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SCHOOL OF CIVIL ENGINEERING & ARCHITECTURE**

**Department of Construction Management Technology Teacher Education
A Project in partial fulfillment of the requirement for the Degree of Master of
Science in Construction Management Technology Teacher Education**

**USING BAMBOO AS ROOF TRUSS AND REINFORCEMENT BAR IN
BUILDING CONSTRUCTION**

BY

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June, 2007 E.C

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APPROVAL BY BOARD OF EXAMINERS

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DECLARATION

We hereby declare that the work which is being presented in this project entitle “**Using Bamboo As Roof Truss and Reinforcement Bar in Building Construction**”, is our original work and has not been presented for a diploma / degree of any other Institution/University and we have acknowledged and referenced all materials used in this work.

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This is to certify that the above declaration made by the candidates is correct to the best of my knowledge and belief. This project has been submitted for examination with my approval.

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ACKNOWLEDGEMENT

We would like to acknowledge the effort of different scholars, Authors, Institutions and so many individuals who directly or indirectly contributed to the successful completion of this project.

First and for most we would like to acknowledge our dearest and respected advisor of. **Fikadu Mehrete** for his insightful direction and Guidance throughout the project. His supports have been invaluable in realizing and completing this project.

Ato Ashenafi Teka, site engineer at Adama town , his kind cooperation to us and his professional advice was appreciable during preparing sample at the site.

We would also appreciate the following individuals in Adama town micro small enterprises who work bamboo products, **Ato Tilahun Niguse** and **Ato Tesfahun Dinku** and other their partners their contribution have been very significant.

Last, but by no means least, we owe a great debt of our university adama science and technology for their supporting financially to implement the project,

ABSTRACT

Now a day different construction works are constructed by miscellaneous modern and traditional materials the following are most common materials for different construction works those are concrete, stone, metal, wood, cement, aluminums, bamboo, steel, glass, iron, mud, etc. Out of these construction materials this project will attempt to address the problem of house for low income group peoples who live in urban area and also to change the straw house of the farmer in to Low cost modern house by using bamboo as reinforcement bar in concrete and as roof truss .

The objective of this project is to minimize the cost and have good quality of house for low and middle level income societies by substituting the steel reinforcement bar and wood roof truss using bamboo reinforcement and bamboo roof truss respectively .

In order to determine the physical, mechanical, and cost analysis we are different laboratory tests and secondary data from different literature to assure bamboo substitute steel reinforcement and wood roof truss.

This project laboratory test result shows that bamboo used as substitute of steel reinforcement in low cost building.

The study also briefs the selection, preparation, placement of Bamboo for reinforcing the concrete and roof truss.

Cost comparison between steel and asphalt coated bamboo is presented as per cost breakdown referring to the present market assessment. As per cost analysis, use of bamboo reinforcement is a better and economical alternative in view of overall cost.

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Acronym and Symbols

RCC	Reinforced Cement Concrete
BRC	Bamboo Reinforced Concrete
KM	Kilo Meter
H	High Land
L	Low Land
SSMI	Small-Scale Micro Enterprise
EMC	Equilibrium moisture content
MC	Moisture content in
D	Density
KN	Kilo Neuter
ϵ	Strain
E	Modulus of Elasticity
σ	Stress
δ	Deflection
mm	Millimeter
m ²	Meter Square
m ³	Meter Cube
ISO	International Standard Organization
V	Volume
R	Radial
T	Tangential
L	Longitudinal
MPa	Mega Pascal

CHAPTER ONE

1. INTRODUCTION

1.1 General Backgrounds

Construction industry may be defined as the production, alteration, renovation, maintenance, facility management, demolition, and re-cycling of building and civil engineering works, including the supply of resources. It includes those who promote the industry's policies, procedures, practices, and culture, which help the industry to fulfill the tasks required of it and thus satisfy its internal and external stakeholders. Now a day different construction works are constructed by miscellaneous modern and traditional materials the following are most common materials for different construction works those are concrete, stone, metal, wood, cement, aluminums, bamboo, steel, glass, iron, mud, etc. Out of these construction materials this project emphasis for urban low income group people and for rural people house which is built by using bamboo as a reinforcement bar and roof truss.

Bamboo is one of the oldest building materials used by mankind [1]. Has been used since 3500 BC and has more than 1500 documented uses. The bamboo Culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. In Asia, bamboo is quite common for bridges, scaffolding and housing, but it is usually a temporary exterior structural material. In many overly populated regions of the tropics, certain bamboos supply the one suitable material that is sufficiently cheap and plentiful to meet the extensive need for economical housing [9].

Bamboo is available in commercial quantities using the established supply system. It is a renewable plant with a short rotation period. Bamboo grows to its full size for about a year. Another two or three years are required for the plant to gain its high strength. Bamboo can be grown even on degraded land. Construction materials from bamboo should be treated in order to achieve longevity. The use of high energy materials, like cement or steel, is minimized. Therefore the adoption of bamboo for house construction helps preserve the environment. Experts have evaluated natural fiber such as bamboo, that are locally available, relatively less expensive, low energy demand during production, environmental friendly and 100%bio-degradable as possible substitutes for steel reinforcement and steel mesh.

Bamboo has a very efficient natural structural design; because of the hollowness and the fibers in longitudinal direction, less material mass is needed than in case of materials with a massive section, e.g., timber. The efficiency of the natural design of bamboo is in the strength and stiffness of various materials is dividing by their mass per volume [5]. Bamboo is an extremely strong fiber with twice the compressive strength of concrete, and roughly the same strength to weight ratio of steel in tension. In addition, testing has shown that the shape of bamboo is hollow tube gives it a strength factor of 1.9 times over an equivalent solid pole. The reason being that in a beam, the only fibers doing the work are those in the very top (compression) and bottom (tension). The rest of the mass is deadweight. The strongest bamboo fibers have a greater sheer resistance than structural woods, and they take much longer to come to ultimate failure.

The structural advantages of bamboo are its strength and light weight whereby properly constructed bamboo buildings are inherently resistant to wind and earthquakes. The construction materials for building a bamboo house should be readily available and accessible. Traditionally used construction materials are considered. The bamboo based house has a very low weight therefore foundations can be minimized. For wall construction are used precast Wall panels which is assembled from split bamboo grids, chicken steel mesh and plastered with Cement mortar. Bamboo can tolerate high values of deformations in the elastic range i.e. possesses high elasticity. Therefore bamboo houses when properly constructed are ductile i.e. being able to sway back and forth during an earthquake, without any damage to the bamboo poles.

The aim of the project provided here is to use bamboo as alternative construction materials to use as a reinforcement bar and roof truss to address the problem of house for low income group peoples who live in urban area and also to change the straw house of the farmer in to Low cost modern house by using bamboo as reinforcement and roof truss. The materials are sustainable, durable, and can often be locally obtained.

1.2 Statement of the Problem

It is well known that many of people in Ethiopia both in urban area and rural area either homeless or inadequately housed. It is also evident that this housing crisis is worsening day by day due to low income of our society and raising the cost of current construction material. In order to improve this problem however there is a need to invest a substantial amount of money in to the development of houses. As this may be difficult to achieve in the short-term, what other

alternative exist? What can be provided as an alternative? This project, therefore, will attempt to address the problem of house for low income group peoples who live in Metahara town urban and rural area and also to change the straw house of the farmer in to Low cost modern house by using bamboo as reinforcement and roof truss .This project also attempted to answer for the following questions:-

- ✓ How does bamboo reinforcement and roof truss minimize the cost of the house as compared to building which have reinforcement bar in structural element of building and wooden roof truss?
- ✓ What are the requirements of bamboo that substitute other building structural Materials such as steel and wooden?
- ✓ To quantify the sustainable benefits and environmental impacts of structural bamboo
- ✓ shows structural applications and structural benefits of bamboo is also presented to provide an introduction to historical, current, and envisioned uses as a construction material in its natural form as well as in the form of engineered products.

1.3 Objectives of the Project

1.3.1 General Objective

This project aimed to having home owner for low and middle income of our society in urban and rural area by construction of a low cost and quality house by using bamboo as roof truss and as reinforcement bar in concrete with other material.

1.3.2 Specific objective

- ✓ To minimize the cost of the house by constructing low cost house by using bamboo as reinforcement bar in concrete and as roof truss material in roof construction.
- ✓ To identify the physical and mechanical properties of bamboo that substitutes steels and wooden truss
- ✓ To show the sustainable benefits and environmental impacts of bamboo

1.4 Significance of the Study

The project has the following advantages:

- ✓ To minimize the shortage of houses in urban and rural area especially in which bamboo is cultivate.
- ✓ To minimize the adverse consequences of deforestation in the environment.
- ✓ To improve the of livelihood of rural community
- ✓ It enable house owner for low & middle level income societies
- ✓ To promote new technology
- ✓ To create job opportunities for Small-Scale Micro Enterprise (SSMI)

1.5. Scope of the project

The project's intension is to describe the bamboo as alternative construction materials to use as a reinforcement bar and roof truss in building to solve the problem of house for low income group peoples who live in urban area and also to change the straw house of the farmer in to Low cost modern house by using bamboo .

Our target area is at Metehara town of urban and rural community as well as for the future it will propagate and adapt to the other parts of the country. This will enable for our country to address housing shortage in urban and rural area and get economical advantage from bamboo.

1.6. Project Methodology

1.6.1 Methodology

The methodology of this project mainly concentrate on the general procedure , the test result and the respondent data in terms of construction methodology, cost analysis, Comparison of bamboo with steel and wood truss .

1.6.2 Source of Data

- Primary data from laboratory test result
- Secondary data from archives and literature review

1.6.3 Methods of Data Analysis

To achieve objective of this study all the data obtained has been analyze and presented to conclude that bamboo used to substitute steel reinforcement and wood roof truss.

1.6.4 Project Construction Methodology

The construction of this project is very simple, very low weight and need less skill because the material to be used is flexible to use for construction purpose and easily Available in our local area. Bamboo reinforced concrete work is characterized by a structural frame approach similar to that RCC reinforced cement concrete work of any building structural element like beam & column.

1.7 Obtaining quality bamboo

Do not use green, fresh cut bamboo. Bamboo has to be completely dry before using it in construction (preferable air dried).

