PERFORMANCE EVALUATION OF CHEMICALLY TREATED BAMBOO REINFORCED CONCRETE

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

Mr. Abhilash Shukla

(Assistant Professor)

by

Sparsh NK Lath (151697)

Kartikey (151698)

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

May – 2019

STUDENT DECLARATION

We hereby declare that the work presented in the Project report entitled **"PERFORMANCE EVALUATION OF CHEMICALLY TREATED BMBOO REINFORCED CONCRETE"** submitted for the partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Abhilash Shukla.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Sparsh NK Lath Kartikey

151697 151698

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

Date……

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **" PERFORMANCE EVALUATION OF CHEMICALLY TREATED BAMBOO REINFORCED CONCRETE"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the department of Civil Engineering , **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Sparsh NK Lath (151697) and Kartikey (151698)** during a period from August, 2018 to May, 2019 under the supervision of **Mr. Abhilash Shukla** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date:……

Signature of Supervisor	Signature of HOD
Mr. Abhilash Shukla	Dr. Ashok Kumar Gupta
Assistant Professor	Professor and Head
Department of Civil Engineering	Department of Civil Engineering

ACKNOWLEDGEMENT

We pay our gratitude to **Dr. Ashok Kumar Gupta (Professor and Head of Department)** of Civil Engineering at Jaypee University of Information Technology Waknaghat, Solan (H.P.). To provide students of Civil Engineering Department an opportunity to choose desirable individual study and providing well knowledgeable faculty to guide the students throughout their course.

We would like to thank our project supervisor **Mr. Abhilash Shukla (Assistant Professor)** of the Department of Civil Engineering at Jaypee University of Information Technology Waknaghat, Solan (H.P.). The door to Mr. Shukla office was always open whenever we ran into trouble spot or had a question about my research or writing. He consistently allowed this study to be our own work, but steered us in the right direction whenever he thought we needed it.

We would also like to thank **Mr. Itesh Singh (Laboratory Technician)** of the department of Civil Engineering at Jaypee University of Information Technology, Waknaghat, Solan (H.P.). He helped us throughout the cement and concrete testing in the concrete technology lab. His presence and guidelines regarding the experimental work of concrete technology helped us to achieve our results. Without his involvement it would have not been easy to get the accurate results.

Finally, we must express our very profound gratitude to our parents for providing us with unfailing support and continuous encouragement throughout our period of study and through the process of researching and writing this report. This accomplishment would not have been possible without them.

Thank you.

ABSTRACT

In the recent times a lot of construction has been undertaken especially in the developing countries and also due to this urge of construction new technologies have come up and one of those is replacing bamboo with steel as a reinforcement. Using bamboo as a substitute for steel is majorly because of the great cost of reinforcing steel in the reinforced concrete. As a need of the hour, more sustainable alternatives in the construction industry are being found and one such option is utilising bamboo as a reinforcement substitute to the costly steel reinforcements, as conventional bamboo is readily obtainable in various tropical and sub-tropical regions. So, this project helps to evaluate structural and environmental performance of chemically treated bamboo reinforced concrete as an alternative to steel reinforced concrete. Hence the use of appropriate sized whole bamboo culms (bar) or bamboo splint (splits or round strips) has been proposed to replace it as a reinforcement instead of steel. Bamboo splits were used by treating them with adhesives known as Araldite and Sikadur 32-Gel for water-proofing to avoid bamboo swelling in the mix, rising the bond strength and toughness of bamboo as reinforcement. Two tests that were performed are Flexural strength test and Split tensile strength test. The outcomes showed, bamboo with suitable chemical treatment is a strong and sustainable substitute for steel reinforced concrete for lightweight construction.

Keywords – Bamboo, Bamboo-reinforced concrete, Bamboo reinforcement, Concrete, Durability.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER-1

1.1 INTRODUCTION

One of the most extensively used building construction material is concrete. Concrete's strength in compression is quite high but is weaker for tension. Due to this reason steel bars as a reinforcement are used to strengthen concrete and the bars provide the required tensile strength to concrete. Be that as it may, utilization of steel reinforcement has its own detriments such as greater expense and non-sustainability of steels. Aside from these, manufacturing of steel is also responsible for causing greenhouse gas emission. Henceforth, many endeavours have been made by a few scientists to give a minimal effort practical option for steel by utilizing readily and cheaply accessible materials that can substitute it. In such manner, numerous scientists researched the conceivable outcomes of utilizing vegetable fibres reinforcement in concrete. So, regular vegetable fibres materials which have been considered in the past incorporates, jute, sisal, babadua, coconut coir, raffia palms, bamboo, and bamboo fibres and so on. Albeit the vast majority of these investigations yielded great outcomes, bamboo had a reasonable preferred standpoint contrasted to the other characteristic materials tested for reinforcement. Bamboo is a quickly developing substance having wood likewise characteristics and belongs to Poaceae which is a grass family. It achieves its ideal strength, right about the age of 3-4 years and accomplishes the development in 5 years. Bamboo has a tensile strength which is generally extremely high, also some species of bamboo have ultimate tensile strength reaching the same order as of mild steel's yield strength. But the strength of bamboo when contrasted to the specific weight ratio is 6 times more than that of steel. Bamboo likewise of steel bars can accept both tension as well as compression though numerous other fibre vegetable materials considered for strengthening the concrete can't take the same compressive load. Besides, amount of energy required for creating 1 cubic meter per unit stress of steel is to

be precise is fifty times more than the energy required by bamboo. Because of such attributes, bamboo is a material highly considered by numerous researchers to be a sustainable and strong reinforcement substitute for steel reinforcements.

Mansur along with Aziz conducted experiments which helped to assess the achievability of bamboo being utilised as a woven mesh for the purpose of reinforcement. This investigation demonstrated the incorporation of bamboo mesh confers extensive ductility to the mortar and also provides high toughness, and increments essentially to its flexural strength, impact strength and tensile strength. Akeju with help from Falade utilized sand and bitumen covering over bamboo in order to decrease bamboo's water ingestion limit for the purpose of utilising bamboo as a reinforcement for both member types i.e column and beam. Ghavami through his research found out that ultimate load conveying limit of a bamboo reinforced concrete (BRC) is multiple times higher in contrast to unreinforced concrete. Moreover, Ghavami also found that, concrete and bamboo's bonding is lower than in contrast to that of concrete and steel which reduces BRC's tension carrying limit. Prasad et al. utilized cement and sand mortar boards reinforced by bamboo for building ease lodging at bumpy locales. Sand showered along bitumen covered bamboo-mats, they were utilized for development of divider and rooftop components. At that point, cement– sand mortar (1:6 blend) was connected on the two appearances with normal width of 12 mm both to confer strength in order to hold up the structure coming under stresses from impact loads and static loads. Maity et al. suggested utilization of BRC wall boards which were precast, as a substitute to block as well as mud walls for minimal effort home development in provincial regions. Toughness examination of bamboo that Lima et al. conducted presumes that, wetting and drying in CaOH (Calcium Hydroxide) and faucet water even after 60 cycles did not result any variety of its Young's modulus and tensile strength which is an imperative feature fulfilled the utilization for strengthening the concrete by using bamboo reinforcement. Rahman et al. assessed the performance of both

singly reinforced and doubly reinforced BRC beams. Salau et al. explored and researched on BRC columns for their basic strength. The fracture conduct of bamboo reinforced concrete beams as displayed by Terai in association with Minai can be assessed using RCC beams current equation. Yamaguchi also considered the performance for bamboo reinforced concrete beams by replacing steel as primary rebar and stirrups with bamboo in order to convey flexural loads. Through all the researches done until now, the disappointment of bamboo reinforced members is watched for the most part because of frail bond among concrete and bamboo. So, current examinations are being carried out for building higher bond strength of the the bamboo concrete composite. Keeping this vision in mind, adhesive known as Araldite and epoxy known as Sikadur 32-Gel has been utilized for treatment reason. Flexural testing was conducted on plain and BRC beams along with split tensile strength tests on plain and BRC columns to look at ultimate loads and failure mode designs.

1.2 OBJECTIVES

The objectives of this study are:

1. Treating Bamboo with epoxy based coatings to prevent its degradation as a reinforcement.
2. Using Bamboo reinforcement as a replacement of steel without highly affecting the strength of the structure.

CHAPTER-2

LITERATURE REVIEW

2.1 GENERAL

In this study we have read about using bamboo as a reinforcement because in today's developing world there is an urgent need for sustainable development. The work done in this study mainly focuses on using bamboo as an alternative to high cost steel reinforcement as bamboo is cheaper and readily available in many regions of the world especially in developing countries where construction is more frequent. By studying it was also made clear that it is important to chemically treat bamboo to increase the bond strength and also to protect it from swelling by water absorption in the matrix so epoxy's Araldite and Sikadur 32- Gel was used for protective coating over bamboo splits and further testing that has to be carried out to check strength and durability of BRC were studied .

