VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Machhe, Belagavi-590018, Karnataka

A Project Report

on

"Eco-Friendly Modular Housing Using Coconut Coir Prefabricated Panels "

In partial fulfilment of the requirement for the award of the degree of

BACHELOR OF ENGINEERING

In

CIVIL ENGINEERING

Submitted by

1 CHANDAN GOWDA H S	**1DT18CV011**
2 MADHU M	**1DT18CV044**
3 NIYAM YAGNIK P	**1DT18CV054**
4 RACHITH VASUMAN S	**1DT18CV062**

Under the guidance of

Prof. GIRISH P

(Assistant Professor)

Department of Civil Engineering

DSATM, Bengaluru-560082

DAYANANDA SAGAR ACADEMY OF TECHNOLOGY & MANAGEMENT

Department of Civil Engineering

Affiliated to Visvesvaraya Technological University, Belagavi & Approved by AICTE, New Delhi

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Udayapura, Opp. Art of living, Kanakapura Road, Bengaluru – 560082.

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Udayapura, Opp. Art of living, Kanakapura Road, Bengaluru – 560082.

.

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CERTIFICATE

This is to Certify that the project work entitled **"Eco-Friendly Modular Housing Using Coconut Coir Prefabricated Panels" is** carried out by **Mr.CHANDAN GOWDA H S, Mr.MADHU M, Mr.NIYAM YAGNIK P and Mr.RACHITH VASUMAN S**, bearing the USN: **1DT18CV011, 1DT18CV044, 1DT18CV054** and **1DT18CV062,** are

bonafide students of **Dayananda Sagar Academy of Technology & Management**, in their final year as a partial fulfilment for the award of the degree of **Bachelor of Engineering** in **Civil Engineering,** from **Visvesvaraya Technological University**, Belagavi, during the Academic year **2021-2022**.

It is certified that all corrections / suggestions indicated during Internal Assessment have been incorporated in the Report and a copy has been deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

Guide	**Head of the Department**	**Principal**
Prof. Girish P	Dr.K.N.Vishwanath	Dr.M.Ravishankar

EXTERNAL VIVA VOCE

Name of the Examiner	**Signature with Date**
1. _____	_____
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DECLARATION

This is to Certify that, we have followed the guidelines provided by the Institute in preparing the project report and hereby declare that the dissertation work entitled **"Eco-Friendly Modular Housing Using Coconut Coir Prefabricated Panels"** have been independently carried out by ourselves, and whenever we have used materials (Data, Theoretical analysis, figures, and text) from other sources, We have given due credit to them by citing them in the text of the project report and giving their details in the references. We have not submitted this dissertation either in part or full to any other university for the award of any degree.

Sl.No.	Name	USN	Signature
1.	CHANDAN GOWDA H S	1DT18CV011	
2.	MADHU M	1DT18CV044	
3.	NIYAM YAGNIK P	1DT18CV054	
4.	RACHITH VASUMAN S	1DT18CV062	

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Abstract

The housing market in India is in urgent demand of sustainable, affordable low-cost housing due to the rise in population and uneconomical growth rate of urbanisation, which has become a major challenge in our country. The aim of this project is to provide affordable, durable and easy construction homes to all walks of society . However, these challenges can be overcome through modular construction. Modular housing is one of the best solutions which is sustainable and available at a low cost. Modular houses consist of one or more structure units which are pre-fabricated and installed at site. Previous studies approve that modular construction has provided many advantages over conventional building methods which includes the reduction of need for workforce, reduction of onsite greenhouse gas emission (GHG) and the improvement of construction schedule and product quality.

Keywords - Precast Panel, Modular Housing , Sustainable , Low-Cost Housing

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CHAPTER-1

INTRODUCTION

1.1 Modular Construction in India

The housing market in India or in that case, the whole world is in urgent demand of sustainable, affordable low-cost housing due to the rise in population and uneconomical growth rate of urbanisation, which has become a major challenge in our country.The current environmental issues involved with energy use (e.g., climate change, fuel cost, limited availability of resources) along with social, economic, and demographic changes implicate a heterogeneous and segmented housing market that demands sustainable, affordable low-cost Housing. Because of the global energy crisis, ensuring quality and personalised housing at affordable costs is a major challenge for many nations. Modular Housing is a suitable strategy to satisfy this compound request because costs and quality can be addressed very well by prefabrication. Modular construction refers to factory-built building units completely assembled or fabricated in a manufacturing plant away from the jobsite, then transported and assembled on site. A modular building normally consists of multiple rooms with three-dimensional units, which are constructed and pre-assembled complete with trim work, mechanical, electrical and plumbing components installed . A large portion of construction research conducted in the United States and globally discusses that the use of modular construction provides many significant advantages including:

1) The reduction of overall project schedules

2) The improvement of product quality

3) Increased onsite safety performance

4) A reduction in the need for onsite skilled workers

5) A decrease in the negative environmental impact caused by construction operations.