- ✓ Depending on the species, 3 to 5 year old bamboo is best for construction purposes
- ✓ The bamboo should be harvest in dry season in order to avoid fungus& excess moisture
- ✓ Use the appropriate species for the particular application.
- ✓ Do not expose the bamboo to direct sun, moisture and rain.
- ✓ Use only straight portions from the bamboo culms for construction
- ✓ Bamboo should be treated against insects and fungus.
- ✓ Do not use bamboo poles with profound vertical cracks.
- ✓ Use appropriate cuts and joints when building with bamboo.

1.8 Limitation of the Project

The rationale for this project is based on the fact that the emergence of new materials (bamboo) and technologies could possibly have a significant impact in the largest market sector for construction materials. To put this into context, the following are some of the key challenges or limitation which is likely to be influential in the construction of the project:

- ✓ Lack of experience to construct such types of building
- ✓ Limited funding for the project construction.
- ✓ Lack of treatment technologies which enhance in service performance
- ✓ Lack of work shop access at required time due to different inconvenient situation.
- ✓ Lack of experimental or testing machine.

CHAPTER TWO

2. LITRATURE RIVIEW

2.1 The Indigenous Bamboo Forests of Ethiopia

Two indigenous species of bamboo, *Oxytenanthera abyssinica*(lowland bamboo) and *Yushane alpine* (highland bamboo), grow in the south-west, south and central parts of Ethiopia in an area close to 4,000 square miles[4] . Due to the lack of sufficient rainfall the eastern part of the country does not support bamboo habitation. Overall Ethiopia has the largest bamboo growing area in Africa.

Oxytenanthera abyssinica grows up to 20 feet in length and 2 inches in diameter, While *Yushane alpine* can reach up to 60 feet high and 4 inches in diameter. Of the total consumption of bamboo in Ethiopia, only 15% *Oxytenanthera abyssinica* and 20% of *Yushane alpine* is used for construction.⁵ Although its use may be limited in a nationalscale, people in bamboo growing parts of the country greatly depend on this resource. Situated in the eastern highland of tropical Africa, Ethiopia has a wide area covered with natural bamboo forests. However, this asset together with its biological diversity is being decimated due to high population pressure, weak economic growth, and slow technological development, adoption and distribution. This situation compels rural people to clear forest areas to expand agricultural land, in order to procure materials essential for construction and fuel wood [10].

Bamboo, the fastest growing perennial plant, would have been the obvious candidate. This trend for introducing new species continues. More and more exotics are being introduced, while indigenous species like bamboo which could grow even faster and could serve similar purposes are being destroyed. In the past, Bamboo forests were located in the more inaccessible areas, which protected them from destruction. The highland bamboo forest at Masha, south-western Ethiopia, and the lowland bamboo forests at Assosa, Metekel, and Manbuk, in western Ethiopia are examples [10].Bamboo has a high potential value, as has been learned from tropical Asia.

The need to utilize this resource wisely on a sustainable basis and to conserve it for future generations, may top the agenda list for tomorrow, but this could be too late. Decisive practical action is needed today, before indigenous bamboo species disappear entirely. This species require further research to develop them as useful commodities and as essential tools in environmental conservation.

Bamboo area	Region	NFPA	Type	Area in ha
Injibara	Amahara	-	H.famrmer	
Hinde(180km N of nekemte)	Amahara	-	L.natural	8,670
Asosa(20-50kmE)	Benishangul/gumuz	-	L.natural	77,947
Bambesi(10-50to E)	Benishangul/gumuz	-	L.natural	64,245
Begi (20-50km toSW)	Benishangul/gumuz	-	L.natural	21,509
Demi(75km NE of nedjo)	Benishangul/gumuz	-	L.natural	27,6152
Dibate(75km SW of chagni)	Benishangul/gumuz	-	L.natural	12,200
Guba (50km toS)	Benishangul/gumuz	-	L.natural	7,757
Kamashi(40km E of nedjo)	Benishangul/gumuz	-	L.natural	33,723
Pouwe(10-50km E of mabuk)	Benishangul/gumuz	-	L.natural	53,830
Agaro	Oromiya	-	H.famrmer	-
G era	Oromiya	+	H.famrmer	-
Bale mountain	Oromiya	-	H.natural	56,851
Shenen,jibat mountain	Oromiya	-	H.natural	1,774
Gimbi (25km toE)	Oromiya	-	L.natural	29,125
Guten (50km N of nekemte)	Oromiya	-	L.natural	6,044
Gera bamboo forest	Oromiya	-	H.natural	1,052
Gera-lola (50km W of Gera)	Oromiya	-	H.natural	34,493
Agere selam- bore	South Eth. Admin.	+	H.famrmer	-
Chencha	South Eth. Admin.	-	H.famrmer	-
Indibir-jembero	South Eth. Admin.	-	H.famrmer	-
Jima-ameya	South Eth. Admin.	-	H.famrmer	-
Mizan tefere -kulish	South Eth. Admin.	-	H.famrmer	-
Wushwush-bonga	South Eth. Admin.	+	H.famrmer	
Bonga ameya(10-20kmtoS)	South Eth. Admin.	+/-	H.natural	7,997
Masha	South Eth. Admin.	+/-	H.natural	18,652
Shashemene	South Eth. Admin.	+	H.natural	4,183

H=high land , L= low land

Table 2.1 Major Bamboo Areas in Ethiopia (lousoconcelt,GMBH.2000)[10].

2.2 Ethiopian Bamboo as a Resource Material in relation to Africa and the World

Ethiopia has two indigenous bamboo species; the African alpine bamboo (*Yushane alpine* K.Schumann Lin; synonym: *Arundinaria alpine* K.Schumann) and the monotypic genus lowland bamboo *Oxytenanthera Abyssinica* [7]. These species are also found in some other African countries, but nowhere else outside the African continent. They are indigenous to Ethiopia and endemic to Africa, confined to the sub-Saharan region. More than 1500 bamboo species are found in the world, covering 14million ha of land. About 80% of these species are found in tropical and sub-tropical Asia. Africa has only 43 species occurring on 1.5 million ha. Of these, 40 are mainly found in Madagascar while the remaining 3 are in mainland Africa. Ethiopia has about 1 million ha of highland and lowland bamboos, the latter being dominant (850,000ha). Thus 67% of African bamboo resources and more than 7% of the World total are found in Ethiopian [4].

2.3 Bamboo Growths

Bamboo is very fast in propagations it is the fastest growing plant in the world. A bamboo plantation the first year will grow stably and if well managed in the second year and third year people can harvest for shoots which can be used as vegetable, the fourth and the fifth year it will be mature for use. Bamboo plantation can last for sixty years [2].

2.4 Bamboo Utilization

Bamboo provides goods and services useful to mankind. It is a source for food, fodder, furniture, building materials, paper, particle board, energy, and medicine. It also plays a vital role in environmental protection, biodiversity preservation, soil conservation and waste purification [8]. The present use of bamboo in Ethiopia is low, mainly limited to tukul (hut) construction, fencing, and to a lesser extent for the production of furniture, containers for water transport and storage, baskets and agricultural tools, household utensils and various articles.

This low level of utilization is due to bamboo's susceptibility to biological and physical deterioration. The durability of bamboo products is believed to be short. Although various treatments are available to increase its service life, people are unaware of these technologies. Bamboo is still considered as a perishable material and, hence, useless, which has led to its

neglect as a useful renewable resource. Its potential for construction and industrial use has yet to be popularized and accepted by both potential investors.

Bamboo utilization is available from tropical Asia. In Nepal, bamboo is used in more than 180 ways. More than 300 machine-intensive bamboo-processing factories have been established from 1985-1992 in Malaysia [8]. Bamboo is widely used in large quantities for pulp and paper production in India, China, Indonesia and other Asian countries. Bamboo pulp is high grade, and the chemical recovery problems arising from high silica content have now been solved by decalcification. In Burma, Bamboo is extensively used as a roofing material. Good quality activated carbon can also be produced from bamboo. Excellent quality particle board that meets Type 1, British standard, requirements is produced from bamboo [1].

In this way, rural people can satisfy their own needs and supplement their income. Bamboo is also the preferred material for shade construction in plant nurseries, and for props to support the growth of agricultural crops like banana, tomatoes, and flowers.

2.5 Selection, Harvesting and Preparation of Bamboo for the Purpose Housing System

2.5.1 Selection

The selections of bamboo, only bamboo showing a pronounced brown color was used to ensure that the plant is at least three years old. The longest large diameter culms available were selected. Whole culms of green, unseasoned bamboo were not used. Bamboo cut in spring or early summer was avoided. These culms are generally weaker due to increased fiber moisture content. Splints (split culms) are generally more desirable than whole culms as reinforcement. Larger culms should be split into splints approximately $\frac{3}{4}$ th inch wide and length of approximately 1.49 meters of which 30mm is embedded in the footing. Splitting the bamboo can be done by separating the base with a sharp knife and then pulling a dulled blade through the Culm. The dull blade will force the stem to split open; this is more desirable than cutting the bamboo since splitting will result in continuous fibers and a nearly straight section.

2.5.2 Harvesting Considerations

Choose only those bamboo which are more than 3 years of old and it can simply determine by observing the color of the culms has changed from clear and shiny green to grayish green and

white bands at each node that have almost disappeared with replacement of grey bands. As chances of attack by fungi will be more while moisture content is large so it is better to harvest bamboo in dry season. Always cut the bamboo 20 to 30 cm above the ground or just above the first node. Always use sharp tool or saw to avoid damaging of bamboo. Keep the bamboo aright with support of other trees or on such arrangement for two to three weeks which helps to reduce the starch content of culms and as a whole it helps to reduce the chances of attack by insects or Bostrichidae and Lyetidae beetle [2]

Sizing: Splints (split culms) are generally more desirable than whole culms as Reinforcement. Larger culms should be split into splints approximately 3/4 inch wide. Whole culms less than 3/4 inch in diameter can be used without splitting. Splitting the bamboo can be done by separating the base with a sharp knife and then pulling a dulled blade through the Culm. The dull blade will force the stem to split open; this is more Desirable than cutting the bamboo since splitting will result in continuous fibers and an early straight section.

Seasoning: When possible, the bamboo should be cut and allowed to dry and season for three to four weeks before using. The culms must be supported at regular spacing's to reduce warping.

