

The experimental investigations carried out in the laboratory to determine the compressivestrength of the concrete, tensile strength of bamboo andflexural strength ofthree types of beams PCB, BRCB and RCB. To determine the tensile strength test, bamboo sticks of length 750 mm and diameter 12mm was used. The sticks were allowed to dry and season for 30 days. The tensile strength of bamboo strip was tested using Universal Testing Machine (UTM).Specimen is placed in UTM and tensile load was recorded. The averages of three test results were recorded.

Concrete Beams 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. Steel and bamboo reinforced beams were tested separately. The displacement was measured at regular intervals. The load is increased constantly and the corresponding displacement was recorded. Strain gauge which is used to measure the deflection of the beam. 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.

EFFECT OF BAMBOO ON FLEXURAL STRENGTH

As per design obtained in accordance to code IS-10262, mix proportion of various materials (viz. Cement, Sand, Aggregate and Water) is calculated for M-235 grade of concrete. The cubes were tested in the laboratory as shown in fig 3 in accordance to code IS 1343-1980. The results of compressive strength of cubes for 7days and 28 days were 47.6 and 57.8N/mm2. The tensile strength of bamboo was 14.6 N/mm2 which is shown in fig.4.Nine beams were cast. Figure 5 shown the casting of all beam specimens.The flexural strength was calculated as per IS 516-1959 as shown in fig. 6 and fig.7.The flexural strength of bamboo reinforced beam is 28% higher than Plain concrete beam and 55% lower than the Reinforced concrete beam which is shown in fig. 8. The deflection at center of bamboo reinforced beam is 50% higher than reinforced concrete beam and 60% lower than the plain concrete beam as shown in fig 9. The ultimate load carrying capacity of bamboo reinforced beam is 29 % higher than reinforced concrete beam and 55%. Higher than the plain concrete beam. Fig.10. shows variation in ultimate load. The failure pattern of the beam as shown in figure 11. The load versus deflection of all beam specimenstill failureload was mentioned in fig.12.

CONCLUSION

- This study reveals that the flexural strength of Bamboo reinforced concrete beam is worked out to be 50% of flexural strength of steel reinforced concrete beam.
- In steel reinforced concrete beams, cracks developed at the point of loading i.e., at L/3 distance from the edges whereas in bamboo reinforced beam the crack is observed only in the centre of the beam.
- The deflection curve of steel reinforced beam increases constantly with respect to application of load, whereas in bamboo reinforced beam initially there is a gradual increase, and after a certain load, there is a steep increase in the deflection value.
- The profile of failure in steel in tension test will occur at the centre whereas in bamboo the failure occurs at the end.
- The tensile strength of bamboo is exactly one half of the steel.
- Carbon – di – oxide emission can be reduced by approximately 25% by using bamboo in small structural elements.

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Table. 1 -Properties of the materials

Sl.No	Parameter	OPC used	Fine Aggregate	Coarse Aggregate
1	Normal Consistency	29%	-	-
2	Fineness by Sieving (%) 90 micron mesh	80	-	-
3	Initial Setting Time (minutes)	38	-	-
4	Final Setting Time(minutes)	300	-	-
5	Specific Gravity	3.15	2.62	2.74
6	Bulk density		1620	1870
7	Fineness modulus (Retain on 90 micron sieve)	5.0%	2.23	7.82
8	Water Absorption	0.8	1.34%	0%
9	Moisture Content	-	0.22%	0.2%
10	Crushing Value	-	-	23.42%
11	Impact Value	-	-	16.1%
12	Elongation index	-	-	8.9%
13	Flakiness index	-	-	8.3%

Table. 2 - Mix proportions of the concrete

Sl.No	Ingredient	Kg/m3	Proportion
1	Portland Cement	410	1: 1.61 : 3.15 W/ C = 0.5
2	Fine Aggregate	821	
3	Coarse Aggregate	1292	