2.2 LITERATURE REVIEW

2.2.1 Khosrow Ghavami (2005)

The goal of this examination is to utilizing Bamboo as reinforcement in basic concrete components. Basically BRC beams, manufactured using laterite, ordinary and lightweight aggregates having a maximum size of 20 mm were tested. The cylindrical sample to be used as a concrete mould of dimensions 150 mm diameter and 300 mm length were used to check the compressive strength of concrete. Through out examination programs utilisation of conventional Ordinary Portland Cement {CP-32) along with river stream sand was carried out.

The concrete of 1:1.4:2.4 of cement, fine aggregates, coarse aggregates respectively was proportioned by weight having a water to cement ratio (w/c) of 0.45, and the extents for lightweight concrete was proportioned at 1:3.22:0.78 by weight with a w/c ratio of 0.55 individually. Cleaning of bamboo braces from outside was done and somewhat roughened. The bamboo reinforcements were dealt with utilizing Sikadur 32-Gel. The testing of beams was done on the completion of 28 days curing period. The test outcomes demonstrated that chemically treated bamboo before utilize improves the concrete and bamboo bonding upto 100%. The ultimate applied load rose to an astonishing 400% after receiving the ideal value of q=3% in contrast to the plain concrete beams. The aftereffects of the examinations demonstrate that bamboo can substitute steel attractively.

2.2.2 Suresh Bhalla, Supratic Gupta, Puttagunta Sudhakar , Rupali Suresh (2008)

The goal of this examination is to utilizing Bamboo as green alternative to concrete and steel for present day structures. This paper has secured the examination and applied plan of a commonplace bamboo based shed construction affected by different combinations of loads. The suggested structure plans on giving a different eco-friendly construction to replace steel's industrial sheds, commonly 10m in range and 5m in height. The rooftop was upheld by tied curves of bamboo and columns were planned as secured by ferrocement ties. Distinctive dead loads, imposed loads and wind loads adjusting to IS 875 section 3 were determined and intended for the testing of the shed structure. The testing was done on bamboo arch curve and furthermore on the bamboo reinforced columns. The axial forces was than determined for M25 as per IS 456 (2000). Diverse wind cases and dead loads were tried together making distinctive conditions and than the tension and compressive axial forces were determined. It was reasoned that bamboo strengthened shed structures can fill different needs, for example, shop for a cottage industry, distribution centre, and for various small-medium ventures. Exclusively is the

construction light contrasted with regular steel but is also in the meantime economical and environment friendly.

2.2.3 Masakazu Terai , Koichi Minami (2011)

The objective of this study is to check the Fracture Behaviour and Mechanical Properties of Bamboo Reinforced Concrete Members. This research was done for the development of BRC and in order to help the masonry work structure's seismic retrofit. An investigation for plausibility and utilisation of some non-steel reinforcing materials and also of bamboo in concrete members was led in the research centre. 6 beam samples to do the testing were developed and the total number of beam tests that were performed were 11 so as to look at the split tensile strength and flexural cracking. Also on 16 column specimens, compression tests that were monotonic were conducted having dimensions 20 cm diameter and 50 cm length with the utilisation of PP-band spirals or binding steel bars, so in order to evaluate the mechanical property of BRC and the crack behaviour. Four sorts of test factors were utilized. With the use of a tensile/compression tester of 5MN limit, loading was applied on columns concentrically, the 3 point bending test and the uniaxial compression tests and were also done. From the test outcomes, accompanying ends were concluded:

a) BRC beam: The outcomes from the test of both reinforced concrete and bamboo reinforced concrete beams are talked about. It was observed that the behaviour of cracking patterns in bamboo reinforced concrete beams was similar to that of reinforced concrete beams, also in correlation of the test information, anticipated split load of bamboo reinforced concrete beam displayed a solid impact. Accordingly, using the RC beam's current equation the fracture behaviour of bamboo reinforced concrete beam can be assessed.

b) BRC column: Through the testing it was clearly affirmed the legitimacy of utilising bamboo for PP Band for Hoop and the longitudinal bar. The bamboo reinforced concrete's ductility can be said to be reliant on concrete's strength.

2.2.4 M. M. Rahman, M. H. Rashid, M. A. Hossain, M. T. Hasan and M. K. Hasan (2011)

The target of this investigation is to check the Performance Evaluation of Bamboo Reinforced Concrete Beam. In this literature, suitable amount of bamboo for the purpose of reinforcement for concrete members was assessed. To survey this, the test of bamboo having three and five nodes for tensile strength was performed. Bamboo sticks having a length of 1m and different cross-sectional areas were utilized in this test. Similarly to evaluate how well bamboo reinforced concrete performs in contrast to plain concrete beam is checked through flexural strength testing. Bamboo reinforced beams having dimensions 150 mm*150 mm*750 mm were used to do this test. The fine aggregates were checked for fineness modulus conforming to ASTM C136 and gradation of coarse aggregates was likewise performed by ASTM C136. So as to lead the testing for strength in tension, bamboo sample were prepared. The bamboo were cut and seasoned for 30 days and were of the dimension 1m length and 20 mm breadth. The concrete which was utilized in the beams had been made utilizing OPC, stone chips (coarse aggregates) with size not more than 20mm and sand (fine aggregate). The concrete mix by cement, fine aggregate and coarse aggregates was proportioned at 1:1.5:2.8 respectively and a w/c ratio of 0.52. 25 MPa strength was intended for the concrete mix at 28 days and 50-70 mm slump value was found out. The concrete moulds used were of cylindrical shape with measurements 0f 300 m length and 150 mm diameter, after that casts are demoulded at 24 hours

mark and then cured for 28 days. Beam specimen had the measurements of 150 mm*150 mm*750 mm . For this examination, 3 sorts of beam were utilized in particular PC (Plain concrete) beam, singly reinforced BRC beam and doubly reinforced BRC beam with the same mould measurements among themselves . For singly reinforced BRC beam 2 bamboo sticks were placed at base with 25 mm clear cover. Correspondingly, for doubly reinforced BRC beam 2 bamboo sticks were placed at both top and bottom with the same cover. Compressive strengthtest of cylindrically shaped concrete specimen was carried out according to the guidelines of ASTM C 39. Similarly for cylindrical shaped concrete moulds the split tension test was carried out by conforming by the guidelines of ASTM C 496. For Flexural strength the setting of beam was cautiously done by setting the support on a measured length of 125mm on the testing machine. Guages of dial are then additionally given on mid span to measure the beam's deflection. The beam placed on the machine was then loaded for one point at the mid span of the beam and load was applied step by step. The beam's deflection at mid span was estimated at steady intervals. The study gives the information of bamboo being a good alternate to steel as concrete reinforcement.

2.2.5 Jigar K. Sevalia, , Chetan S. Agrawal, Nirav B. Siddhpura, Jai V. Kapadia, Deep B. Shah (2013)

The objective of this investigation is the Study of Bamboo as Reinforcement in Cement Concrete. So, as to examine the performance of bamboo these tests were conducted the compression test on cement concrete cubes, flexural strength tests on BRC beams and tensile test for bamboo splits. So, as to conduct the tensile strength test on bamboo splits bamboo of size 520 mm of length and an average 10 mm of thickness were used. So for a better hold in

the UTM (Universal Testing Machine) the bamboo specimen were roughened at both the ends. The compression test was conducted on the cube specimens to legitimate the amount of ingredients to be used to provide the specific strength of concrete. The cubes were prepared of the dimensions 150 mm* 150 mm*150 mm and cured in the water of an open tank for 28 days, after their demoulding that took place over the age of 24 hours and the compressive strength test was finally then conducted. The testing for flexural strength was conducted utilising bamboo of length 730 mm and the dimensions of the mould were 130 mm* 130 mm* 750 mm. The tests were done on three different beam types:

1) Plain Concrete Beam

2) Singly reinforced BRC utilising two bamboo splits having 20 mm of clear cover.

3) Doubly reinforced BRC beams utilising two bamboo splits both at the bottom and the top with a clear cover of 20 mm.

From the above tests it was concluded that:

1) The bamboo splits showcased elastic behaviour.

2) Both the BRC beams have displayed elastic behaviour.

3) Doubly reinforced BRC beams are more elastic than the singly reinforced BRC beams in the flexural tests.

4) There was an rise of 29.3% of load bearing capacity of doubly reinforced BRC beams in contrast to singly reinforced BRC beams.

5) There is a vertical crack development inside the third region of beam on the failure of the beam, which is a proof presence of pure moment with no shear.

6) Doubly reinforced BRC beams have twice the modulus of elasticity in contrast to the singly reinforced BRC beams.