Bending: Bamboo can be permanently bent if heat, either dry or wet, is applied while applying pressure. This procedure can be used for forming splints into C-shaped stirrups and for putting hooks on reinforcement for additional anchorage.

Waterproof Coatings: When seasoned bamboo, either split or whole, is used as reinforcement, it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking and the member may be damaged, especially if more than 4 percent bamboo is used. The type of coating will depend on the materials available. A brush coat or dip coat of asphalt emulsion is preferable. Native latex, coal tar, paint, dilute varnish, and water-glass (sodium silicate) are other suitable coatings. In any case, only a thin coating should be applied; a thick coating will lubricate the surface and weaken the bond with the concrete.

CHAPTER THREE

3. PRESERVATION OF BAMBOO

Bamboo is subject to attack by micro-organisms and insects in almost any construction application. Unfortunately like most lignocelluloses a material, bamboo has very low resistance to biological degrading agents the service life is therefore mainly determined by the rate of attack. A variety of methods to improve the durability of bamboo have, however, been developed. Bamboo can be treated mainly two ways [12].

I. Non chemical Treatment (traditional)

II. Chemical Treatment

I. Non chemical Treatment (traditional)

Non-chemical methods of preservation, otherwise known as traditional methods are widely used by villagers and can be undertaken without the use of any special or sophisticated plant and equipment or significant increase in costs [12].

Typical traditional Methods include:

A. Smoking

B. Whitewashing

C. Elevated construction

A. Smoking method

Traditionally, bamboo culms are placed above fireplaces inside the house so that the smoke and heat rises up and both dry and blacken the culms. It is possible that the process produces some toxic agents that provide a degree of protection. Alternatively, the heat generated by the fire could possibly destroy or reduce the starch content of the parenchyma cells by pyrolysis.

B. Whitewashing method Bamboo culms and bamboo mats for housing Construction is often painted with slaked lime. This is carried out mainly to enhance the appearance, but there is also an expectation that the process will prolong the life of the bamboo structure by preventing moisture entering the culms. It is possible that water or moisture absorption is delayed or in some cases prevented which will provide a higher resistance to fungal attack. However, there remains a question as to whether the bamboo can be weakened over time by such an alkaline treatment.

C. Elevated construction The elevated construction method is designed to method prevent the bamboo coming into direct contact with the ground by placing the bamboo posts on stones or pre constructed cement walls. In this way the bamboo can be kept dry, thereby reducing deterioration due to fungal attack. Good air circulation throughout the structure is also necessary. Furthermore, treatment of the bamboo with water-repellent formulations reduces the hygroscopic properties with the effect that moulds are discouraged.

II. Chemical treatment

Several permanent treatment method are available to protect bamboos and from insect attack and fungal attack. These methods are both preventive and remedial. For such kind of treatment many kind of chemicals are in use like creosote oil, Borax and Boric Acid [11].

a) Internodes Injection

Simple method requiring little equipment 6 mm hole should be drilled in each internodes of a whole bamboo Culm and 20-50 ml creosote (tar oil/molten bitumen) combined with kerosene/ sump oil/ Mobil/ diesel should be injected with a large syringe. Paraffin wax (or putty, if available) should be used to plug the holes. The culms should be rolled 2-3 times a day for 7-10 days to distribute the preservative and complete the treatment. Treatment method applicable for green or dry culms used for making member sex posed to occasional wetting, such as bamboo posts.

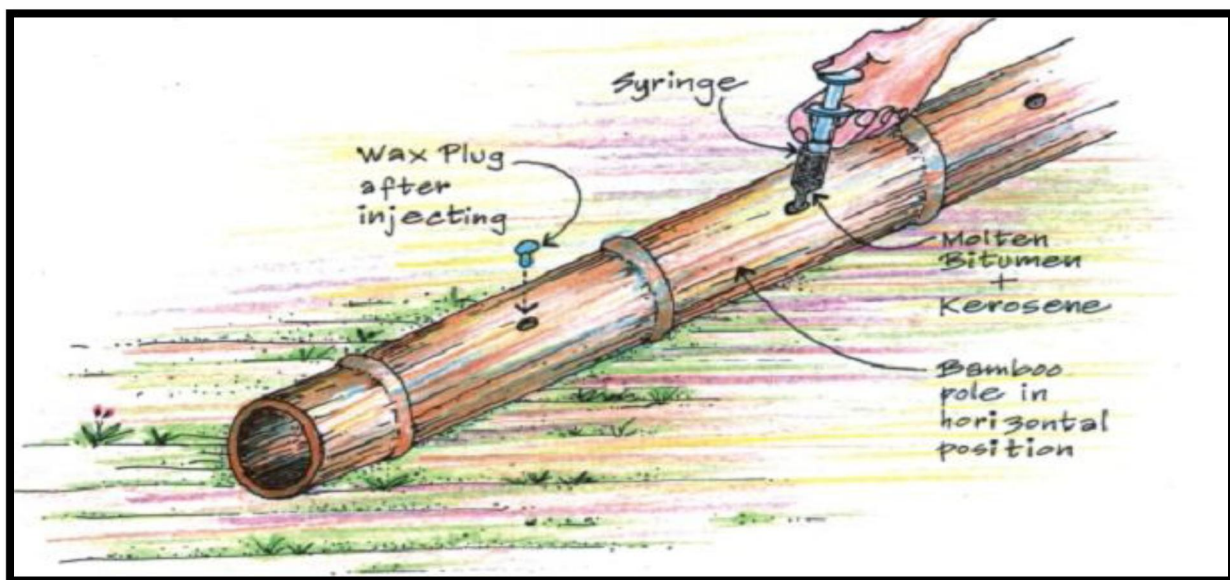


Figure .3.1 Inter-nodal injection method for treatment of whole bamboo Culm

b. Dip diffusion Method

Mixture should be prepared in the proportion 3:1:4 (copper sulphate: sodium dichromate:arsenic acid). Whole or split bamboo culms are cut to size or bamboo mats of suitable dimensions are dipped in chemical solution (preferable CCB or boron) in a tank. Instead of a brick and concrete tank, a simpler tank can be made from oil drums cut in half lengthwise and welded end-to-end. Even cheaper to line an excavation in the ground with polythene sheet. If metal tank, its inside should be painted with bituminous coating to protect from corrosion.

During dipping the bamboo should be pressed down with stones or bricks to completely immerse in solution. For whole bamboo culms, a 6 mm hole should be drilled in each node for more effective chemical penetration. Whole bamboo should soak for at least a week, split sections for three days. The tank should be covered with polythene sheet to keep rain out. After soaking, the preservative should be allowed to drain back by raising the treated bamboo above tank on bamboo supports for a few hours. Finally the treated bamboo should dry for 1 week in a rack, protected from direct sunlight and rain[11]

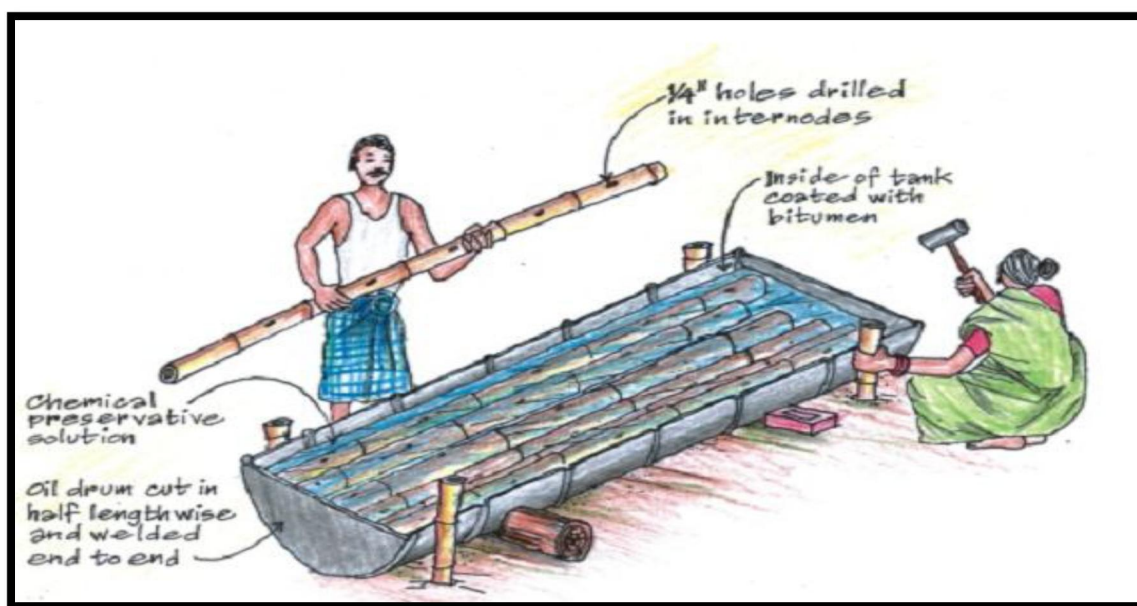


Figure. 3.2 Dip diffusion treatments of whole bamboo culms

C. Hot and Cold Method

Bamboo to be treated should be submerged in tank or oil drum of preservative that is directly heated by fire. After a period of maintaining constant temperature, the container should be allowed to cool, when the preservative is drawn into the bamboo. This method can be used for green or dry culms. 10% boron solution or creosote +kerosene/Mobil/sump oil/diesel should be used as preservative. If creosote, should be used to treat lower 600-900 mm ends of several bamboo posts at the same time by immersing in container. Should be heated to about 90°C for 3-4 hours and then allowed to cool overnight [12].