Table. 3 - Beam Details

Type of Beam	PCB	BRCB	RCB
Size of Beam	150 x150 x 700	150 x 150x 700	150 x 150x 700
Grade of Concrete	M 35	M 35	M 35
Type of reinforcement bars	-	Bamboo Stick	Reinforcement
Percentage of reinforcement provided	-	2 %	2 %
Reinforcement provided	-	4 –Nos 12 mm dia	4 – Nos 12 mm dia
Stirrups	-	120mm c/c	120mm c/c
Cover	30 mm	30mm	30mm

Figure. 1 - Bamboo as Reinforcement in Beam

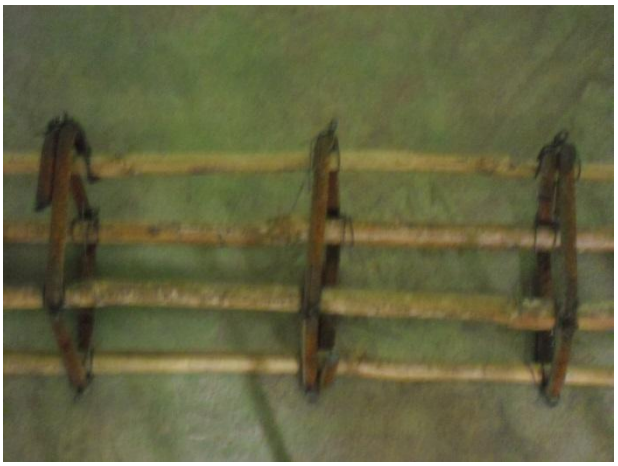

Figure. 2 - Bamboo as Reinforcement in Beam

Figure. 3 - Casting of BeamSpecimen

Figure. 4 -Compression Test onCube

Figure. 5 - Tension Test on Bamboo

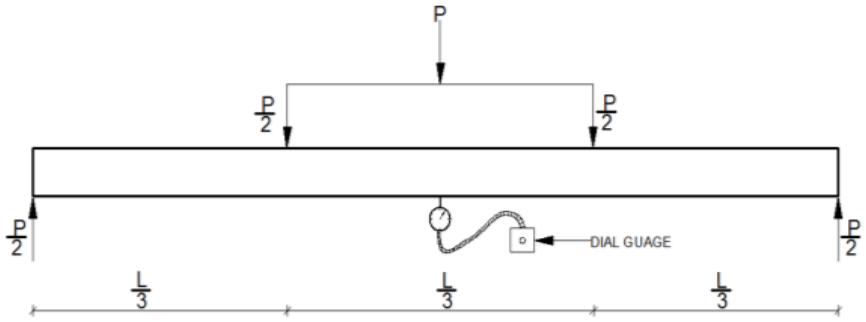

Figure. 6 -Loading Arrangement

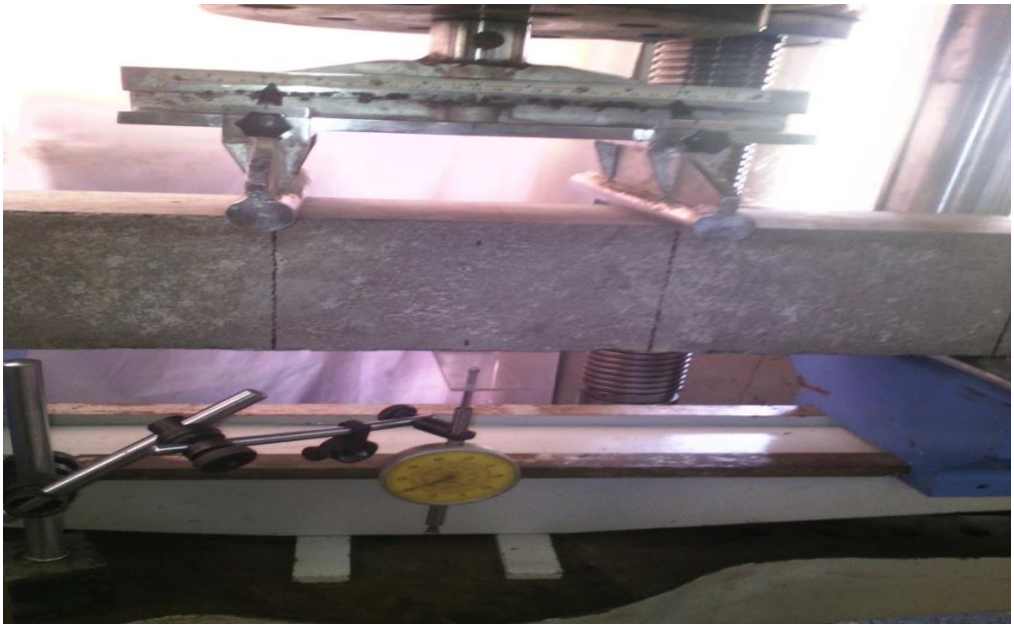

Figure. 7 - Load of Bamboo as Reinforced Beam

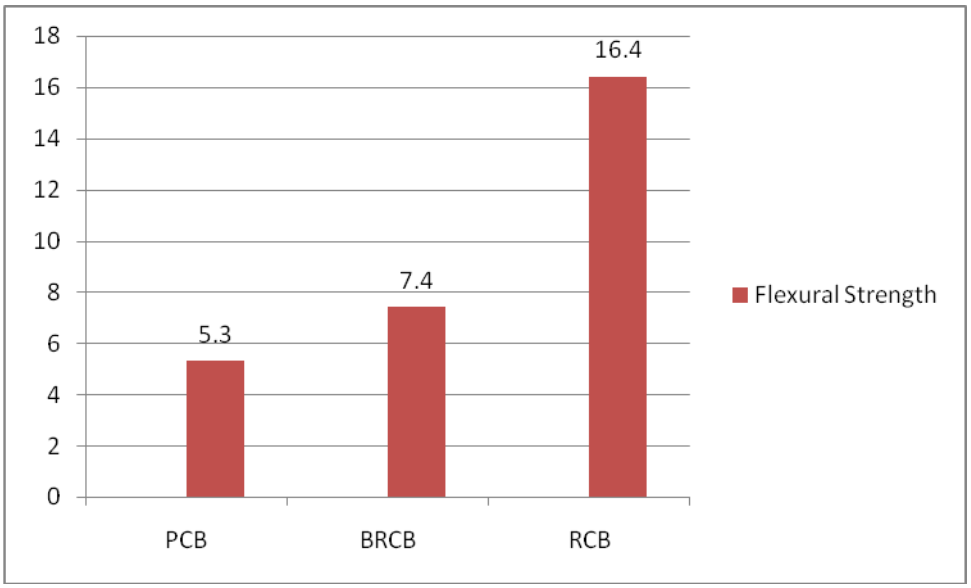