The choice of materials used for the Modular Construction becomes a major challenge when taken into consideration the various factors like availability, eco-friendly and economical, durable and has sufficient strength that complies with the required industrial standards. In this study ,efforts have been made to use coir fibre made wood as a replacement for the existing materials in the

field of Modular Construction to reduce the impact of the use of conventional materials in the field of construction.

1.2 Coir - The Future

The future of the coir industry mainly lies in the creation of new eco-friendly and trendy,coir based building and furnishing products. The trends in the market are visibly changing,the industry may bring in immediate changes and efforts to tackle this situation. The proper management of the situation will alone ensure the sustainable development of the industry in the country.

1.3 Building Materials for Coconut Palm

Given coir's close resemblance to wood in its chemical composition and the availability of renewable fibre every 45-60 days, it would be a good replacement for tropical timber. The increased use of coir composite as alternatives for forest timber, plastics,asbestos etc. encourage sustainable development.

The coconut shells are used mainly as fuel, activated carbon and shell flour. It was reported that coconut shells were used in building construction either as a primarily structural material or as a filter material. It is also used beneath the ground floors in predominantly water-logged areas in order to resist the upthrust due to water pressure and incorporated in roof weathering cores to increase thermal insulation. The coir pith is used for producing hard boards, thermal insulant slabs and bricks.The coconut wood has been used for roofing components like rafters, beams, joints, purlins. Compared with conventional furniture timbers, coconut wood, because of its abrasive nature, has less desirable working qualities. Coconut stem wood does not suffer from degrading defects such as knots. This could facilitate stem bending and use of curved profiles. Coconut stems are ideally suitable as natural round timber because the strongest wood is on the outside surface of the stem.

1.4 Coir Wood Composites

Coir wood composites, the new entrants, could become the sunrise sector of the coir industry. Coir wood made from coir fibre and resin has diversified new uses that will save the tropical forests, increase rural employment opportunities and also promotes agriculture leading to sustainable development.Coir composite board has to compete with these wood panel industry's products for

a place in the market. There are many factors that go for and against coir composite boards. The advantages score, much above the negatives in the long run. It can be judged from the market information that coir composite boards have a bright future ahead.

A composite material is a material where two or more materials are present out of which some load bearing members and the others are for holding the load bearing members in proper orientation. Coir wood composites belong to the fibre reinforced plastics.

In the fibre-reinforced plastics, the fibres are embedded in a polymer matrix so that the former form a discontinuous phase in the continuous phase of the latter. The resinous matrix in the material used to envelop the reinforcement. The compound materials are superior to conventional metallic materials, wood and timber, are mainly used in civil engineering,building and constructions, chemical, transportation, marine and off- shore engineering and sports good applications.The primary advantage of the coir wood composites is due to the coir, which is natural, eco-friendly and abundantly available material. Coir is very strong due to its high content of crystalline alpha cellulose (40%) and high resistance to borer, termite, water and other natural elements due to high lignin content (45%). The coir fibre is very strong and flexible.

1.5 Importance of Coir Wood Composites As Substitutes

One unit of coir ply with a production capacity of 40 cubic metres a day would be able to save about 22 trees per day which means 6,600 trees per year. Assuming that one such tree requires 40 sq.metre, then it would be 25 trees in one acre so that a coir ply unit could save about 264 acres of tropical forest every year. If 10 % of coir fibre produced is utilised in the manufacture of coir ply, it would save about 8, 80,000 tropical trees per year which corresponds to 8,800 acres of tropical forests per year.

CHAPTER – 2

LITERATURE REVIEW

2.1 Literature Survey and Summary

SL No	Author	Year of Publication	Summary
1	Diana Lopez Thomas M Froese	2016	The paper addressed the research concluding that the modular construction methods are most cost effective. Modules arrive 95% completed to the site, hence reducing onsite construction time.
2	E S Soegoto R Sunrat T Valentina	2019	The concepts and idea efforts were raised to produce an efficient housing .Several aspects were covered like thermal comfort, water efficiency ,design of panel system and design of notches to the modules for electrical cables.
3	Luther Mark	2009	This paper provides an organised approach to understand the different types of prefabricated modular building.
4	Elena M Generalova Viktor P Generalova Anna A Kuznestsova	2016	The application of modular technology results in affordable, comfortable and eco-friendly structures that reduce time of on-site construction ,noise and air pollution, increase construction safety and minimum construction waste.
5	Na Lu Thomas Kerman	2010	BIM technology is an accurate virtual model of a building constructed with precise geometry and relevant data needed to support the procurement , fabrication ,on-site installation activities .It allows designers and engineers to visualise the entire scope of a building project in 3D .
6	Qingxin Xu Lexan Sun	2019	Carbon Emissions are the inevitable part of any type of construction .The entire life cycle of a building is considered as a system that emits Carbon dioxide by consuming energy and resources.
7	R Rajesh K K Saju	2017	Application of appropriate chemical compounds to make the coir composites fire and water resistant.