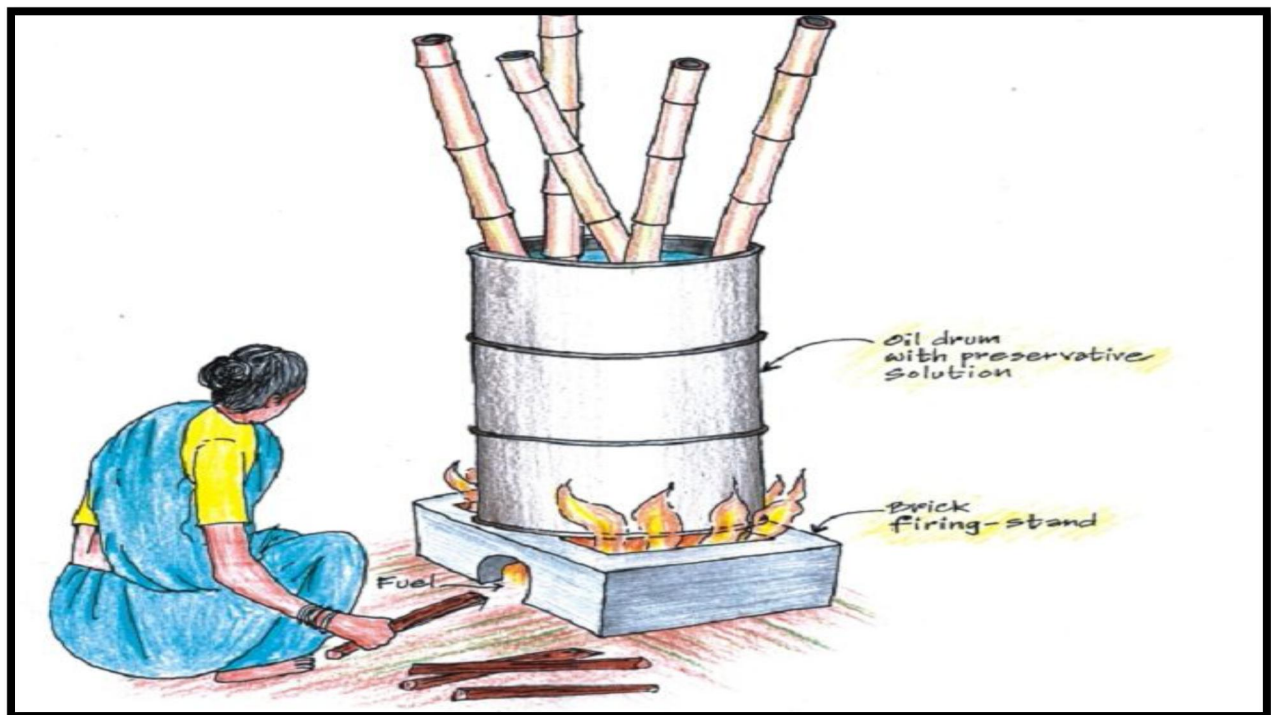


Figure 3.3 Hot and cold method of treating bamboo posts

D. Boucherie Method

The basic Boucherie method has been improved by method the introduction of pneumatic pressure over the preservative fluid in a reservoir, for example by using an air pump or electric pump. The preservative is forced axially through the culm by the air pressure in the reservoir. In this way the time of treatment can be reduced from several days to 3-8 hours. In other respects the process is similar to that for the basic Boucherie method.

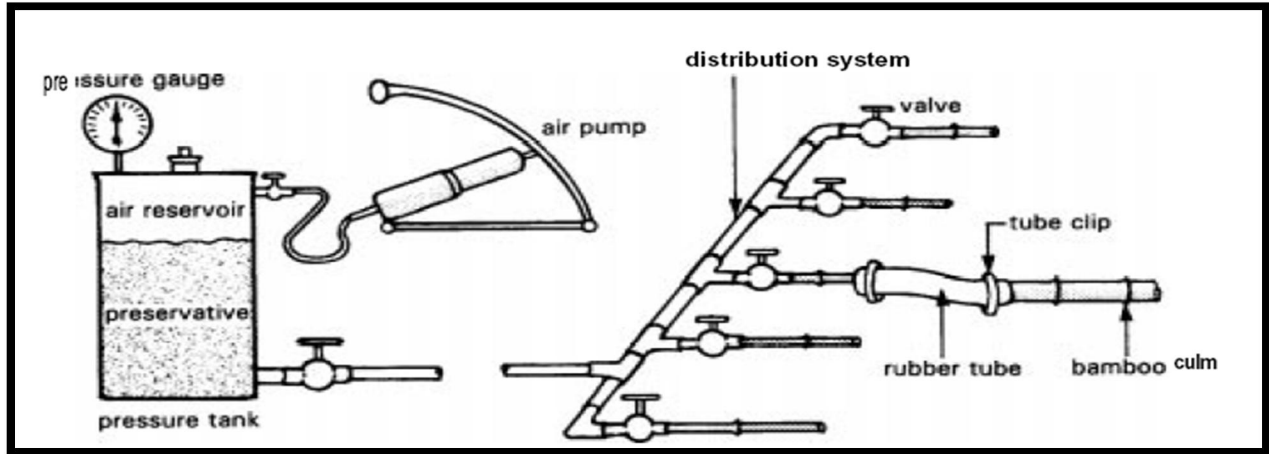


Figure 3.4 The modified Boucherie apparatus

CHAPTER FOUR

5. BAMBOO AS CONSTRUCTION MATERIAL

Bamboo along with fast grown plantation species its surface is smooth, clean and hard, enabling use for specific purposes without much Processing and consequently avoiding wastage. Low cost as compare to other type of construction material Bamboo is one of the oldest materials used for the construction of houses and other structures. Its strength, flexibility and versatility make it a suitable material for addressing every housing component when treated and used properly. Bamboo is relatively cheap, easy to work with and readily available in most warm climate countries. It is estimated that more than one billion people in the world live in bamboo house [6]. Bamboo is a versatile material because of its high strength-to-weight ratio, easy workability and availability.

Bamboo needs to be chemically treated due to their low natural durability. It can be used as Bamboo Trusses, Bamboo Roofs Skeleton, Bamboo walling/ceiling, Bamboo Doors and Windows, Bamboo Flooring, Reed Boards, Scaffolding. Bamboo is an extremely strong natural fiber, on par with standard hard woods, when cultivated, harvested, prepared and stored properly. The strongest part of a bamboo stalk is its node, where ranching occurs. Bamboo is an exceptionally versatile material. It is used in a myriad of ways for building, such as for scaffolding, roofing, concrete reinforcement, walls and piping. It may be used structurally and as a decorative element [12].

Bamboo is extremely flexible. During its growth, it may be trained to grow in unconventional shapes. After harvest, it may be bent and utilized in archways and other curved areas. It has a great capacity for shock absorption, which makes it particularly useful in earthquake-prone areas. It is considered to be sustainable and renewable alternative to hardwoods, foremost because it regenerates at exceptionally fast rates. It is cost-effective, especially in areas where it is cultivated and is readily available. Transporting lightweight bamboo is less costly than transporting its heavier alternatives [12].

5.1 Strength properties of bamboo

It has also been found that bamboo acts very well in buckling but due to low stresses than compared to steel and due to it not being straight it may not be very good. Further, it has been established that in seismic zones the failure of bamboo is very less as the maximum absorption of the energy is at the joints. Cellulose is the main component present in bamboo which is the main source of mechanical properties of bamboo. Some specific properties of Bamboo are as given below [13].

- ✓ Specific gravity - 0.575 to 0.655
- ✓ Average weight - 0.625kg/m run
- ✓ Modulus of rupture - 610 to 1600kg/cm²
- ✓ Modulus of elasticity - 1.5 to 2.0 x10⁵kg/cm²
- ✓ Ultimate compressive stress- 794 to 864kg/cm²
- ✓ Safe working stress in compression – 105kg/cm²

US Naval Civil Engineering Laboratory in 1966 reported a study providing a set of Instructions on how to design and properly construct using bamboo as reinforcement in concrete members. This study recommends 3/4inch (19mm) wide bamboo splits to use as Reinforcement and apply waterproof coating to reduce swelling when in contact with Concrete. The type of coating depends on the materials available. A brush coat or dip coat of asphalt emulsion is preferable. Native latex, coal tar, paint, dilute varnish, and water glass (sodium silicate) are other suitable coatings. In any case, only a thin coating should be applied; a thick coating will lubricate the surface and weaken the bond with the concrete [13].

5.2 Characteristics of Bamboo

The bamboo Culm, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibers and low strength perpendicular to the fibers. The thickness and strength of bamboo, however, decreases from the base to the top of the bamboo shell [16]. The density of the fibers in the cross-section of a bamboo shell varies along its thickness. On the outer skin of a bamboo shell the fibers are concentrated and more resistant to environmental degradation. This presents a functionally gradient material, grew according to the state of stress distribution in its natural environment. In view of the hollowness and the fibers in longitudinal direction, bamboo has a very efficient natural structural design and less material mass is needed than materials with a massive section, such as timber.

In terms of load-bearing mass, as with all tubular elements, bamboo functions as an I-shaped cross-section, in each direction it is loaded, whereas other cross-sections are most efficient in one or two directions. The parts of a bamboo which are usual to most of the species. First, the part called the trunk or the stem in the case of a tree is called the Culm for a bamboo. Usually, a Culm is hollow. The hollow space inside a Culm is called the cavity “a”. The cavities are separated from each other by diaphragms “b”, which appears at outside of the culms as nodes “c”, where branches “d” leave the Culm. A Culm between two nodes is another nodes “e”; and finally the wall thickness “f” [14]. One major problem with bamboo is that it is a living organism which is subjected to degradation and decay. It is more prone to insect attack because of its high content of nutrients. The other constraint to the application of bamboo species is swelling behavior when it is in contact with water, shrinking behavior when it dries, degradation behavior when in contact with alkaline environment.

5.3. Bond Strength of Bamboo

When fresh concrete poured, its water moistens the bamboo. Then during the next month the concrete will harden and loss water so it will again dry out. This drying process can result in shrinkage of bamboo with more than the shrinkage of concrete. The differential shrinkage breaks down the bond between concrete interface and bamboo. But, in case of steel bar the dimensions will remain constant while the concrete shrinks. Consequently this problem will not happen in

steel reinforcement. To minimize the above problem many researches have been made on bond strength with different treatment and suggest techniques that improve the durability as well as the bond strength of bamboo. Here, a few outcomes of the researches are discussed in detail [13] discussed four techniques that minimize shrinkage and increase bond strength of bamboo. The methods are;

Melting bitumen and applying it to the bamboo strips uniformly with a brush to form thin coats while still hot, the bamboo is covered with coarse sand for 24hours. The bitumen has proved an effective moisture barrier and the sand makes rough surface thus improving the bond.

Melting bitumen, as above, but 25mm diameter nails are driven into the bamboo strips 75mm apart, so that they protrude on either side of the strips. This nails will maintain the bond.