Figure.8 –Flexural strength for different type of Beam

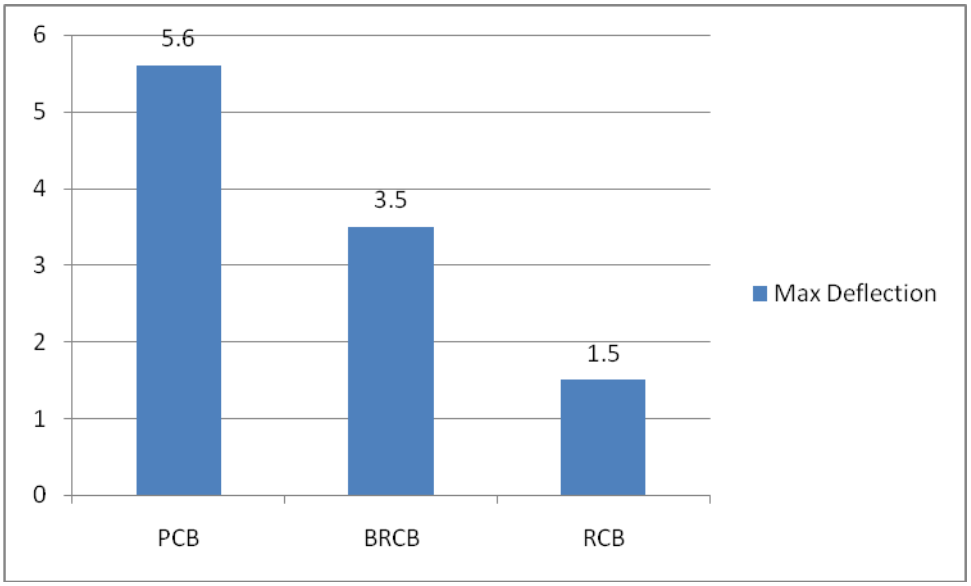

Figure.9 –Maximum Deflection for different type of Beam

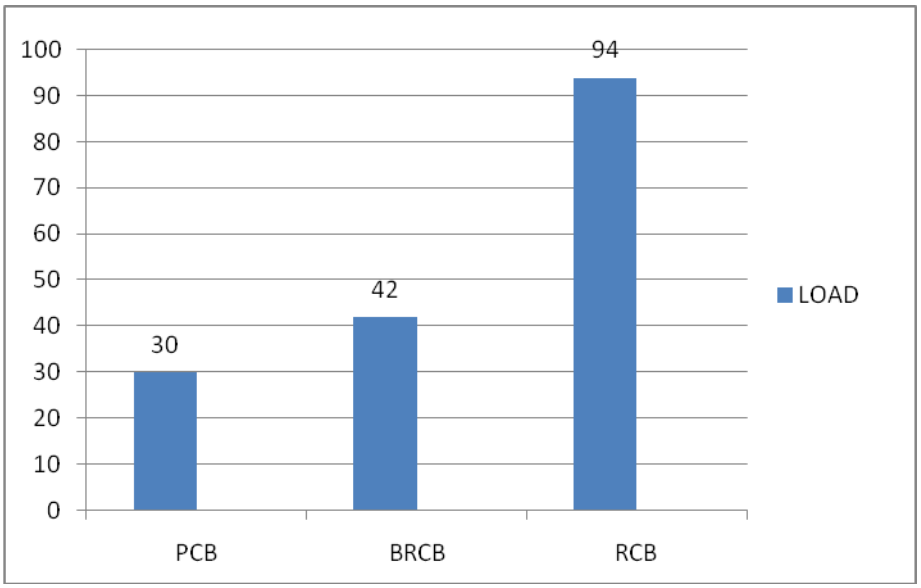

Figure.10 -Load for different type of Beam

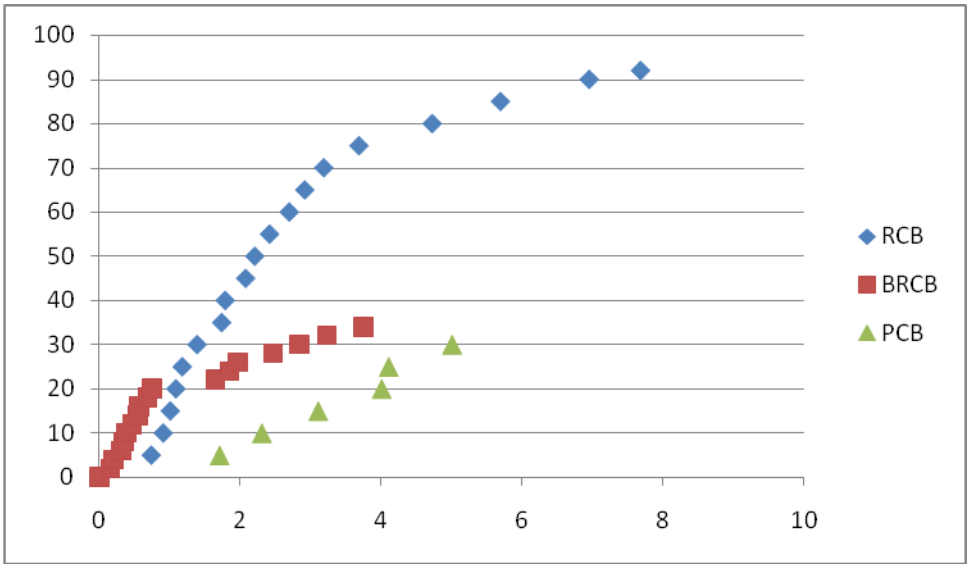

Figure.11 - Load versus Deflection Curve for different types of Beams

Figure.12 - Crack Pattern of the Beam Specimen