Table 1 : Literature Survey

2.2 Gap Identification

- Coir fibre made Composite wood is not being used in the construction industry as a replacement for the concrete made partition walls. It also has not been used in the modular construction sector.
- Use of cement in construction releases around 2.88 gigaton of carbon footprint into the atmosphere every year in India. Replacement of the concrete by coir wood will reduce the carbon footprint by at least 2% .
- Coir Composite wood is made of Coconut husk ,which is originally a waste product .Hence the waste is being converted into a useful eco friendly product to solve major prevailing problems in the country and in the world.
- The use of timber in construction of houses can be replaced by coir wood . By the use of a standard coir wood panel, 5 trees can be saved from getting cut down.
- Demolition waste production in India is around 198 million tonnes every year of which only 1% is recycled. The project aims at reducing the demolition waste at least by 1- 2% in the initial stages of the project.
- Cost of construction of partition walls can be reduced up to 5% by the use of composite coir panels.

2.3 Objectives

- To convert the coir husk which is originally a waste product into useful sustainable composite panels.
- To develop sustainable prefabricated interlocking panels for partition walls.
- To reduce the onsite construction time and manpower.
- To reduce middlemen contractors to possible extent.

CHAPTER - 3

MATERIALS & METHODOLOGY

3.1 Materials

3.1.1 Coconut Coir Fibres

Coconut coir or coir fibre is an extracted fibrous material from the outer husk of the coconut shell. The coir fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature, but later become hardened and yellowed as a layer of lignin is deposited on their walls. coir fibres are typically 10 to 30 centi-metres long. The two varieties of coir are Brown and White coir fibres.

The important properties of coir fibres are listed.

Ultimate Length	0.6 mm
Diameter/Width	16 microns
Length	6-8 inches
Density	1.4 g/cc
Tenacity	10 g/tex
Breaking elongation	30 %
Moisture regains at 65 % RH	10.5 %
Swelling in Water	5 % in diameter

Table 2: Coir fibre properties

Fig 1 : Coir Fibre

3.1.2 Recycled Deal wood

Deal wood is a recycled wood made by compressing waste wood powder. The strength parameters of the deal wood is nearly the same as a solid ply.

3.1.3 Wood Putty

Wood putty, also called plastic wood, is a substance used to fill imperfections, such as nail holes, in wood prior to finishing. It is often composed of wood dust combined with a binder that dries and a diluent (thinner), and, sometimes, pigment. Pore fillers used for large flat surfaces such as floors or table tops generally contain silica instead of or in addition to wood dust. Pores can also be filled using multiple coats of the final finish rather than a pore filler.

Many different brands, types, and colours are commercially available. Binders include lacquer, water-base, and linseed oil. Some woodworkers make their own putty using fine sanding dust (not sawdust, which is too coarse) with wood glue or a wood finish such as shellac.

Fig 2 : Wood Putty

3.1.4 Phenol Formaldehyde Resin

Phenol formaldehyde resins (PF) or phenolic resins are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. Used as the basis for Bakelite, PFs were the first commercial synthetic resins (plastics).There are two main production methods. One reacts phenol and formaldehyde directly to produce a thermosetting network polymer, while the other restricts the formaldehyde to produce a prepolymer known as novolac which can be moulded and then cured with the addition of more formaldehyde and heat.There are many variations in both production and input materials that are used to produce a wide variety of resins for special purposes.

Phenolic resins are used for making exterior plywood commonly known as weather and boil proof (WBP) plywood because phenolic resins have no melting point but only a decomposing point in the temperature zone of 220 °C (428 °F) and above.