2.2.6 Atul Agarwal, Bharadwaj Nanda, Damodar Maity (2014)

The objective of this study is the Experimental investigation on chemically treated bamboo reinforced concrete beams and columns. Bamboo with proper treatment can possibly substitute steel as reinforcement. The achievability for utilization of an alternate material for reinforcement i.e bamboo in concrete is assessed by progression of investigational examinations in the current literature. In this study bamboo that was locally procured was assessed for its building properties and also the ultimate strength properties. Four adhesive types were used for bamboo's treatment and those were Sikadur 32 Gel, Anti Corr RC, Tapecrete P-151 and Araldite and they were used to increase the matrix bond between the concrete and bamboo. The transverse loading tests and axial compression were conducted on plain concrete column, steel reinforced concrete column and bamboo reinforced concrete columns to measure failure mode pattern, lateral deflection and load carrying capacity. Likewise, to consider the conduct of beams under bending we also conducted two-point load test. All of the tests give us the outline that bamboo can replace steel as a reinforcement with proper chemical treatment. Moulds of dimensions 150 mm*150 mm*1000 mm are used to perform axial compression test. Four columns of each type of following were casted i.e total number of 24 columns were made:

a) Plain Concrete

b) Untreated bamboo reinforced concrete.

c) Chemically treated bamboo reinforced concrete.

d) Steel Reinforced Concrete (0.89% reinforcement).

The casts are demoulded over the time period of 24 hours and curing is done for 28 days. Uniaxial compression machine with a loading rate of 20 kN/minute is used to carry out the testing. The load will be applied on the sample until it fails. It is seen from pull out test that

Sikadur 32 gel as contrasted with all other adhesives that are Anti Corr RC, Tapercrete P-151 and Araldite gives the best bonding between the concrete and bamboo matrix. It was concluded from the axial load test that the first two beam types showcased brittle nature and did not provide with any warning before the failure however all Sikadur 32 Gel treated bamboo reinforced columns show ductile behaviour and provides with just enough warning of the imminent failure of the concrete member. Moreover, from the study it was discovered that, chemically treated bamboo reinforced concrete with 8% reinforcement gives almost the same strength as that of the steel reinforced concrete column used in the tests.

2.2.7 J.G. Moroz, S.L. Lissel, M.D. Hagel (2014)

The objective of this study is to check the Performance of bamboo reinforced concrete masonry shear walls. In this research, 7 masonry walls and the outcomes from their tests different types of loading are accounted for. One of these walls was fortified with regular steel reinforcement. Tonkin cane bamboo was used as reinforcement in other walls in varying amounts and percentages both horizontally and vertically. The study deals with the performance that these reinforced walls give with varying designs of reinforcement and by grouting the walls both partially and completely. A total of 7 of these masonry walls were built utilizing the dimensions of 190 mm*390 mm*190 mm and the regular 200 mm in length being 4 blocks and height block seven courses. This gave us the total dimension of the wall as 1590 mm length and 1390 height. All of the walls were constructed by the same mason , so as to keep up the nature of workmanship for all the walls constructed same. Out of these walls, normal strength concrete blocks was utilised to build 6 of them and the last wall was built a utilising a low strength block.

With the incorporation of bamboo as a reinforcement there was a gradual rise in the ductility and shear capacity of the walls contrasted with plain masonry walls. Indeed, even though there was there was no reinforcement provided horizontally, the shear capacity increased just by the incorporation of vertical bamboo reinforcement.

2.2.8 EfeIkponmwosa, Otu Eyo, Olamiposi Kolajo, Christopher Fapohunda (2015)

The basic structural properties that were examined in the study are: ultimate moment, compressive strength, load–deflection characteristics, crack development pattern, density and failure pattern. The tests were also performed byutilizing the moulds of 150mm*150mm*150mm for density tests and compressive strength. The slab specimen moulds of dimensions 1300mm*500mm*100mm were used for examining flexural behaviour. The outcomes demonstrated that:

(a) PW replacing sand partially helped the concrete specimens which were foam aerated to increase their compressive strength.

(b) The specimen of slab with PW replacing sand partially displayed bending failure in shear

(c) For the same loading all the moulds of slab which had PW's partial replacement with sand displayed lesser deflection.

(d) The bending capacity of all the slab moulds rise with the rise in quantity of PW replacement of sand.

The conclusion from the outcomes of this study are:

1.) As the PW replacement with sand incremented , it also resulted in the rise of compressive strength for all the slab moulds.

2.) Every slab specimen which had sand replaced partially with PW had showed failure in shear, for the control slab specimens as against daigonal shear.

3.) For the same loading on all of the slab moulds which had sand replaced partially with PW gave us lesser amount of deflection as the replacement of the PW rose.

4.) The slab specimen displayed better performance for bending with the rise in the percentage of PW replacing sand.

2.2.9 Amit Singh, A K Singh, Shyam Kishor Kumar (2016)

The objective of this study is the Experimental Investigation on Flexural Strength of Bamboo Reinforced Concrete Beam. As of today, the most broadly utilised development materials on the planet are steel and concrete. From all the testing we know that the tensile strength of concrete is very low but has compressive strength that is quite high. Thusly, we use steel to strengthen concrete in tension because steel has a very high strength in tension when we contrast it with concrete. But there are many issues related to the manufacturing of steel because it is very costly, requires huge amount of energy for its creation and emits large quantity of carbon. So as to solve these problems without compromising the strength of reinforced concrete structural members, it has incited various researcher to search for materials that are readily, cheaply and locally available and can be used as a replacement for concrete reinforcement. So, after testing various materials bamboo is found out to be the most appropriate substitute as reinforcement instead of steel. This study was carried out to evaluate the reasonableness of utilising bamboo as a reinforcement in concrete. So, conforming to the IS code 10262 -2009, a concrete mix of M25 grade concrete was used for the testing. In this venture, two different sizes of beams were chosen, which are of dimensions 150 mm* 150 mm* 700 mm and the

other being of 150 mm*200 mm*700 mm. So, different types of beams were used for flexural testing and those were:

1) PCC beam (Plain cement concrete).

2) BRC beam (Bamboo reinforced concrete).

3) TBRC (Treated bamboo reinforced concrete).

4) SRC beam (Steel reinforced concrete).

The specimens incorporated a total of six beams for all of the above beam sorts.reinforcement area for all beams was kept equal. The materials used for reinforcing the concrete were Fe 415 grade of steel, bamboo splits and chemically treated bamboo splits. Bamboo was utilised in concrete as a reinforcement after seasoning it for 2 -3 weeks. The SRC beam demonstrated the most flexural strength in contrast to other beams. Be that as it may, bamboo fortified concrete beams demonstrated a huge flexural strength rise when contrasted with PCC beam. Consequently, bamboo may very well be prescribed to be used for strengthening the concrete beams for transitory structures and also light weight structures.

2.2.10 Alireza Javadian, Mateusz Wielopolski , Ian F.C. Smith , Dirk E. Hebel (2016)

The objective of the study is the Bond-behaviour study of newly developed bamboo-composite reinforcement in concrete. New innovations have been suggested in thi study in order to save bamboo's mechanical properties and to upgrade the qualities of bamboo physically in order to apply it in construction. Aim of this research is to study bonding properties of bamboo reinforced concrete through pull out test . Different coverings are done on the bamboo to decide bonding behaviour among the recently developed bamboo-composite reinforcement and

concrete. The outcomes from this research show even without covering bamboo composites creates sufficient bond strength with concrete matrix. Anyway covering of epoxy adhesive along sand particles could give additional insurance. The newly developed bamboo reinforced composite specimen were used by cutting them into dimension 0f 10mm by 10 mm of half dog bone shaped bars. This shape of the hold guaranteed slippage was limited in comparison to the past experience from tensile-test setups. 200 mm was the bonding length, various mechanical bonding strategies and 10 different chemicals were utilised for the purpose of this study. The chemical compounds and coatings utilized in this examination are Enamel Coating, a two-section water based epoxy covering, a two-section epoxy gum covering, a Bio-based epoxy resin system, Truegrip BT and EP, ExaPhen covering, a two-section epoxy sap based surfacing system and Moisture seal. An aggregate of 75 tests were readied. Sand utilised was of two different sizes, particle sizes between 0.20 mm-0.30 mm was the first type known as fine silica sand and particle sizes of 0.70 mm-1 mm was the second type known as coarse silica sand. The Ordinary Portland Cement (OPC) of grade 20 was utilized for purpose of examination. For the purpose of limiting the concrete matrix's mechanical properties, just a single kind of concrete mix was utilized in this examination. Pull out test was performed by using composite specimen of dimensions 15cm diameter and 30 cm length . A laboratory mixer of 60 litres capacity was used to prepare the concrete mix. Conforming to ASTM C143 for every batch slump test was performed in order to check the quality of concrete. 95mm-110 mm was the variation of values for each batch of. At a predetermined length of 200 mm the bamboo reinforcements were placed at the centre of the cylindrical specimen; these specimen were then demoulded after a time period of 24 hours and then cured for about 28 days before testing. Cube shaped concrete specimens along with cylindrical shaped samples were tested for checking the strength of concrete at 7 and 28 days. 17 MPa was the average compressive strength at 7 days and 20MPa was found to be the average compressive strength at 28 days. Elastic modulus of concrete

utilised was 25 GPa and tensile strength was 3.5 MPa. So, in order to avoid the chemical reactions harming the concrete-bamboo bonding in the matrix for a longer period of time it is essential to cover bamboo with epoxies and sand on top of it. Because of no critical differences between the two sand types used any one them can be utilised for increasing the strength of bond in matrix