Outer half of the bamboo possesses better tensile strength, better lounge's modulus and less shrinkage than the inner part. In order that uses of only the outer half of the bamboo as reinforcement is recommended.

Bitumen coat, but the bond is provided by roughly 3mm diameter coconut fibre ropes wound around the strips at a 100mm pitch along their length. The rope is also dipped in hot bitumen before being wound around the bamboo strips.

5.4. Bamboo and Its Applications in Building

5.4.1 Domestic Housing and Small Buildings

There is a long-standing tradition of bamboo construction, dating back to many hundreds of years. Different cultures have found in this material an economical system of building, offering sound yet light and easily replaceable forms of shelter. The methods, activities and tools are often simple, straightforward, accessible even to the young and unskilled. Despite human exploitation and unfavorable treatment, trees maintain its contributively role towards the dwelling of mankind. Man has for centuries enjoyed the benefits of the free gift of nature.

Housing is one of the priority items and sensing the current shortage of the dwelling units, the present administrative leaders around the world find tough to hit upon a solution for. Bamboo building construction is characterized by a structural frame approach similar to that applied in traditional timber frame design and construction. Bamboo based materials are widely used too.

In its natural condition as solid culms, halved culms or as longitudinally split strips, bamboo has been used in almost all parts of house construction except for the fireplace and the chimneys. These are described in detail below:

4.4.1.1 Foundation

The use of bamboo for foundation is rather restricted. This is mainly due to the fact that like timber when in contact with damp ground, they deteriorate and decay very quickly unless treated with some very effective preservatives. However, in spite of their short life considerable use of bamboos is made as foundation or supporting posts in case of houses built on raised platforms [1]. The types of bamboo foundations identified are:

- ✓ Bamboo in direct ground contact: Bamboo is placed either on the surface or buried. For strength and stability, large diameter and thick walled sections of bamboo with closely spaced nodes should be used. Where these are not available, smaller sections can be tied together. It can decay within six months to two years, and hence preservative treatment is recommended.
- ✓ Bamboo on rock or preformed concrete footings: where bamboo is being used For bearings, it should be placed out of ground contact on footings of either rock or preformed concrete. The largest and stiffest sections of bamboo should be used.
- ✓ Composite bamboo/concrete columns: a concrete extension is given to a Bamboo post using a plastic tube of the same diameter. The result is a bamboo post with an integral durable foundation.
- ✓ Bamboo piles: it is used to stabilize soft soils and reduce building settlement. The treated split bamboo piles were filled with coconut coir strands wrapped with jute. The sections were then tied with wire. After installation of the piles the area was covered with a sandy material.

4.4.1.2. Flooring

The floors may be at ground level, and therefore consists only of compacted earth, with or without a covering of bamboo matting. The preferred solution is to raise the floor above the ground creating a stilt type of construction. This improves comfort and hygiene and can provide a covered storage area below the floor. The surface of earth floor is sometimes made more stable by paving it with crude bamboo boards made by opening and flattening whole culms. The various types used are:

- ✓ Small bamboo culms: they are directly tied and nailed together.
- ✓ Split bamboo: culms are split along their length into strips, several centimetres wide.
- ✓ Flattened bamboo: formed by splitting green bamboo culms removing the diaphragms, then rolling and flattening them. The resulting board is laid across the joists and fixed by nailing or tying. They are screened with cement mortar for reasons of hygiene and comfort as they are uneven and difficult to clean.
- ✓ Bamboo mats: thin strips varying in size from 5-6mm or 10-15mm and thickness of 0.6-1.2mm. These slivers are then woven into mats of different sizes according to the available hot-press plates and user's demands. After drying the mats to 6-10% moisture content, sufficient glue is applied to ensure enough bonding between the overlapped areas. In construction using bamboo mats, phenol cresins are employed.
- ✓ Bamboo plastic composites: it is an innovative technology in which bamboo fibre is the raw material and compounded with plastic as the core material of the flooring. This has higher water resistance and dimensional stability properties than those of normal floorings.

4.4.1.3. Walls

The most extensive use of bamboo in construction is for the walls and partitions. The major elements, the posts and beams, generally constitute part or structural framework. They are to carry the self-weight of building and loads imposed by the occupants and the weather. An infill between framing members is required to complete the wall. The purpose of the infill is to protect against rain, wind and animals, to offer privacy and to provide in plane bracing to ensure the overall stability of the overall structure when subjected to horizontal forces [2].

4.4.1.4. Roofing

It is well-known that low-cost new buildings should integrate with the habits of communities for availability of materials technical maintenance. Past experiences have shown that a strict import of modern construction techniques leads to rapid deteriorations due to problems of sustainability of the work and maintenance techniques and management. The implementation of indigenous building materials and structural forms should be socially harmonized to perform real improvements in the construction types. Bamboo is a low-cost building material available in wide parts of the world: it is lightweight, durable, flexible, and easily cultivated and processed.

The roof offers protection against extremes of weather including rain, sun and wind and to provide shelter, clear and usable space beneath the canopy. Above all it must be strong enough to resist the considerable forces generated by wind and roof coverings. In this respect, bamboo is ideal as a roofing material- it is strong, resilient and light weighted. The bamboo structure of a roof can comprise of purlins, rafters and trusses.

- a) The simplest form consists of a bamboo purlin and beams, supported on perimeter posts. Halved culms are then laid convex side down, edge-to-edge, spanning from the ridge to the eaves. A second layer, convex side up, is then laid to cover the joints.
- b) Corrugated sheets made out of bamboo are also used commonly as roof Covering. The bamboo mats are dipped in resin, dried and heat pressed under Pressure in a specially made platen, to give strong, reliable sheets of bamboo, which is lightweight. It has good insulation properties too.
- c) A layer of bitumen is sandwiched between two mats of bamboo forming a semi rigid panel. The mats can be fixed to rafters at 200-250mm center to center. A bituminous or rubberized weatherproof coating is then applied to the finished roof.
- d) Plastered bamboo: A cement plaster, with or without the addition of organic fibers, is traditionally applied to bamboo roofs, to get stronger roof coverings. Various forms of trusses are also adopted using bamboo culms of diameter ranging from 40mm-100mm. The king post trusses are the most common and the simplest.

4.4.1.5. Scaffolding

Because of the favorable relationship between load-bearing capacity and weight, bamboo can be used for the construction of save scaffoldings even for very tall buildings. Only lashed joints are used. The cane extension is carried out by lashing the cane ends together with several ties. The ties are arranged in such a way that forces acting vertically downwards wedges the nodes in the lashing. The vertical and horizontal canes used for scaffolding are almost exclusively joined using soft lashing. This technique has the great advantage that the joints can be re-tensioned to the right degree without difficulty and also quickly released again [9].

4.4.1.6. Bamboo Reinforced Concrete (BRC)

The use of bamboo as concrete reinforcement is concrete one of the more broadly covered topics relating to bamboo in construction and considerable research effort continues to be directed at

this subject There are several good reasons why bamboo might be considered as reinforcement for concrete:

- ✓ It is of low cost compared with steel
- ✓ It is readily available
- ✓ Its strength to weight ratio compares favourably with steel

CHAPTER FIVE

5. COST ANALYSIS

Bill of Quantity Of 12m² Single G+0 Room All Structural Elements Are Rcc And Roof Truss Are Wooden

Item no	Description	unit	Qty	Unit rate	Total amount
1	A.SUB STRUCTURE				
1.1	excavation and earth work	m3	23.834	790	1,680.00 birr
1.2	masonry work	m3	4.2	215	1,743birr
1.3	concrete work	m3	95.44	1146	13,623.00 birr
	sub –total A				17,046.00 birr
2	B.SUPER STRUCTURE				
2.1	concrete work	m3	63.51	790	5,656birr
2.2	block work	m3	31.03	150	4,650 birr
2.3	carpentry and joinery	m ²	9.36	310	8,657 birr
2.4	metal work	m ²	2	2100	4,428 birr
2.5	finishing	m ²	34.22	656	5,389birr
2.6	plastering and pointing	m ²	31	25	775birr
2.7	painting	m ²	31	25	775birr
2.8	glazing	m ²	4.3	270	1,161birr
2.9	electrical works				914.00birr
	sub –total B				32,405.00birr
	GRAND TOTAL=A+B				49,451.00birr

Table 6.1 bill of quantity of RCC (reinforced cement concrete) room

Bill of Quantity of 12m² Single G+0 Room All Structural Elements Are Brc(Bamboo Reinforced Concrete) And Roof Truss Are Bamboo

Item no	Description	unit	Qty	Unit rate	Total amount
1	A.SUB STRUCTURE				
1.1	excavation and earth work	m3	23.834	790	1,680.00 birr
1.2	masonry work	m3	4.2	215	1,743birr
1.3	concrete work	m3	95.34	71.44	6,812.00 birr
	sub –total A				10,235.00 birr
2	B.SUPER STRUCTURE				
2.1	concrete work	m3	31.2	90.64	2,828 birr
2.2	block work	m3	31.03	150	4,650 birr
2.3	carpentry and joinery	m ²	9.36	464.5	4,329 birr
2.4	metal work	m ²	2	2100	4,428 birr
2.5	finishing	m ²	34.22	656	5,389birr
2.6	plastering and pointing	m ²	31	25	775birr
2.7	painting	m ²	31	25	775birr
2.8	glazing	m ²	4.3	270	1,161birr
2.9	electrical works				914.00birr
	sub –total B				25,249.00birr
	GRAND TOTAL=A+B				35,484.00birr

Table 6.2 bill of quantity of BRC (bamboo reinforced concrete) room

Cost Comparison between Bamboo Reinforcement and Steel Reinforcement house when we comparing two building costs the house built using bamboo construction material minimize the total cost by 40%than the house built steel reinforcement and wood roof truss construction material. Minimizing the total cost of building is the main objective of this study. By promoting the use of bamboo as construction material for low-cost house construction, the steel reinforcement can be replaced whose price is becoming prohibited ably high in the international market.