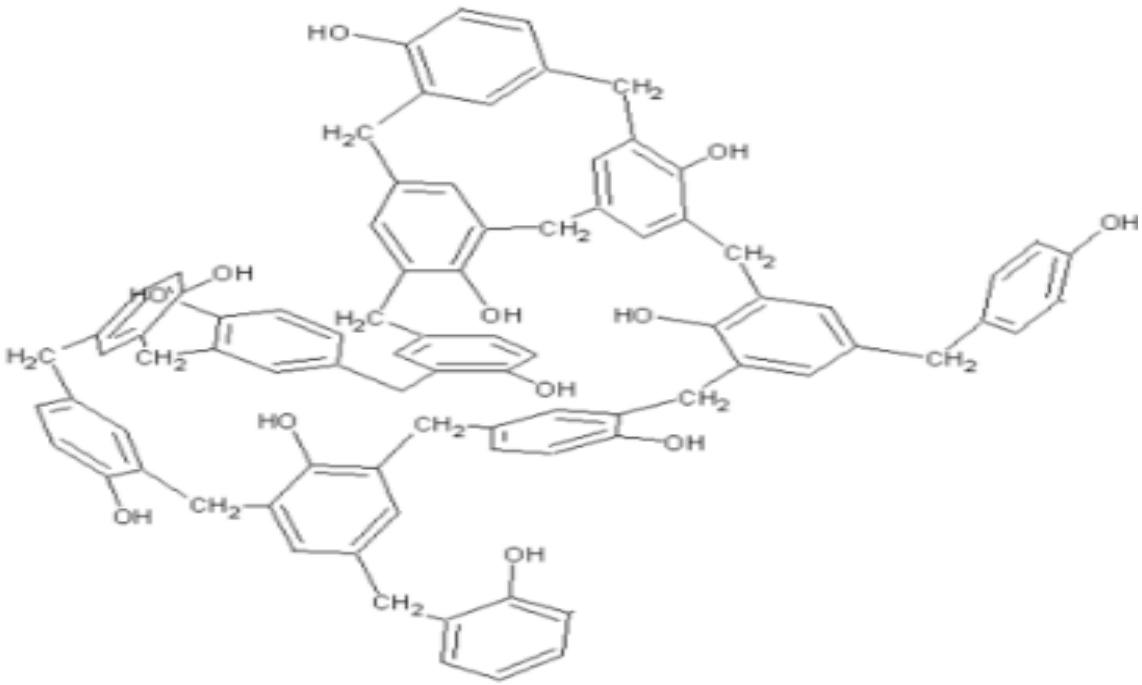

Fig 3 : Phenol Formaldehyde Resin

3.1.5 Primer and Exterior Paint

Primer is a chemical compound applied over the wooden surfaces before applying paint.Various brands of primers are commercially available.

The Exterior paint used is an enamel paint that provides waterproofing to the coir panel surface.

Fig 4 : Enamel Paint

3.2 Methodology

The process of manufacturing the composite coir prefabricated panels can be divided into mainly 4 stages,namely

1. Manufacture of Coir Wood
2. Provision of Wooden Reinforcements
3. Application of wood putty
4. Design of Interlocking systems

3.2.1 Manufacture of Coir Wood

Coir Wood is made by Hot pressing number of Prepreg Sheets made of coir felt .The machine used for the coir felt manufacture is called Indigenous coir felt machine. The machine is made in Austria and is compliant with the coir industry standard.

Fig 5 : Indigenous Coir Felt Machine

3.2.1.1 Preparation of Coir Needle Felt

Well- cleaned coir fibre of good staple length passes through the cleaning machines by pneumatic suction and is needled by the needle loom on one side to evolve felts of different density, punching intensity, needle penetration and thickness. The fibre is mechanically bonded (interlocked) to form a continuous length of sheet. No bonding material is used in the manufacture of coir needle felt. It can be manufactured in thickness from 10 mm to 20 mm with a density varying from 500 to 1500 g/sq.metre. The felt is available in the form of rolls of 4 ft. width and 25 metre length. Some of the important features of Coir Needle Felt are Non-woven fabric with interlocked fibre,Resilient product of porous structures, Low thermal conductivity coupled with good sound absorption coefficient, Light material, with ease of handling and application, Low cost product made of natural fibre.