2.2.11 S. Karthik, P. Ram Mohan Rao, P.O. Awoyera (2016)

The objective of the study is to study Strength properties of bamboo and steel reinforced concrete containing manufactured sand and mineral admixtures. In the pursuit to guarantee sustainability of things for the coming generations, different research endeavours are concentrating on utilization of elective resources for the purpose of construction. In this examination, bamboo splits have been utilized for strengthening concrete which was created with valuable cementitious materials also, produced sand known as M-sand was used as fractional replacement to the sand utilised in testing. An adhesive mix of Fly ash and Ground granulated blast furnace slag (GGBS) were used for a partial replacement of 25% to that of cement. In arrangement with standard requirements, concrete specimen were casted and those were of cubical, cylindrical and beam shapes and testing of these was carried out at specified time periods. Bamboo is a durable material and is quite ductile as per the outcomes concluded from tensile strength tests and micro scale testing. The use of the mix of all the adhesives paved way for increase in the strengths both in tension and. In the testing for flexural strength, the BRC made with fly ash, Ground granulated blast furnace slag (GGBS) and Manufactured sand (M-sand) displayed lower performance in contrast to bamboo reinforced concrete containing regular materials. Also, bamboo reinforced concrete created with ordinary components displayed greater bending strength in comparison to the steel reinforced concrete, with an

increase in strength of 6.5%.This examination was centered around the strength properties of both BRC and SRC which are containing produced sand known as M-sand and mineral admixtures. The results concluded under this study are:

a.) Bamboo is a good ductile reinforcing material. It also has tensile strength of high order making it a very appropriate substitute as reinforcement in place of steel. Bamboo has the potential to be a magnificent component for members that bear bending and compression stresses due to its emphatically strong bonded particles

b.) Partial replacement of cement with the adhesive mix of all the three materials used displayed a good strength in compression. Even though, the reference concrete has better qualities than the adhesives use, they can still be utilised as promising materials for some structural construction. However the split tensile strength of the adhesive materials was far better than the reference concrete.

2.2.12 Nabihah Rahmana, Leong Wen Shinga, Lee Simonb, Müller Philippb, Javadian Alirezab, Hebel Dirk E.b, Chen Shui Linga, Lee He Wuana, ng Valavan Sa, Song Sin Neea (2017)

The objective of the study is to examine Enhanced bamboo composite with protective coating for structural concrete application. The specimen were exposed to different corrosive conditions typically experienced amid the lifecycle of building materials to assess the strength of bamboo composite covered with protective epoxy. The specimen at accelerated conditions, were immersed in three different liquid solution for 28 days and those solutions are simulated

acidic rain solution, simulated concrete pore water solution and plain water. To study the effects of various acidic conditions, microstructural examination and tensile tests were performed . The outcomes uncovered that without compromising the mechanical properties of bamboo with utilization of coating epoxy over composite effectively ensured bamboo's trustworthiness, especially in corrosive conditions. Also pull out test was conducted as usual to measure the bonding strength of concrete and bamboo. With the addition of sand particles covering over the epoxy coating on bamboo helped to increase bonding in concrete matrix. Conforming to ASTM D7913 the testing for single rebar was performed with the rebar having a length of 600mm. The bond length of samples was pre planned to being 5 times to that of rebar's nominal diameter (db). Amid every testing, LVDT was utilised to check the slippage of rebar. 1mm/min was the rate of displacement that was used for testing. Strain rate of 2mm/min was used to measure the flexural strength in conformance to ASTM D3039. A total of 5 samples were prepared for each type and were tested under 100kN UTM. Mann-Whitney U Test ($p<0.05$) was utlisied to contrast the different specimen types for mean stresses of tension. This investigation gave the results that the alkaline concrete pore water arrangement had lesser effect over the composite whereas in its comparison the simulated acid rain solution arrangement had a forceful effect towards BFRP. The effects of pore water solution on the composite showcases and supplements the yester year researches that bamboo can withstand the alkaline nature without heavily compromising its mechanical properties in such an concrete environment. The use of Sikadur 31 gel was more of a lose than profit because according to the results even though if it increased the bond strength it was not able to protect the composite BFRP rebar from corrosive attacks and made it more susceptible to the degradation done by alkaline environment. But the BFRP rebar that was coated with BPA based epoxy and sand particles on top of that displayed better resistance to acidic attacks and also increased the bond strength in the matrix.

2.2.13 Wen-Tao Li , Yue-Ling Long , Jun Huang , Yan Lin (2017)

The objective of this study is Axial load behaviour of structural bamboo filled with concrete and cement mortar. This study suggested that by filling the bamboo from inside with concrete or cement mortar the load bearing capacity of bamboo can be increased by many folds. The structural bamboo which was filled with material was tested for axial loading and the effects of the stiffener used, the nodes of bamboo and the materials used to fill bamboo were observed. So, for the infilled bamboo sticks axial compression testing was carried out for a total number of 19 samples. The testing gave enough proof that the bamboo filled with any of the two whether concrete or cement mortar displayed a substantial increase in the load carrying capacity in contrast to the typical bamboo and hence confirmed the plausibility of using infilled bamboo as suggested in the paper. When the two infilled bamboo types were compared i.e concrete filled and cement mortar filled bamboo, the former displayed better ductility in comparison to the latter's testing for ductility. Moreover, in order to increase the ductility of concrete infilled bamboo columns we can also incorporate higher percentage of steel reinforcements. Also, what we can conclude and observe from the testing is that the node of a bamboo infilled with material is very important to it for the bearing capacities. Additionally, stiffener passing through the internode of a material filled or a plain bamboo highly benefits the axial strain capacities and also the ultimate load bearing strength of them. However if the stiffener passes through the node it can decrement the bearing strength of bamboo substantially. At long last, a basic and effective strategy to measure the ultimate bearing strength of bamboo infilled columns was suggested. The strategy that was proposed and the outcomes from it were contrasted with the results obtained by experimental testing and it was determined that the

stiffness and load bearing capacity of both the material fill types of bamboo that are concrete and cement mortar fill are a lot higher when compared to conventional bamboo. So, the plausibility of the suggested hardening plan of structural bamboo was confirmed.

2.2.14 Dr. M.Usha Rani, J.Martina Jenifer (2017)

The objective of this research is Investigation on the flexural behaviour of bamboo reinforced concrete beams. The utilization of bamboo which is quickly developing and biologically well disposed material for basic applications is being considered as very fitting. The tensile strength of bamboo can be upto 125 MPa which is quite high. The utilization of bamboo as a basic component may add to the decrease of material-based energy utilization of a structure. To explore the possibility of utilizing bamboo as a reinforcing material in strengthened concrete members, flexural strength test were conducted on reinforced concrete beams in which all rebars were replaced with bamboo. In this examination nine beams every one of the measurements of 150 mm*150 mm*750 mm were casted to find out the flexural strength. Tests on beam were carried out in flexure under two equivalent concentrated loads each connected at the 1/3 rd point of the beam with the assistance of hydraulic jack. From these experimental works, it was presumed that bamboo can be utilised in non-structural component in low cost construction. In this present investigation nine beams every one of dimensions 750 mm*150 mm*150 mm were cast to examine the flexural strength, out of which 3 beams utilized as a Plain concrete beam. Doubly strengthened concrete was casted. Reinforcement is given on the two sides of the beam with a clear cover of 30mm. Steel stirrups is utilized in both steel reinforced beams and bamboo reinforced beams. Bamboo chose for reinforcement had a normal diameter of 12mm. Three of each steel and bamboo reinforced beams were casted. Plain concrete beam assigned as PCB, Bamboo fortified reinforced concrete beam named as BRCB

and Reinforced Concrete Beam noted as RCB. The experimental examinations completed in the research center to decide the compressive strength of the concrete, tensile strength of bamboo and flexural strength of three kinds of beams plain, bamboo reinforced and steel reinforced beams. To decide the tensile strength test, bamboo sticks of length 750 mm and diameter 12mm were utilized. The sticks were permitted to dry and season for 30 days to gain proper strength and durability. The tensile strength of bamboo splits were tested by utilizing Universal Testing Machine (UTM). Samples are put in UTM and tensile load was measured. The average of the tests outcomes were recorded. The displacement was estimated at regular time intervals. The load is risen at a constant rate always and the relating displacement was recorded. Strain gauge was utilized to check the beam deflection. As the load rises, the deflection likewise increments. Cracking begins to show up in the beam because of of load increase. The study concluded that:

This investigation uncovers that BRC beam has half the flexural strength when we compare it to the flexural strength obtained by beam reinforced with steel.