CHAPTER SIX

7. PHYSICAL AND MECHANICAL PROPERTIES

7.1 Physical Properties

The suitability of bamboo for structural composite products is demonstrated by its physical properties. These properties are the results of genetic design, as well as the affect of the climate and soil condition. Color, grain pattern and texture are among the qualitative factors that are important for the value of appearance-type products. In this dissertation, where structural application of bamboo is stressed, quantitative factors are the subject of concern. The physical properties investigated are relative density (specific gravity), equilibrium moisture content and the dimensional stability. As with many other building materials, bamboo displays variability in its physical properties.

7.1.1 Equilibrium Moisture Content

Equilibrium moisture content (EMC) is defined as the moisture content that is in equilibrium with the relative humidity and temperature of the surrounding air. EMC is an important in-service factor because wood and other woody material like bamboo is subjected to long-term and short-term variation in surrounding relative humidity and temperature. Hence, this material is always undergoing at least small changes in moisture content, due to the fluctuation of the surrounding environment. In most cases, the changes are gradual and usually affect only the surface of the substrate when briefly exposed to moisture fluctuations. Commonly, it is not desirable to have a material that changes rapidly under the moisture stress because moisture affects the physical and mechanical properties of wood and woody materials. As for bamboo, it is most desirable to have a comparable behavior to wood, if not better. The conditioning of bamboo to different moisture contents was carried out using the standard guide for moisture conditioning of wood and wood-based materials,

Moisture content is the mass of moisture in the substance expressed as a percentage of the oven-dry mass. The expression is produced below

$$\text{Moisture Content (\%)} = \frac{M - M_o}{M_o} \times 100\%$$

Where;

Mc= moisture content in %

Mo= the mass of the test specimen

M=the oven dry mass of the test specimen

7.1.2 Dry density

For the determination of density oven-dry mass is used because these will not change irrespective of whether condition.

The density is to be reported at the natural moisture content of the test specimen. Here the mass is taken as the oven-dry mass and only the volume is taken at the natural moisture content of the specimen.

The density each test specimens is calculated using Equation

$$D=M/V$$

Where;

D =density in Kg/m³

M = the oven-dry mass in gm of the test specimens

V = the oven-dry volume of the test specimens in mm³

7.1.3 Shrinkage and Swelling

Bamboo, like wood, changes its dimension when it loses or gains moisture. Bamboo is a hygroscopic material, thus the moisture content changes with the changes in the relative humidity and temperature of the surrounding environment. Dimensional stability is very crucial in structural composite products because the safety and comfort in a structure usually depends on them.

As was mentioned in the latter section, bamboo begins to change its dimension as soon as it starts to lose moisture. This characteristic is in contrast to wood, where it will shrink or swell only below the fiber saturation point (FSP). The FSP of wood is reached when wood loses its free water and the cell wall is saturated with bound water. The immediate shrinkage behavior of bamboo was reported by several authors, but there was no explanation of why it happens. Free water and bound water exists in bamboo, however the amount of free water may be small compare to bound water. This could explain why it starts to shrink as soon as it loses moisture. Hay green and Bowyer explained that shrinkage in wood happens as bound water molecules

leave from between long-chained cellulose and hemicelluloses molecules. The shrinkage occurs in proportion to the amount of water loss from the cell wall. The introduction of water molecules into the cell wall will result in swelling, although not completely reversible to the same degree. The volumetric, radial and tangential shrinkage of bamboo was carried out with the guidance of the standard methods of testing small clear specimens of timber.

The Shrinkage and swelling of bamboo in the volume (V), longitudinal (L), radial (R) or tangential (T) direction are expressed by the following equation

$$\text{Shrinkage (\%)} = \frac{\text{decrease dimension (V, L, R or T)} \times 100\%}{\text{Original dimension}}$$

$$\text{Swelling (\%)} = \frac{\text{increase dimension (V, L, R or T)} \times 100\%}{\text{Original dimension}}$$

Table 7.1 This table shows physical properties test result the specimen be for others mechanical test will conduct

S.NO	Specimen Size		Cross Sectional Area			Moisture Content (%)	Dry Density (kg/m ³)	Radial Shrinkage (%)
	Length (mm)	Thickness (mm)	One End	Other	Average			
1	520	10	562	556	260	11.00	765.45	1.00
2	520	10	142	198	170	4.90	716.78	0.76
3	520	10	215	207	211	9.50	748.00	0.92

Note-Longitudinal shrinkage deformation in all samples is negligible

7.2 Mechanical properties

Analysis of mechanical properties is the investigation of behavior of the materials under different loading conditions. Information about the deformation behavior, stress state and the failure behavior of different bamboo species in different forms is an important requirement for the

effective use of these bamboo species for different engineering applications. Different test techniques, specimen preparation and test data have been presented for typical bamboo species.

7.2.1 Tensile strength parallel to grains

Tension tests parallel to the grain are seldom investigated for bamboo. Tensile strength value cannot be utilized in practical work, as bamboo will fail by shear long before its full tensile stress is developed. They recommended modulus of rupture and modulus of elasticity in static bending to represent the most reliable estimate of the tensile strength. However, in order to design bamboo tension members loaded in direct tension, the tension strength value is a fundamental criterion. The tension parallel to grain test carried out was adjusted from the standard methods of testing small clear specimens of timber. The test considers factors such as moisture content, density, shrinkage, position along the culms, presence of node and internodes. ISO 3345 standard is used for the determination of tensile strength. Due to the nature of bamboo, it is impossible to cut similar specimen dimensions suggested in the standard.

The tensile stress at ultimate tensile stress (σ_{ult}) and tensile modulus of elasticity (E) was calculated using the following equations

The ultimate tensile strength is determined by using Equation

$$\sigma_{ult} = \frac{P_{ult}}{A}$$

Where, σ_{ult} = the ultimate tensile strength in MPA

A = the mean cross-sectional area of the gauge portion in mm²

P_{ult} = the maximum load at which the test piece fails, in N.

The modulus of elasticity, E, is calculated from the mean of the readings of the strain gauges, at areas where the relationship between stress and strain is linear.

7.2.1.1 Tensile Test on Bamboo

As the bamboo is used as to take tensile load in the flexural element the tensile test was conducted on the bamboo.

The Bamboo strip was of the length 520 mm and the thickness of the Bamboo was average 10 mm. Specimens of such specifications were prepared. The ends of the specimen were roughed at both the ends to have a better grip in Testing Machine.

Table 7.2: Description of Tensile Test Specimen

Sample No.	Specimen Size		Cross Sectional Area (mm ²)		
	Length (mm)	Thickness (mm)	One end	Other end	Average cross sectional area
1	520	10	562	556	260
2	520	10	142	198	170
3	520	10	215	207	211

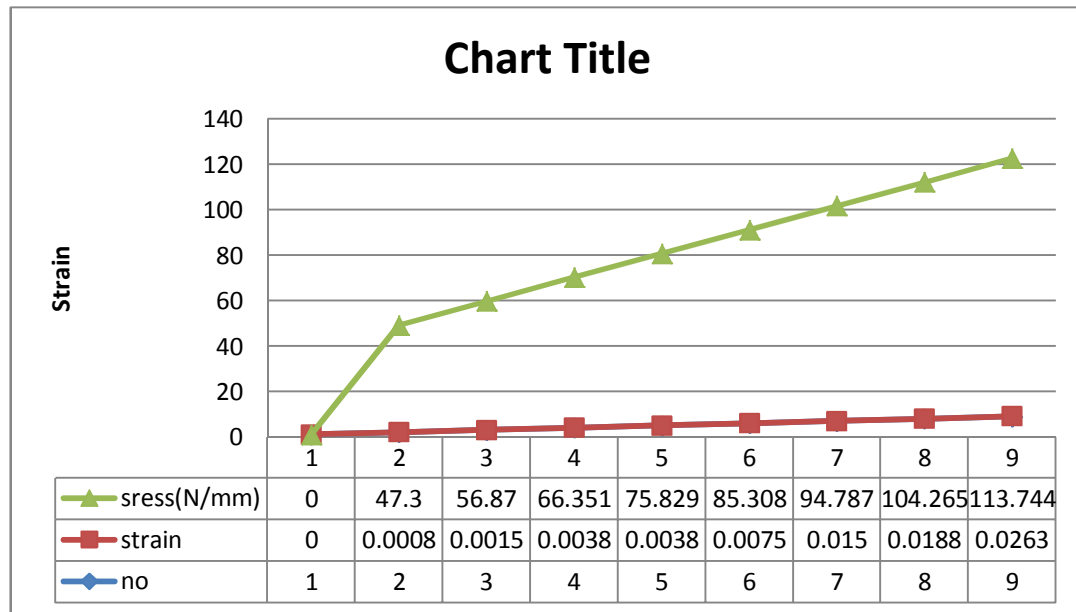
Tensile test was conducted on Testing Machine. To have a grip of the Bamboo in the machine the cast iron grips were used.

7.2.1.2 Tensile Test Results

Tensile tests were conducted on specimens having nodes at the end. Nodes are weak and brittle in resistance to tensile force as referred. This test was performed on specimens with nodes at gauge position and its main purpose was to determine modulus of elasticity of the specified species Bamboo. It has been observed that mostly the failure occurred at mid height. The failure occurred looks like the splitting of the fibers . The general tensile test results are summarized in the Table shown below.

Table 7.3: Results of the Tensile Test

Load P(KN)	Elongation(mm)	Strain	Stress(N/mm)
0	0.0	0.0000	0.000
10	0.1	0.0008	47.300
12	0.2	0.0015	56.870
14	0.5	0.0038	66.351
16	0.5	0.0038	75.829
18	1	0.0075	85.308
20	2	0.0150	94.787
22	2.5	0.0188	104.265
24	3.5	0.0263	113.744



The mean yield stress of the Bamboo is 113.744 N/mm².

The equation to calculate the Modulus of Elasticity is as mentioned below:

$$E = \sigma / \epsilon$$

Where, σ = Stress.

ϵ = Strain.

E = Modulus of Elasticity.

The data are $\sigma = 113.744 \text{ N/mm}^2$. $\epsilon = 0.0188$

Thus, $E = 113.744 \text{ N/mm}^2 / 0.0188$

$$E = 6050.21 \text{ N/mm}^2$$

The Modulus of Elasticity of the Bamboo is 6050.21 N/mm².

7.2.2 Compressive strength parallel to grains

Compression test is conducted by a method for compression parallel to the fibers on specimens made from bamboo culms. The test covers tests on specimens of bamboo that are conducted to arrive at ultimate compressive stresses. . The test considers factors such as moisture content, density, shrinkage, position along the culms, presence of node and internodes. Standard is used for the determination of tensile strength.