3.2.1.2 Prepreg Sheet Resin Coating Process for Coir Wood Composite

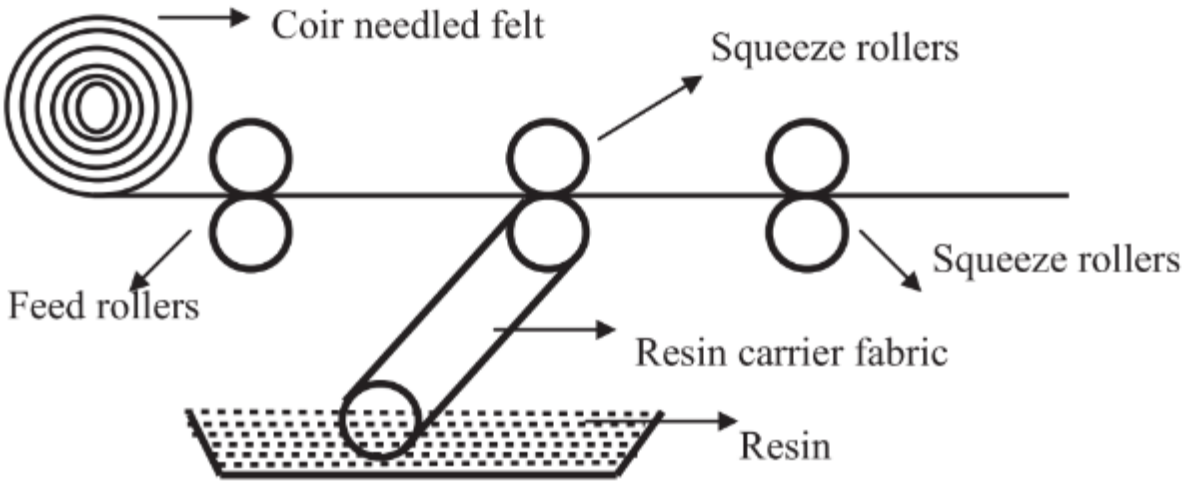

Fig 6 Resin Coating Process

A Prepreg Sheet is a polymer impregnated coir fibre mat. More than 60% by weight of coir fibre can be incorporated in the composite by prepreg sheet moulding process. Non-woven coir needled mat is used for impregnation with resin to prepare prepreg sheets. The non-woven coir needled mat is preferred as it is more economical and the resulting prepreg can be moulded into desired shapes. The coir mat is ideal due to uniformity and ease of handling.

The incorporation of controlled amounts of resin to coir needle felt is achieved by polymer impregnation process in which a resin carrier fabric is pressed against the needle felt so that a part of the resin is transferred to the needle felt from the resin carrier fabric instantaneously. The resin uptake by the needled felt is controlled mainly by the resin carrying capacity of the fabric, pressure applied on the needled felt over the fabric, speed and the properties of the resin such as viscosity and solid content. Composite products from prepreg sheets are prepared by hot press moulding. The prepreg sheets are cut into the required size and stacked one over the other. The number of layers is dependent on the requirement of thickness of the component and the pressure applied for moulding varies depending on the density and surface finish of the product. The overall mechanical strength of the fibre reinforced plastic depends on the combined effect of the amount and kind of reinforcement and on its arrangement in the finished article.

The chemical, electrical and thermal properties result from the type and formula of the resinous matrix. The cost and quality of the product depend on design and proper choice of reinforcement

and matrix. Coir polymer composites' economic viability depends mainly on the amount of coir in the composite and the processing parameters like rate of production, resin content and quality control.

Trimming and polishing of the edges of mouldings and wastage of prepreg sheet can be minimised by taking care of the size of prepreg sheet used for moulding.