1. In steel concrete beams, cracks occur at the point of loading and in BRC beam the split is developed just at the centre point of the beam.

2. The deflection of steel concrete beam increments continually with thw application of load, though in BRC beam at first there is a slow increment, and after a specific load, there is a a very sharp increment in the value of deflection.

3. Failure in bamboo due to tension occurs towards the end where as in case of steel the failure happens at the centre.

4. Tensile strength of bamboo when contrasted to that of steel is just one half of it.

5. CO_2 emission can be diminished by roughly 25% by utilizing bamboo in small structural components.

CHAPTER-3
METHODOLOGY

3.1 GENERAL

This chapter consists of all the materials used to carry out this study, the equipment used for the testing of normal concrete and bamboo reinforced concrete specimens. We also study the methodology and preparation of the bamboo as splits to be used as a reinforcement. The chemical treatment of the bamboo that was carried out and how it was casted as a reinforcement will be studied in this chapter.

3.2 MATERIALS AND EQUIPMENTS USED

3.2.1 Materials Used:

The materials required for the testing are as follows:

Table 3.1. Material used for cement and concrete testing

S. No	Material
1.	Ordinary Portland Cement (43-Grade) conforming to IS 8112
2.	Coarse Aggregates.
3.	Fine Aggregates.
4.	Bamboo (Dendrocalamus Strictus)
5.	Epoxy-Araldite.
6.	Epoxy-Sikadur 32 Gel

- Ordinary Portland cement (43-Grade) which was conforming to IS 8112 was used for testing and had been obtained from the cement plant of ACC Limited, Barmana, Bilaspur, Himachal Pradesh.

Figure 3.1 OPC Grade 43

- Coarse aggregates were those whose size which are retained on IS sieve of 475 micron and size upto 40 mm.

Figure 3.2 Coarse Aggregates

- Fine aggregates, these are those aggregates who pass through sieve of 475 micron conforming to Indian standards and having minimum size of upto 0.075 mm.

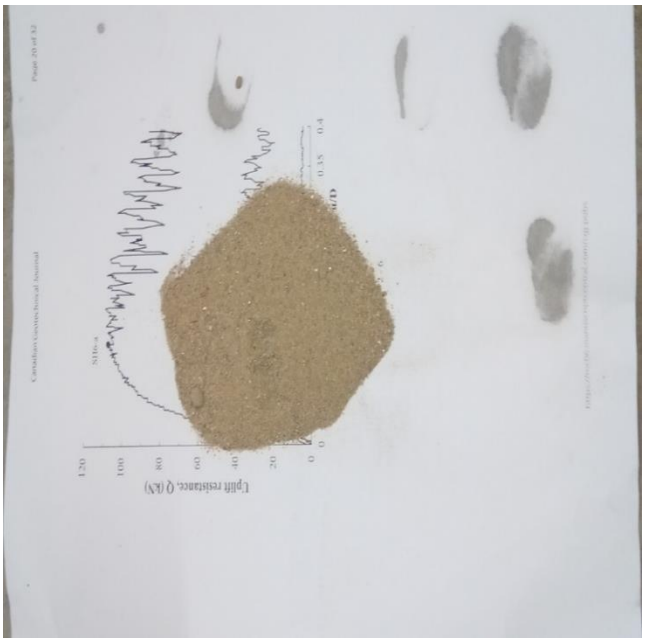

Figure 3.3 Fine aggregate

- The bamboo used was of species Dendrocalamus Strictus which was locally available and was procured from Solan, Himachal Pradesh.

Figure 3.4 Bamboo (Dendrocalamus Strictus)

- Araldite is a thermosetting adhesive and is epoxy based with characteristics such as high creep opposition, lower shrinkage and provides a great level of attachment to every one of the substances aside from few such as some elastomers, low surface energy and untreated plastics. Araldite epoxy provides astounding protection from oil, water and numerous different solvents. It's a two range created epoxy adhesive containing a resin and hardener mixed in 100g resin and 80g hardener

Figure 3.5 Epoxy - Araldite

- Sikadur 32-Gel is a two element bonding agent based on epoxy resins. Sikadur 32-Gel, gives an bond whose strength is very high in comprison to the tensile strength of concrete itself. Sikadur 32-Gel can likewise be utilized as a bonding specialist on steel,mortar,iron and so forth.

Figure 3.6 Sikadur 32-Gel

3.2.2 Equipment Used:

The equipment used for the preparation of cement and concrete samples are as follows:

- Trowel: It is a basic hand tool which is utilised for gauging i.e. shaping, smoothening, spreading and levelling of the concrete or mortar.
- Tamping Rod: Tamping rod is utilised to compact the aggregates and concrete in the moulds to avoid air voids and honeycombing effect in the specimen.

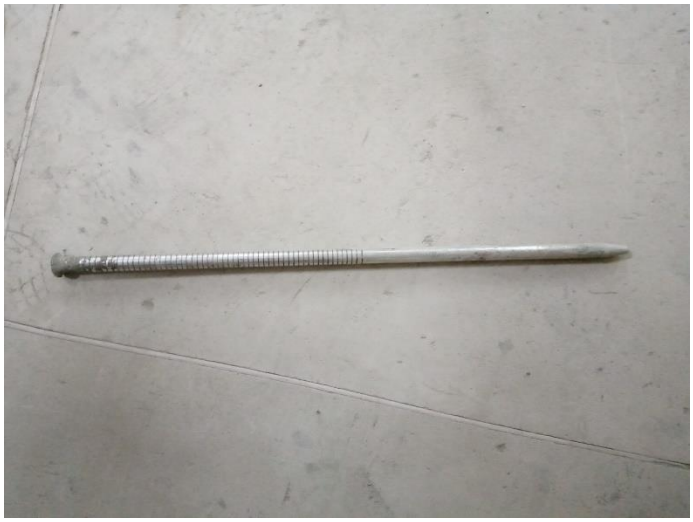

Figure 3.7 Tamping Rod

- Measuring Cylinder: It is a commonly used lab equipment which is basically utilised for measuring the volume of a liquid.
- Sieve: It is the equipment which is used for the particle size gradation of the aggregates conforming to Indian Standards.

Figure 3.8 IS Sieve

- Weighing Balance: Used to weigh the materials as per the appropriate requirement for testing and concrete moulding.

Figure 3.9 Weighing machine

- Stop watch: It is used for noting down the time elapsed from guaging to moulding and for other different testing.
- Vibration Machine: It is used for concrete compaction.

Table 3.2. Equipment used for preparation of Cement and Concrete samples.

S. No	Equipment	Use
1.	Trowel	Gauging of concrete mix
2.	Tamping Rod	Compaction
3.	Measuring Cylinder	Measuring water
4.	IS Sieve	Particle size gradation
5.	Weighing Machine	To weigh materials
6.	Stop-Watch	Note of time
7.	Vibration Machine	Concrete compaction

The equipment and apparatus that were used for testing of cement and concrete samples are:

- Vicat Apparatus: It is used for testing the consistency, initial setting time (IST) and final setting time of cement. Conforming to IS:4031(4)-1988 and IS:4031(5)-1988.

Figure 3.10 Vicat Apparatus

- 90 micron sieve: It is used to check the fineness of cement i.e the cement should pass through the sieve as per the requirements of cement and concrete testing. The sieve conforms to IS:4031(1)-1996.
- Le-Chatelier Flask: It was utilised for measuring the specific gravity of cement conforming to IS:4031(11)-1988.
- Compression testing machine: It was used to find out the compressive strength.

Figure 3.11 Compression Testing Machine

- Flexural Testing Machine: This machine was used to check the flexural strength of different types of beams.
- Universal Testing Machine: This machine is also known as UTM was used to carry out the testing to measure the split tensile strength of the specimen

3.3 METHODOLOGY

3.3.1 Preparation of Concrete testing samples

To carry out the testing Ordinary Portland Cement Grade 43 conforming to IS 8112 was utilised and required testing was conducted to check the basic properties of the cement. A mould of Le-Chatelier was prepared and the Le-Chatelier flask was utilised to find out the specific gravity of cement. A cube shaped specimen of dimensions 70.6 mm*70.6 mm*70.6 mm was made up of mortar (i.e. cement, sand and water), it was then utilized for measuring the

compressive strength of the cement by utilising Compression Testing Machine. The design mix of M30 was prepared.