To determine the modulus of elasticity, E, strain gauge is attached. The ultimate compressive stress is determined by using this Equation

$$\sigma_{ult} = \frac{P_{ult}}{A}$$

Where;

σ_{ults} = the ultimate compressive strength (MPa)

p_{ult} = the maximum load at which the test specimen fails (N).

A = the mean cross-sectional area (mm²)

Compressive strength properties have been evaluated using the specimens made parallel to the grains. Generally, the failure modes under longitudinal compression are: micro buckling of fibers leading to kink band formation and shear failure mode. For most of the specimens, shear failure mode was observed under longitudinal compression.

Compressive strength properties were determined using specimens of cuboids shape also. The loading was along the grain direction. Overall, both the test techniques gave nearly identical results.

7.2.3 Bending Test

Bending test is conducted on specimens of bamboo to obtain the ultimate bending factors such as moisture content, density, and shrinkage. A mid-span loading method was conducted.

The ultimate bending strength, σ_{ult} , is given by the following Equation

$$F_b = \frac{PLD}{12I}$$

Where;

σ = the ultimate bending strength (MPa)

P = the applied maximum load (KN)

L = the free span in mm, (or clear span)

D = diameter in mm I = the moment of Inertia in mm⁴

The Modulus of Elasticity (E) is given by the following equation

$$E = \frac{23 * W * L^3}{648 * \delta * I}$$

Where, W = load.

L = Length of the Beam

δ = Deflection

I = Moment of inertia.

Now, $I = 1/12 (b \cdot d^3)$

Where, b = Width of the beam

d = Depth of the Beam.

CHAPTER SEVEN

7. TEST AND QUESTION

7.1. Laboratory test

Bamboo has been used as construction material, but its application as reinforcement in reinforced concrete has not been studied in Ethiopia. In this study bamboo is given consideration for use as reinforcement for the construction of low-cost houses in Ethiopia. So that to reduces the cost of construction of houses and be made affordable tote society. In the present research work bamboo sticks had been provided as reinforcement in concrete beams in place of steel bars. High demand of owning houses in Ethiopia is highly increasing, urgent and effective action is required to secure the demand in sustainable basis. The results of this investigation form the basis of the conclusions and recommendations.

7.1.2 Bending Test of Reinforced Concrete Beams

Concrete is strong in compression but weak in tension. As a result, cracks develop whenever loads, or restrained shrinkage of temperature changes. The later give rise to tensile stresses in excess of the tensile strength of the concrete. In plain concrete beams, the moment due to applied loads are resisted by an internal tension-compression couple involving tension in the concrete. Such a beam fails very suddenly and completely when the first crack forms.

In reinforced concrete beam bamboos are embedded in the concrete in such a way that the tension forces needed for the moment equilibrium after the concrete cracks can be taken care by in the bamboo bars.

In order to study the behavior of the bamboo reinforced concrete beam subjected to force acting transverse to their longitudinal axis, bending test is selected.

Two types of bending tests are conducted

1. Mid - Span loading:

In this arrangement of loading, the maximum bending moment occurs at mid –span.

2. Two point loading:

Two point loading is considered as a more accurate measure of the bending properties, since in this type of loading, the maximum pure moment, hence stress, is applied over an appreciable

length of the specimen. Furthermore, with two point loading, bending stresses free from transverse shear stresses are produced for an appreciable length of the specimen.

7.1.3. Reinforced Concrete and Bamboo Reinforced Concrete Test Specimen

Preparation Selection of Bamboo

The following factors were considered in the selection of bamboo culms for use as reinforcement during the test only bamboo showing no defects are used Bamboo with little variation in diameter along the length is selected. Bamboo having shorter inter node dimension has to be selected in orders to acquire more nodes to increase bond.

7.1.3.1. Preparation of Bamboo

1. Sizing:

The bamboo was cut with sharp saw. During cutting great care was taken not to split the specimen, because splitting will result in continuous tearing of fiber.

2. Water Proof Coatings:

After selecting and sizing, water proof coating is applied because it reduces swelling when the bamboo contacted with concrete. Without coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking and the member may be damaged. The type of coating used is asphalt emulsion. Only a thin coating shall be applied. A thick coating will lubricate the surface and weaken the bond between the concrete and bamboo.

In general, techniques used in conventional reinforced concrete test specimen preparation need not be changed when bamboo is to be used as reinforcement. Therefore, the conventional specimen preparation was strictly followed when preparing the test specimen.

3. Concrete mix preparation

Normal mix design that is widely used for normal steel reinforced concrete is selected to be used when preparing the specimen. However, concrete slump should be as low as possible provided that good workability is attained. This is because excess water causes swelling of the bamboo.

4. Placement of Bamboos

When placing the bamboo, the top and bottom of the stems should be altered in every row and the nodes should be staggered. This will ensure a fairly uniform cross-section of the bamboo reinforcement throughout the length of the member, and the wedging effect obtained at the nodes

will materially increase the bond between concrete and bamboo. Bamboo is securely tied down with diameter 8 bamboo as stirrups before placing in to formwork. It is fixed at regular interval of 150mm.

5. Laboratory Testing

Bending test was conducted based on the methods stated earlier. During the test, the load was applied by a testing machine while the deflection was measured by a strain gauge which was placed under the specimen's center. The loads and the corresponding deflections are measured at failure.

In order to study the performance evaluation of Bamboo as reinforcement in Reinforced Cement Concrete Specimen following tests are executed. The dimensions of each specimen were 200x200x750mm, and C-20 concrete grade was used. The three types of test specimens were;

1. Flexural strength test Mass Concrete Cubes (without reinforcement)
2. Flexural strength test of mild steel Reinforced Concrete Beams.
3. Flexural strength test of Bamboo Reinforced Concrete Beams.

The diameter of steel and bamboo reinforcements are selected in such a way that the compressive force in the rectangular stress blocks of singly reinforced rectangular sections to be equal. It also considers the beam to be under-reinforced in order the reinforcement to yield before the concrete crushes. The geometric steel ratio of the beam is calculated from the conventional equation as shown below;

To make the tests result comparable;

$$f_y A_s = f_{y,b} A_b$$

Where;

f_y = yield stress of steel

$f_{y,b}$ = tensile stress of bamboo

A_s = area of steel in tension zone

A_b = area of bamboo in tension zone.

f_y = 260 MPA (obtained from laboratory testing)

$f_{y,b}$ = 113.744 Mpa obtained from this study.

$A_s = 2(113) = 226 \text{ mm}^2$ – 2 diameter 12 steel reinforcement

$A_b = 2(258) = 516.599 \text{ mm}^2$ – 2 diameter 18mm bamboo reinforcement

Substituting the values,

$$f_y A_s = f_{y,b} A_b$$

$$260 \text{ N/mm}^2 \times 226 \text{ mm}^2 = 113.744 \text{ N/mm}^2 \times A_b$$

$$A_b = 516.599 \text{ mm}^2 \quad \text{use 2 diameter 18mm bamboos}$$

7.1.4 Flexural Strength Test Beams

In order to check flexural strength of Circular Bamboo Reinforced cement concrete, Reinforced cement concrete beam specimens are casted with dimension 200*200*750 mm. The Bamboo strips of the length 730 mm were used as reinforcement. To be acquainted with the behavior of Bamboo in concrete, different Bamboo reinforced concrete beam specimens were prepared.

The dimension of the specimen used in Mass Concrete Cube, Circular Bamboo Reinforced Concrete and Reinforced Concrete Beam are shown in figure below;

750mm 200mm



Flexural tests were conducted on Testing Machine. The test was conducted with two points loading.

Table 8.1: Reinforcement Details in Beams

Type of Reinforcement	Cross-section of Reinforcement(mm)	Total Area(mm ²)	Number of Reinforcement
Circular Mild Steel	12	452	4
Circular Bamboo	18	1033.198	4

7.1.5 Testing of Beams

All the beams were tested under two concentrated load each applied at one third point of the beam with the help of hydraulic jack as shown in the Figure. Loads were gradually increased and corresponding deflections were recorded at three different locations viz. under the two loads and at the centre of the beam with the help of three dial gauges. In each case in each case beam was tested up to failure.

7.1.6 Flexural Test Results

From the experimental test the load deflection graph, ultimate carrying capacity and the type of failure were recorded. The deflection at first crack was recorded from the load and deflection curve which was found at the point where the stiffness of the beam changed. In addition the maximum deflection was read from this curve. Generally Flexure failure was seen.

Table 8.2: Ultimate load and deflection at ultimate load

S.NO.	Beam Designation	ultimate load (KN)	Deflection at ultimate load (mm)	Flexural Strength (MPA)	Modulus of elasticity(N/mm ²)
1	Mass Concrete Cube (Without Reinforcement)	16.60	9.5	1.87	192
2	Reinforced Cement Concrete(RCC)	82.3	7.50	9.25	1232
3	Circular Bamboo Reinforcement(BRC)	59.20	10.50	6.67	631

On the basis of Flexural strength test Mass Concrete Cubes (without reinforcement), Flexural strength test of mild steel Reinforced Concrete Beams and Flexural strength test of Bamboo Reinforced Concrete Beams test results, the following conclusions are made,

- Plain Cement Concrete Beam failed suddenly without any prior notice. Hence, it is to be said that it has shown brittle failure. Both Reinforced Cement Concrete and Circular Bamboo reinforcement Beam has shown elastic behavior but mass concrete cube do not have elastic behavior.
- Reinforced Cement Concrete Beam has performed more than twice of Modulus of Elasticity Circular Bamboo Reinforced Beam while performing flexural tests. Load carrying capacity in Reinforced Cement Concrete Beam increased by 27.31 % as compared to Circular Bamboo Reinforced Beam.

Based on the limited number of test conducted, it was concluded that Bamboo may be used as substitute of steel reinforcement in beams.

7.2 Questioner result

7.2.1 Data Sources and Collection Techniques

All data collected from both primary and secondary sources. The primary data collected through interviews questioners, observations and laboratory test. The secondary data relevant to the project are taken from books, magazines, internet sources.