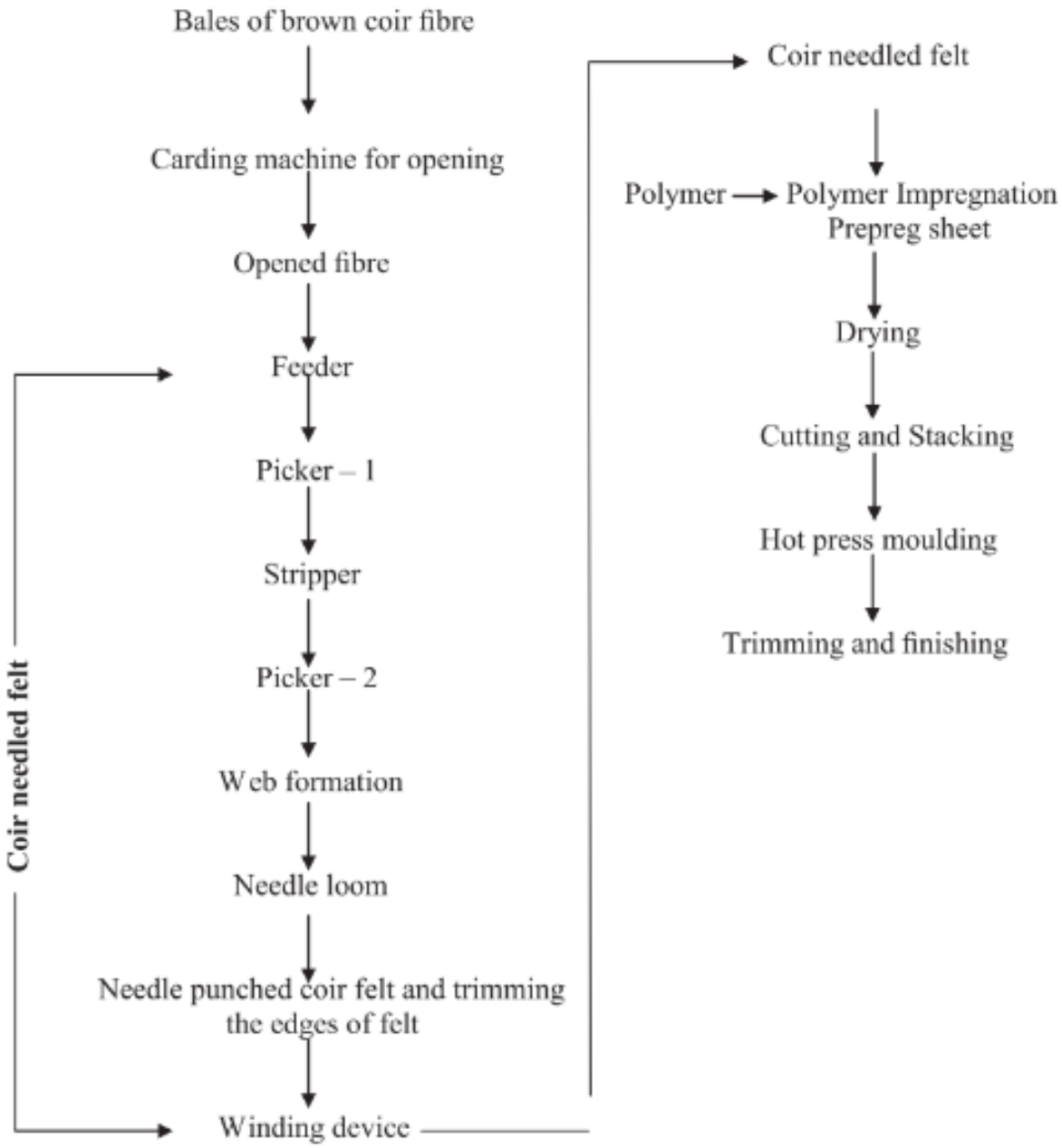

Fig 7 Manufacture of Coir Wood

3.2.2 Provision of Wooden Reinforcements

The prefabricated composite coir panel is a sandwich of 2 individual coir woods of dimension 4 feet in length and 2 feet in width. In between the sandwich , the wood reinforcement of size 1.5 inch in width , 075 inch in thickness and 2 feet in depth is provided for every 6 inches on the coir wood. The wooden reinforcement is provided mainly to prevent the coir wood from bending due to its own weight and also the induced loads.

Fig 8 : Wooden Reinforcement on the inside of composite coir panel

3.2.3 Application of Wood Putty

The main purpose of applying the Wood Putty is to make the surface of the coir panel free from any voids and depressions and to obtain a smooth and even surface.

The dry putty is mixed with the fluid to the required consistency and is applied on the surface to the required thickness. Once the entire surface has been applied with the putty, it is left for drying and setting for about 8 hours. Then the surface is initially rubbed with a sand paper of 650 micron. Then water cut sand paper is rubbed to obtain a smooth and even surface.

Fig 9 : Sanding and water cutting

3.2.4 Design of Interlocking System

The Interlocking system is basically an interconnecting system between two individual coir panels.It spans along the longer dimension of the coir panel and is of thickness 1.5 feet and 4 inch deep. There are teeth up to a depth of 2 inches on one side and for the required width .Three such teeth are present in each interlocking element.

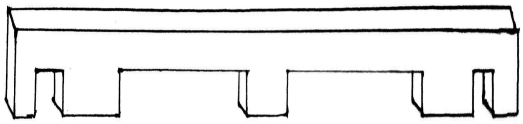

Fig 10 : Interlocking system

The individual sandwich panels are as shown in the figure below. The exterior surface can be painted with enamel paint for aesthetic appearance. The individual panels are mounted on one another with the help of an interlocking system to obtain a partition wall of dimensions 8 feet high and 2 feet wide. The total thickness of the partition will be around 3.5 inches.

Fig 11 : Composite Coir Prefabricated Panels

CHAPTER - 4

EXPERIMENTATION

The tests conducted on the coir wood are compliant with the Indian Standard Code IS:1734 1983. Bearing ,Shear and Flexural Tests are not conducted in this research due to lack of compliant codes and materials.The tests conducted on coir wood are

1. Density and Moisture Content
2. Tensile Strength
3. Compressive Strength
4. Nail and Screw Holding Power

4.1 Determination of Density and Moisture Content

Objective: The object of this test is to determine the density of coir wood which is an indicator of the properties of timber species. The determination of moisture content is necessary since it has a bearing on several important mechanical properties of coir wood.

Test Specimen: Each test specimen shall be of the full thickness of the material and 75 mm wide and 150 mm long. Smaller specimens may be used when deemed necessary. The dimensions of the test specimens shall be measured to an accuracy of not less than ± 0.3 percent.