3.3.2 Design mix of M30 grade of Concrete for 1 cubic metre

- Grade designation : M30 Concrete mix
- Type of cement : OPC 43 grade conforming to IS 8112
- Maximum nominal size of aggregate : 20 mm
- Minimum cement content : 320 kg/m^3
- Maximum water-cement ratio : 0.45
- Workability : 20 mm - 50 mm
- Exposure condition : Severe
- Type of aggregate : Crushed angular aggregate
- Maximum cement content : 450 kg/m^3
- Specific gravity of Cement : 3.15
- Specific gravity of Coarse aggregate : 2.8
- Specific gravity of Fine aggregate : 2.6

The Target Mean Strength for the M30 design mix concrete:

$f'_{ck} = f_{ck} + 1.65\ s$

where, f'_{ck} = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days, and

s = standard deviation.

$f'_{ck} = 30 + 1.65 \text{ X } 5$

= 38.250 MPa

Water to Cement ratio = 0.45

Maximum water content for 20 mm aggregate = 186kg

Therefore, Cement content = 186/0.45

= 413.830 kg/m^3

Volume of Coarse aggregates / Volume of Total aggregates = 0.62

Volume of Fine aggregates/ Volume of Total aggregates = 0.38

Volume of Total aggregates = 1-186/1000 – 413.33/3150

= 0.683 m^3

Therefore,

Mass of Coarse aggregates = 0.683X0.62X2.8X1000

= 1186.688 kg/m^3

Mass of Fine aggregates = 0.683X0.38X2.6X1000

= 674.804 kg/m^3

Hence,

Minimum requirements for M30 concrete mix for 1$m^3$are

- Cement = 413 kg
- Water = 186 kg
- Coarse aggregates = 1186.688 kg
- Fine aggregates = 674.804 kg

3.3.3 Preparation of Bamboo Reinforced Beam samples

To carry out the study of BRC firstly bamboo has to be cut and chemically treated. Bamboo was firstly air dried for 30 days and after that cutting of bamboo took place. The bamboo was cut as “Bamboo Splits” having a diameter of 20 mm and 500 mm in length. The bamboo splits were than chemically treated by applying a thin layer of an adhesive known as Araldite and also with the Sikadur 32-Gel. These splits were then put to the process of air drying for 24

hours for appropriate drying of the epoxy on bamboo splits so as to make it water proof and also to increase the bond strength for the purpose of being used as a reinforcement. After the coating of bamboo was dry it was used as a reinforcement in a beam specimen having dimensions 150 mm*150 mm*500 mm and giving a nominal cover of 20 mm conforming to IS 456 (2000).

Figure 3.12 Bamboo Splits

Figure 3.13 Araldite Coated Bamboo Splits

Figure 3.14 Sikadur 32-Gel Coated Bamboo Splits

Figure 3.15 (a) Bamboo as Reinforcement

Figure 3.15 (b) BRC Beam

3.3.4 Preparation of Bamboo Reinforced Column samples

To prepare the bamboo reinforced concrete column samples the bamboo was firstly seasoned for 30 days. After that it has to be cut and then meant to be chemically treated. The bamboo was cut as “Bamboo Splits” having dimensions of 20 mm diameter and 300 mm in length. The bamboo splits were than chemically treated by applying a thin layer of an adhesive known as Araldite and with Sikadur 32-Gel These splits were then put to the process of air drying for 24 hours for appropriate drying of the epoxy on bamboo splits so as to make it water proof and also to increase the bond strength for the purpose of being used as a reinforcement. After the coating of bamboo was dried it was used as a reinforcement in a column specimen of dimensions 150mm diameter and 300 mm length with a clear cover of 25 mm and minimum reinforcement of 6 bars was used conforming to IS 456 (2000) and the bars were tied together using rebar tie wire.

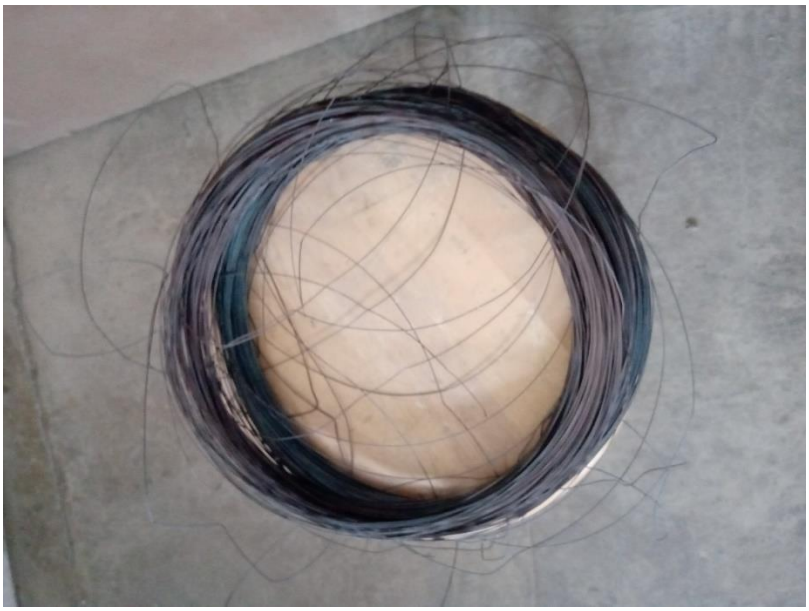

Figure 3.16 Rebar Tie Wire

Figure 3.17 Untreated Bamboo

Figure 3.18 Chemically treated bamboo

Figure 3.19 Araldite coated Reinforcement

Figure 3.20 Sikadur 32-Gel coated Reinforcement

Figure 3.21 BRC Column Specimen

3.3.5 Testing of Construction Materials

To become more acquainted with the fundamental properties and specifications of the cement following tests were carried out.

a) Specific gravity of cement: This test was conducted to measure the specific gravity of the cement. This testing was done by conforming to the IS 4031 (11) – 1988. The equipments used were Specific gravity bottle, Le-Chatelier flask of 250 ml capacity, Pycnometer of 100 ml capacity and Kerosene. The equation to calculate cement's specific gravity is:

$$\text{Specific Gravity } (S_g) = (W_2\text{-}W_1)/(W_2\text{-}W_1)\text{-}(W_3\text{-}W_4)X0.79$$

where, W_1 = Weight of the empty flask.

W_2 = Weight of the flask and cement.

W_3 = Weight of the flask, cement and kerosene.

W_4 = Weight of the flask and kerosene.

Figure 3.22 Le-Chatelier Flask

b) Compressive strength of cement: This test is performed on mortar cubes which are primarily compacted with the help of a standard vibration machine for the calculation of cement's compressive strength. The sample used is of cubical shape having dimensions of 70.6mm*70.6mm*70.6mm and testing of the compressive strength of cement conforms to IS 4031 (6) – 1988. A thorough dry mix is then prepared consisting of 600 g of standard sand of 200 g of cement. Water is than utilized as (P/4+0.3) % of water for testing (where to get the paste of standard consistency P is the percentage of water necessary) to the dry mix sand-cement blended altogether. After, 7 days of curing the mortar cube was then tested for compressive strength.

Figure 3.23 Vibrating Machine

3.3.5 Testing of Concrete samples

To measure the flexural strength of concrete, concrete beams were tested for flexural strength.

a) Flexural Strength of Concrete: To measure the flexural strength of the concrete, concrete beams of measurement 150 mm*150 mm*500 mm were arranged and testing of the samples was done following 7 days and 28 days of curing in an open water tank. The testing were carried out with conformance to IS 516 (1959). Prior to casting the specimen, the moulds are ought to be cleaned properly and given a coating with oil on the inside. The testing machine has two rollers with diameters of 38 mm each and a centre to centre separation of 600 mm and the samples are placed on these rollers. Two comparative rollers which are mounted at the third points that is separated at a centre to centre distance of 200 mm are used to apply the load. The load is applied without any shock and is kept at an continuously rising rate of 0.7 N/mm^2/minute up to specimen's failure

Modulus of rupture = pl/bd^2 (where a>200 mm)

where, a = distance between the line of fracture and the nearest support.

b = width of sample.

d = depth of sample.

l = length of span over which the sample is supported.

p = max load applied on the sample.

Figure 3.24 Normal Concrete Beams

Figure 3.25 Flexural Testing Machine

Figure 3.26 Failure of Plain concrete beam

Figure 3.27 Development of Crack in Sikadur 32 gel BRC beam

Figure 3.28 Failure of Araldite BRC beam in flexural testing

b) Split tensile strength test of concrete: To measure the split tensile strength of concrete cylindrical shaped specimen of dimensions 150 mm diameter and 300 mm length were prepared conforming to IS 5816 (1959). The test comprises in applying a compressive load to the concrete sample until the point of failure because of the prompted stresses of tension in the

sample. Its an indirect method to measure the concrete specimen's tensile strength. The concrete cylindrical specimen is placed such that its axis level lies horizontally between the wooden platens and the compressive loads are applied along the contrary generators. The load is applied on the specimen at a gradual rate of 2 N/mm^2/min until the specimen can bear no more loading. The sample fails by splitting along the loaded diameter. The test is done under Universal Testing Machine (UTM). The equation for splitting tensile strength is:

$$T = 2P/\pi DL$$

Where, P = max load in Newton (N) applied on the sample.