Primary Data Collection

- ✓ Visiting and observing Metehara town house condition and availability bamboo.
- ✓ Interview with the community and other stakeholders.
- ✓ Interview with the municipality of the town.

7.2.2 Result and interpretation

This topic deals with analysis and interpretation of the data obtained from respondents. It covers every pieces of information that is supposed to be relevant to the paper.

Table 8.3:- Demographic result of participants.

No	Items	Option	Respondents	Percentage
	Age	36-45	36	53.84%
		46-55	16	46.15%
			52	100%
2	Sex	Male	32	61.53%
		Female	20	38.46%
			52	100%

As it is indicated in the above table 8.3, more than half of the respondents age interval is 36-45 age which accounts 16(53.84%) and followed by 45-55 age which accounts 10(46.15%).Regarding sex distribution of respondents, 32(61.53%) of the respondents are male and 20(38.46%) of them are female. We distributed totally 70 questionnaires. From this 52 give the respond and 18 do not give the respond, because of they do not understand our paper, they consider towards politics, in addition to this those who do not submit the paper is due to carelessness and not giving attention to it.

Table 8.4: The Living status of the residential

No	Items	Option	Respondents	Percentage
1	Living status of the residential	Private rental	15	28.85%
		Government rental	11	21.15%
		Private house	20	38.45%
		Dependent	6	11.55%
	Total		52	100%

As it is indicated above table 8.4, private rental 15(28.85%), 11(21.15%) of them government rental, 20(38.45%) privet house and About 6(11.55%) of them are dependent.

Table 8.5: Respondents Answer for the Questioners

No	Items	option	respondents	Percentage
1	The development of housing in our local area is good?	Yes	36	69.23%
		No	16	30.76%
	Total		52	100%
2	Is bamboo cultivated in your area?	Yes	42	80.76%
		No	10	19.23%
	Total		52	100%
3	Do you have knowledge about bamboo to use as a construction material?	Yes	20	38.46%
		No	36	61.53%
	Total		52	100%
4	Are you interesting to change your home standard?	Yes	34	63.38%
		No	18	34.61%
	Total		52	100%

As indicated in the above table 8.5, majority of the respondents are said development of housing in their local area is good, which account 36(69.23%) and 16(30.76%) of them are said development of housing in their local area is not good.

The majority of the respondents said bamboo is cultivated in their area. Which account 42(80.76%) and 10(19.23%) of them bamboo is not cultivate in our area?

As shown in the above 8.5, more than half of the respondents don't have knowledge about bamboo to use as a construction material, which account 36(61.53 %). 20 (38.46 %) of them response have knowledge about bamboo to use as a construction material.

As shown in the table 8.5, above, more than half of the respondents response are interested to change their home standard, which account 34(63.38%).18(34.61%) of them response are no interested to change our home standard.

The samples are distributed in terms of living status of the demographic respondents like: private rental, government rental, private house and dependent.

From the results of the various respondents performed, the following conclusions can be drawn:

More than half the respondent's responses are interested to change their home standard and the rest of the respondents response are not interested to change their home standard.

We improve the project by making awareness for the respondents not interested to change their home standard and the respondents interested to change their home standard.

The construction of this project is very simple, very low weight and need less skill because the material to be used is flexible to use for construction purpose and easily to available in our local area and address housing shortage in urban and rural area and get economical advantage from bamboo.

CHAPTER NINE

9. CONCLUSION AND RECOMMENDATIONS

9.1 Conclusion

Now a day bamboo is the most abundant natural resource and is the easiest materials to work with it. An article or building that made up of bamboo has been in general useful. Tools and machines especially suited in the construction of this project are readily available.

The study is identified the potential use of bamboo as a reinforced bar in concrete and as roof truss in roof as an alternative method for low-cost construction house. The test result indicates the load carrying capacity of bamboo reinforced concrete is 72.69% compared to steel reinforced concrete. So the strength of bamboo is good for reinforcement in concrete for low cost house and also can be considered as an alternative material to substitute other construction material.

The cost analysis, it can be seen that the bamboo reinforcement and bamboo roof truss house cost is less than that of the construction cost of reinforced cement concrete (RCC) and wooden truss. So that constructing a house with bamboo reinforced concrete and roof truss for roof part is very encouraging and also advantageous cost wise for middle and low income group of society in urban area and rural area of our country.

9.2 Recommendations

Based on the study carried out and the observations made, the following recommendations are suggested towards utility of bamboo for roof truss and as reinforcement bar for the low cost housing.

For Government

Government bodies should create awareness on how to use these locally available materials among the people.

Bamboo has many advantages like fast growth, high yield, growing into full size in short time and high renewable, and play great role in rehabilitation of degraded area.

Government must take initiation to motivate small enterprises to participate in such type of house construction by giving appropriate concession on materials.

For Contractors

Bamboo is a primary construction materials for many generation and it is still used in construction of modern house, building scaffolding, house frame, substitute steel reinforcement, flooring, stair, fence, garden furniture, bridge, doors, so if contractors use bamboo as construction materials they will be effective in their work.

For Community

Due to its low cost and easy construction, bamboo structure homes can be used for small and middle income people.

Bamboo structure houses are recommendable for every interested

Individual because it is cost effective and it can be built easily with less man power and machinery.

Bamboo structure house has a good quality in terms of strength and cost effective.

For all users of bamboo material for construction purpose we highly recommended that when they use bamboo as construction material high concentrations should be taken for harvesting and treating bamboo with appropriate mechanisms. Finally, further studies will be required to put complete confidence on the material presented here and to make the bamboo as structural and reinforced concrete construction to be more effective.

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APPENDIX - I

Pictures of during sample Preparation



Bamboo selection



Sample preparation



Bamboo roof truss

APPENDIX-II

Question for data collection

Place of data collection: methehara town

Dear participant:

The purpose of this questionnaire is to collect data about need assessment of low cost modern house and to observe current house condition in the town and availability of local construction material and bamboo , for the project of master graduate project that using bamboo in building construction as a roof truss and reinforcement in concrete at Adama Science and Technology University.

For the ideas that you will give us genuine information about your residence and family status we would like to thank you in advance.

Direction

Tick (✓ or x) in the given box.

The following questionnaires are prepared for gathering primary data

Family status(Age and house hold members)

Number of house hold_____

Number less than 10 years_____

Number less than 18 years_____

Number greater than 18 years_____

Income (salary) status

Low income-

<2000 birr per/month ☐

Middle income- ☐

2000-4000 birr per/month ☐

Higher income-

>5000 birr per/month ☐

Living status of the residential

Rental –private rental ☐

Private house ☐

-government rental ☐

Dependent ☐

Construction material used

Mud house ☐

hollow Block (hcb) ☐

Straw house ☐

House condition

Very good ☐

good ☐

Satisfactory ☐

Poor ☐

Part 2 written

1. For how many years live in this town? And how can you describe the development of housing? If you say the development of housing in our local area is good? How? And if your answer is no? Why

2. How can describe your residence quality based on design and material

3. Is bamboo cultivate in your area

4. Do you have knowledge about bamboo to use as a construction material?

5. Are you interesting to change your home standard? If your answer is yes why? And If not why?

የመጠይቅ ፎርም

መረጃ የተሰጠበት ስፍራ መተሃራ:-

ውድ ተሳተፊዎች

የመጠየቁ አለማ በተመጣጣኝ ዋጋ የመኖሪያ ቤት አቅርቦት:- በአሁኑ ሠዓት የለውን የቤት አሰራር ሁኔታና በአቅራቢያ ያለ የቤት መስሪያ ግብአቶችንን ማጥነት ይሆናል። በተለይም የቀርከህ ግባአት።

ይህን መጠይቅ በአዳማ ሳይንስ እና ቴክኖሎጂ ዩኒቨርሲቲ የድህር ምረቃ ተማሪዎች ለመማረቂያ ጽሁፍ የተዘገጀ ነው።

የፕሮጀክቱ አላማ የጠሪያ ውቅርና ፊርማ በኮንክሪት ውስጥ በቀርካ መተካት ነው።

መመሪያ በጭር ፅሁፍ መልሱን በተዘጋጀው ቦታ ላይ የውሉ

ይህን ምልክት በመጠይቅ ውስጥ ያኑሩ ($\sqrt{\text{or x}}$)

ክፍል አንድ:- ከዚህ በታች ያለው መጠይቅ የተዘገጀው ለባለድርሻ አከላት ጠቀሚ መረጃ ለመሰብሰብ ነው።

የትደር ሁኔታ (ዕድሜ እና የቤተሰብ አባላት)

ያገባ ☐

ያላገባ ☐

የቤተሠብ አባላት -----

ከ 10 ዓመት በታች -----

ከ18 ዓመት በታች -----

ከ18 ዓመት በታች -----

የወር ገቢ መረጃ

ዝቅተኛ ገቢ ከ2000 ብር በታች ☐

መካከለኛ ገቢ 2000-4000 ብር ☐

ከፍተኛ ገቢ ከ 5000 ብር በላይ ☐

የመኖሪያ ቤት ሁኔታ

የግል ቤት ተከራይ ☐

የግል ቤት በለቤት ☐

የመንግስት ቤት ተከራይ ☐

ጥገኛ ☐

የተሠረበት ግብዓት

የጭቃ ቤት ☐

ብሎኬት ☐

የሣር ቤት ☐

የቤቱ ይዞታ መግለጫ

በጣም ጥሩ ☐

ጥሩ ☐

በቂ ☐

ጥሩ ያለሆነ ☐

ክፍል ሁለት :- የፅሁፍ መልስ

ለምን የህል ጊዜ በዚህ ከተማ ኖሮዋል? የቤቶች እድገት ይመለከተቸዋል? በከተማው የቤቶች ዕድገት ጥሩ እንዴት?
አይ ከሆነ መልሱ ለምን ?

ቤቱን ለመስራት የተጠቀሙበት ግብዓት መሠረት የቤቱን ሁኔታ እንዴት ይገልፁታል?

ቀርከህ በአቅራቢያዎ ይገኛል?

የቀርከህ ተክል ለቤት መስሪያ አገልግሎት እንደሚውል ከዚህ ቀደም እውቀቱ አሎት?

የቤቶችን መስሪያ ግብአት በቀርከህ ለመተከት ፍለጎቱ አሎት? መልሱ አዎ ከሆነ ለምን? አይ ከሆነ ለምን?