Apparatus:

Oven: An oven that can be maintained at a temperature of 103 ± 2°C through the drying chamber for the time required to dry the specimen to constant mass. It may require forced air circulation to maintain uniform temperature. The oven shall be vented to allow the evaporated moisture to escape.

Balance: A balance to weigh a specimen within ± 0.2 percent. The accuracy and sensitivity of the weighing balance shall be checked frequently.

Procedure: The test specimen shall be weighed. The specimen shall then be dried in an oven at a temperature of 103 ± 2°C until approximately constant mass is obtained. The specimen shall be weighed to an accuracy of not less than ± 0.2 percent.

Calculation:

The density shall be calculated as follows:

Density, in kg/m^3 = M_o/Lwt

Where : *Mo* = oven dry mass of specimen in g, *L* = length of the specimen in cm, *w* = width of the specimen in cm, and *t* = thickness of the specimen in cm.

The moisture content shall be calculated as follows:

Moisture content, percent = $(M_1\text{-}M_0 /M_o)*100$

Where : M_1 = initial mass of specimen, and M_o = oven-dry mass of specimen

4.2 Determination of Tensile Strength

Objective: This test is intended to evaluate the ultimate tensile strength of coir wood.

Test Specimen: When the evaluation of the ultimate tensile strength only is required specimens of Types D and E may be used. Type D is designed for specimens greater than 6 mm in thickness, and Type E for specimens 6 mm or less in thickness. Measurements of each specimen shall be made to an accuracy of not less than ± 0.3 percent.

In this study, specimens of thickness greater than 6mm was used.

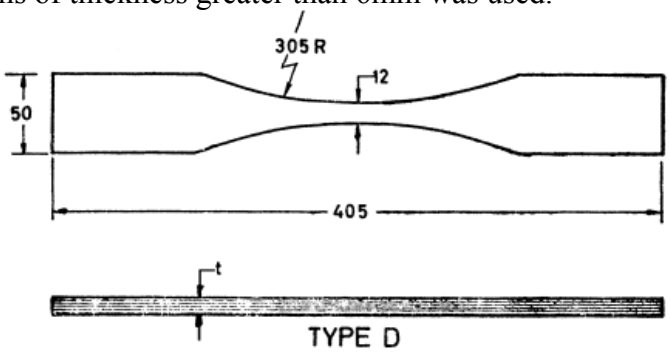

Fig 12 : Specimen type for Tensile Strength Test

Procedure: The load shall be applied continuously throughout the test at a rate of traverse of the movable head of 1 mm/min. The specimen shall be held in wedge-type self-tightening and self-aligning grips.

Data for load-deformation curves may be taken to determine the modulus of elasticity and the tensile stress at proportional limit. Increments of load shall be chosen so that not less than 12 and preferably 15 or more readings of load and deformation are taken to the proportional limit. The deformation measuring apparatus shall be attached at the central portion of the length of the specimen at the central portion of the constant cross section. Deformation readings shall be taken

to the nearest 0.002 mm.

4.3 Determination of Compressive Strength

Objective: This test is intended to evaluate the compressive strength at elastic limit as well as maximum compressive strength of coir wood.

Test Specimen: When tests to evaluate maximum compressive strength alone are required coir wood specimens of 10 cm length shall be glued together such that the total thickness is equal to the width and lies between 20 mm and 40 mm.4 Care shall be taken in preparing the test specimen to make the end surfaces smooth and parallel to each other and at right angles to the length.

Procedure: Specimens shall be held together by suitable supports, and the load shall be applied through a spherical bearing block of self-aligning type with a continuous rate of cross-head movement of 0.5 mm per minute till a failure is indicated. Maximum crushing stress shall be calculated and reported with reference to the grain of the face veneer.

4.4 Determination of Nail and Screw Holding Power

Objective: This test is intended to assess the nail and screw holding capacity of the coir wood.

Equipment: The test shall be conducted on a suitable testing machine with an arrangement to pull the screw and nails so as to measure the maximum load required for complete withdrawal.

Nails shall be 50 mm long and 2.5 mm shank and shall be bright, galvanised, diamond pointed and shall have plain heads. These shall conform to IS : 723-1972.

Screws shall be of 4 mm size and 5 cm in length and shall be galvanised gimlet pointed conforming to IS : 6761-1972.

Each nail and screw shall be used only once

Test Specimen: coir wood strips of 5 × 25 cm shall be glued one over the other to give total thickness of more than 5 cm. Grain direction of the face ply shall be parallel to length. After conditioning the specimen to constant mass at a relative humidity of 65 ± 5 percent and at a temperature of 27 ± 2°C, two nails and two screws mentioned in 3.2 and 3.3 shall be driven to a total penetrative of 25 mm exactly at right angle to the surface of the coir wood specimen at a regular distance of 5 cm on the middle line of the surface. In the case of screw a prebore of 2.5

mm diameter shall be made.