D = diameter of sample in mm.

L = length of sample in mm.

Figure 3.29 Universal Testing Machine

Figure 3.30 Split tensile strength test

Figure 3.31 Failure of Araldite BRC cylinder

Figure 3.32 Failure of Sikadur 32-Gel BRC cylinder

Figure 3.33 Failure of bamboo reinforcement

CHAPTER-4

RESULTS

4.1 GENERAL

The results which were obtained from different testing, are considered in this chapter. The result part consists of testing cement and also of normal and bamboo reinforced concrete beams for the flexural strength.

4.2 RESULTS

4.2.1 Results of Cement testing

After conducting the required essentials tests for the specifications of the OPC the following results were obtained:

Table 4.1 Result values of material used after experimentation.

Sr. No	Experiment	Result Values
1.	Specific Gravity of Cement	3.14
2.	Compressive Strength of Cement	43 MPa

4.2.2 Results of Concrete Testing

a) Flexural Strength Testing: It was determined using Flexural Testing Machine after 7 days and 28 days of curing in water. The testing was done for four different types of beams:

1. Plain Concrete.
2. Bamboo Reinforced Concrete.

3. Bamboo Reinforced Concrete (Araldite Coated)
4. Bamboo Reinforced Concrete (Sikadur 32-Gel Coated)

Table 4.2 Flexural Strength at 7 Days

Sr. No	Type of Beam	Days	Flexural Strength	Average Flexural Strength
1.	Plain Concrete	7 days	2.30MPa	2.31 MPa
		7 days	2.32 MPa	
2.	Bamboo Reinforced Concrete	7 days	3.63 MPa	3.64 MPa
		7 days	3.66 MPa	
3.	Bamboo Reinforced Concrete (Araldite Coated)	7 days	4.18 MPa	4.19 MPa
		7 days	4.20 MPa	
4.	Bamboo Reinforced Concrete (Sikadur 32-Gel Coated)	7 days	4.48 MPa	4.48 MPa
		7 days	4.49 MPa	

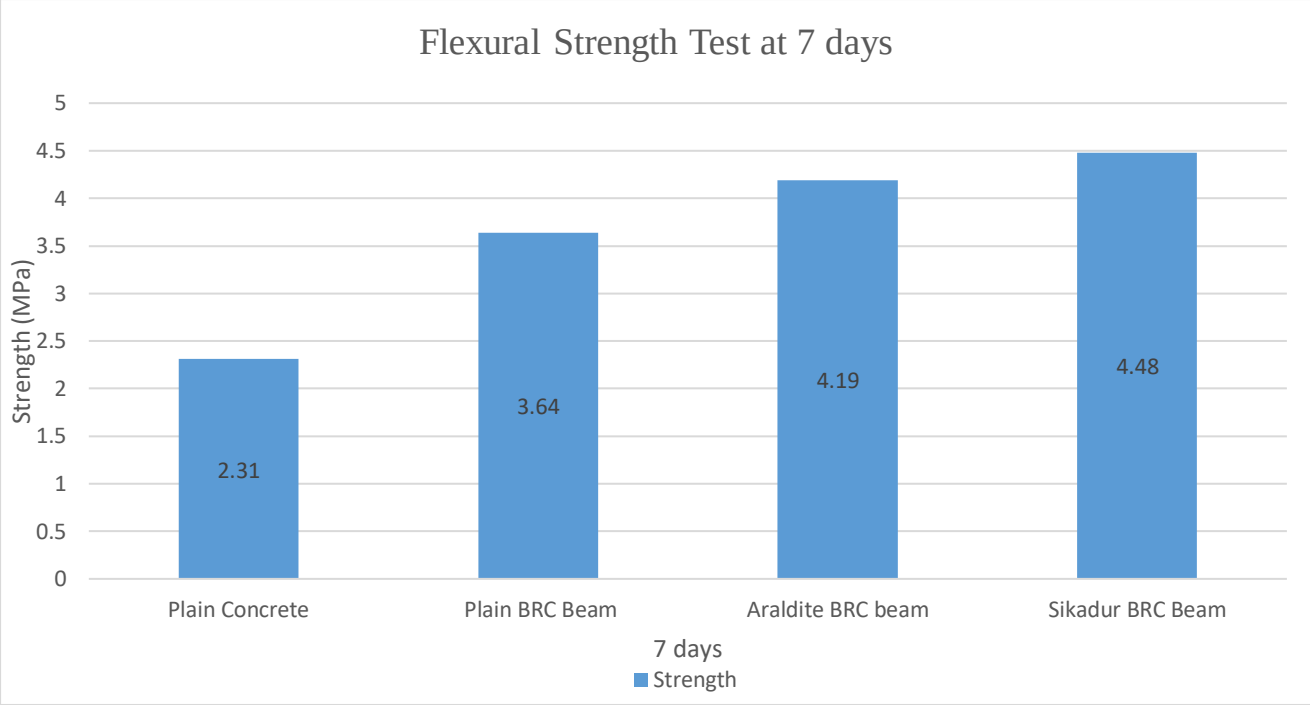

Figure 4.1 Flexural strength of Beam specimen at 7 days

Table 4.3 Flexural strength at 28 days

Sr. No	Type of Beam	Days	Flexural Strength	Average Flexural Strength
1.	Plain Concrete	28 days	3.52MPa	3.53 MPa
		28 days	3.54 MPa	
2.	Bamboo Reinforced Concrete	28 days	5.93MPa	5.93 MPa
		28 days	5.93 MPA	
3.	Bamboo Reinforced Concrete (Araldite Coated)	28 days	6.57MPa	6.58 MPa
		28 days	6.58 MPa	
4.	Bamboo Reinforced Concrete (Sikadur 32-Gel Coated)	28 days	7.01MPa	7.02 MPa
		28 days	7.04 MPa	

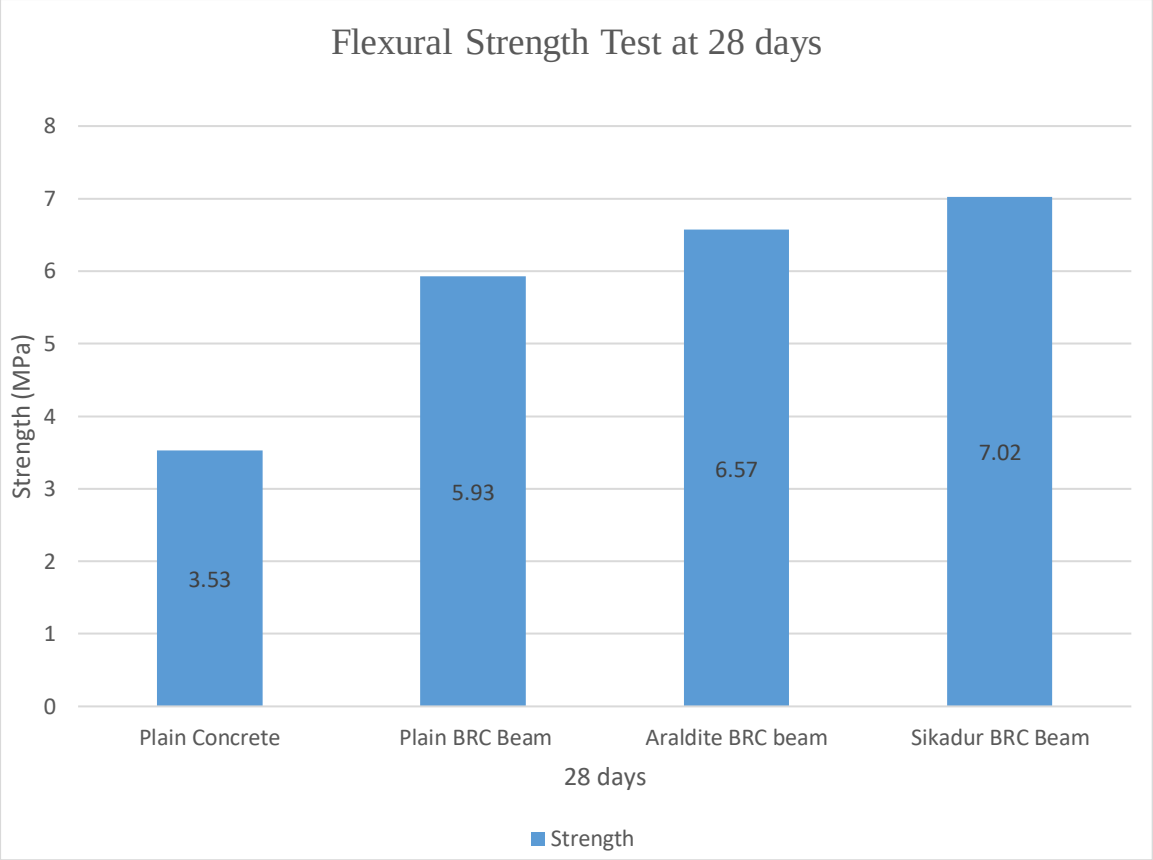

Figure 4.2 Flexural strength of Beam specimen at 28 days

b) Split tensile strength test: The cylinders were tested for split tensile strength by utilising Universal Testing Machine after curing of 7 days and 28 days. The tests were carried out for four different types of cylinder specimen:

1. Plain Concrete.
2. Bamboo Reinforced Concrete.
3. Bamboo Reinforced Concrete (Araldite Coated).
4. Bamboo Reinforced Concrete (Sikadur 32-Gel Coated).

Table 4.4 Split Tensile Strength at 7 days

Sr. No	Type of Column	Days	Ultimate Load	Split Tensile Strength
1.	Plain Concrete	7 days	92.3 kN	1.31 MPa
2.	Bamboo Reinforced Concrete	7 days	122.3 kN	1.73 MPa
3.	Bamboo Reinforced Concrete (Araldite Coated)	7 days	148.7 kN	2.10 MPa
4.	Bamboo Reinforced Concrete (Sikadur 32-Gel Coated)	7 days	173.7 kN	2.46 MPa

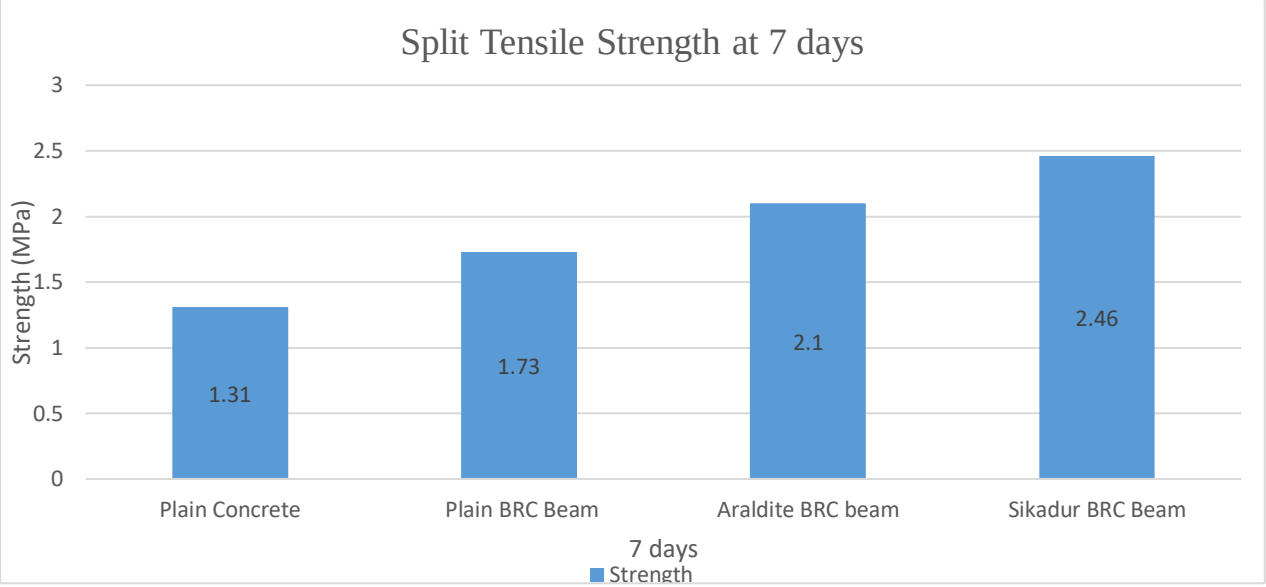

Figure 4.3 Split Tensile strength of Cylinder specimen at 7 day

Table 4.5 Split Tensile Strength at 28 days

Sr. No	Type of Column	Days	Ultimate Load	Split Tensile Strength
1.	Plain Concrete	28 days	218.3 kN	3.09 MPa
2.	Bamboo Reinforced Concrete	28 days	291.7 kN	4.13 MPa
3.	Bamboo Reinforced Concrete (Araldite Coated)	28 days	328.1 kN	4.64 MPa
4.	Bamboo Reinforced Concrete (Sikadur 32-Gel Coated)	28 days	360 kN	5.01 MPa

Figure 4.4 Split Tensile Strength of Cylinder Specimen at 28 days

CHAPTER – 5

CONCLUSION

5.1 CONCLUSION

After conducting various test and analysing the experimental results of our M30 mix design concrete beams and concrete columns which were of four types:

1. Plain Concrete.
2. Bamboo Reinforced Concrete.
3. Bamboo Reinforced Concrete (Araldite Coated).
4. Bamboo Reinforced Concrete (Sikadur 32-Gel Coated).

It was noted that bamboo with suitable chemical treatment has the potential to be used as a promising reinforcement material and after conducting flexural and split tensile strength testing on various specimen following conclusions were made:

- Both treated and untreated BRC beams and columns displayed ductile behaviour and gave a warning before the imminent failure in contrast to the plain concrete beam which did not display any signs before failure.
- Some of the specimen of untreated BRC beam also displayed cracking and debonding of the matrix due to selling up of bamboo inside the composite and provided with the need of chemical treatment to avoid water absorption.
- Both treated and untreated BRC specimen performed very well and gave high values of strength in comparison to the conventional unreinforced concrete specimen

- Sikadur 32-Gel gave the best results among the two adhesives used and had better bond, flexural and split tensile strength in comparison to the other plain, treated and untreated specimen.

From all the testing and observations done to carry out this study it can be said that bamboo as a reinforcement is a viable and sustainable replacement for steel and can be used readily in developing countries like India where bamboo is available in vast majority especially in the rural areas where it can be so useful for the construction of lightweight and temporary structures.

REFRENCES

1. Ghavami, K., 2005. Bamboo as reinforcement in structural concrete elements. *Cement and concrete composites*, *27*(6), pp.637-649.

2. Bhalla, S., Gupta, S., Sudhakar, P. and Suresh, R., 2008, October. Bamboo as green alternative to concrete and steel for modern structures. In *International Congress Of Environmental Research (ICER)*,11,pp.510 - 528

3. Terai, M. and Minami, K., 2011. Fracture behavior and mechanical properties of bamboo reinforced concrete members. *Procedia Engineering*, *10*, pp.2967-2972.

4. Rahman, M.M., Rashid, M.H., Hossain, M.A., Hasan, M.T. and Hasan, M.K., 2011. Performance evaluation of bamboo reinforced concrete beam. *Int J Eng Technology*, *11*(4), pp.142-146.

5. Sevalia, J.K., Siddhpura, N.B., Agrawal, C.S., Shah, D.B. and Kapadia, J.V., 2013. Study on bamboo as reinforcement in cement concrete. *Int. JERA*, *3*(2), pp.1181-1190.

6. Agarwal, A., Nanda, B. and Maity, D., 2014. Experimental investigation on chemically treated bamboo reinforced concrete beams and columns. *Construction and Building Materials*, *71*, pp.610-617.

7. Moroz, J.G., Lissel, S.L. and Hagel, M.D., 2014. Performance of bamboo reinforced concrete masonry shear walls. *Construction and Building Materials*, *61*, pp.125-137.

8. Ikponmwosa, E., Fapohunda, C., Kolajo, O. and Eyo, O., 2017. Structural behaviour of bamboo-reinforced foamed concrete slab containing polyvinyl wastes (PW) as partial replacement of fine aggregate. *Journal of King Saud University-Engineering Sciences*, *29*(4), pp.348-355.

9. Javadian, A., Wielopolski, M., Smith, I.F. and Hebel, D.E., 2016. Bond-behavior study of newly developed bamboo-composite reinforcement in concrete. *Construction and Building Materials*, *122*, pp.110-117.

10. Karthik, S., Rao, P.R.M. and Awoyera, P.O., 2017. Strength properties of bamboo and steel reinforced concrete containing manufactured sand and mineral admixtures. *Journal of King Saud University-Engineering Sciences*, *29*(4), pp.400-406.

11. Rahman, N., Shing, L.W., Simon, L., Philipp, M., Alireza, J., Ling, C.S., Wuan, L.H., Valavan, S. and Nee, S.S., 2017. Enhanced bamboo

composite with protective coating for structural concrete application. *Energy Procedia*, *143*, pp.167-172.

12. Li, W.T., Long, Y.L., Huang, J. and Lin, Y., 2017. Axial load behavior of structural bamboo filled with concrete and cement mortar. *Construction and building materials*, *148*, pp.273-287.