Procedure: The specimen shall be placed on the testing machine and the nail or screw shall be withdrawn one at a time at a uniform rate of 2 mm/min until the nail or screw is pulled out completely. Maximum load for complete withdrawal of nail or screw shall be recorded.

CHAPTER – 5

RESULTS & DESCRIPTION

Density of the coir wood determined from the test is 784 kg/cm^3. Moisture content is 6.5%. The Tensile Strength of the coir wood is 23.6 N/mm^2 and Compressive Strength is 51.02 N/mm^2. Nail Holding capacity is 50 kg.

5.1 Comparison of coir wood with other similar materials

	Coir Ply	Plywood	Medium Density Fiberboard
Testes as per IS	1734	1734	1734
Density (kg/cm^3)	748	650	750-800
Moisture (%)	6.5	10	5-15
Tensile Strength (N/mm^2)	23.6	35.55	7-8
Compressive Strength (N/mm^2)	51.02	29.24	N.A
Nail Holding Power (kg)	50	125	N.A

Table 3 : Properties of Different Materials in comparison to coir ply

From the table it is evident that coir wood /coir ply possess better magnitude of properties in comparison to other materials of the same class.

CHAPTER – 6

CONCLUSIONS & DISCUSSIONS

It can be concluded from this research that use of prefabricated composite coir panels (modular panels) will greatly influence and reduce the embodied energy of a building. The modular housing can be a low-cost alternative to conventional building construction which is dependent on the use of natural resources for the construction process. Coconut coir is an industrial waste product which can be extracted from the outer shell of the coconut.

The coconut coir is found to exhibit excellent strength and bonding characteristics in comparison with cement. The modular construction thrives on the technology or use of prefabricated wall panels which are cast in a factory and installed in-situ, this reduces the construction time and delays in construction projects. It is proposed to use coconut coir as a prefabricated material for manufacture of wall panels with interlocking grid. The feasibility of construction/ transportation and durability of the said wall panels is to be tested in field conditions. The coconut coir will serve as a sustainable material for the manufacture of the wall panels along with the use of Phenol Formaldehyde as binding material for the coir. The research aims to reduce the cost and time of construction from manufacture to casting of the wall panels.

According to a rough estimate ,use of coconut coir composite panel made partition walls instead of cement made partition walls can reduce up to 0.06 gigaton of carbon emission.

Below table compares the composite coir panelled partition with other types of partition that exist as of today's market.

price/square feet in Rs	Gypsum	MDF	Concrete	Hollow Mud Block	Coir Composite
Construction Cost	125	500	100	560	75-90
Extra	40	0	35	70	35
Total	165	500	135	630	110-125
Durability (years)	20	25	30-40	15-20	15-20

Table 4 : Cost and Durability Comparison

SCOPE OF FURTHER STUDY

- This study is at its initial stage where only interior use of the coir has been explored .There is scope for external use of coir in the coming days.
- Coir composites can also be used in load bearing structures with use of appropriate material combination.
- Entire module of the house made of coir composites are possible
- Use of other industrial waste as an admixture for coir composites to enhance their overall properties is also a possibility
- Only vertical interlocking has been studied in this research. Horizontal and foldable interlocking is very much possible with more research.

CHAPTER – 7

REFERENCES:

1. Diana. Lopez , Thomas.M.Froese , Analysis of costs and benefits of panelized and modular prefabricated homes , 2016:precedia engineering 145 (2016) 1291-1297.

2. E S Soegoto , Subarjit and T Valentina , Modular panel house design with prefabricated production Technology , 2019:Physics conference . ser : 1402022001.

3. Mark B Luther , Prefabricated Sustainable Housing – An Introduction , 2008-2009: BEDP Environment Design Guide , vol.TEC 28 , pp.1-11.

4. Elena M Generalovaa , Viktor P Generalova , Anna A Kuznetsovaa , Modular Building In Modern Construction , 2016: procedia Engineering 153(2016) 167-172.

5. Na Lu , Thomas Kerman , Implementation of Building Information Modeling in Modular Constructions: Benefits and Challenges , USA , 2010:Conference Paper , Construction Research Congress.

6. Qingxin Xu , Lexan Sun , Application Analysis of Prefabricated Buildings under Green Construction , Harbin, China , 2019: ICCREM conference paper , Department of Construction and Real Estate, Harbin Institute of Technology.

7. R Rajesh , K K Saju , Application of appropriate chemical compounds to make the coir composites fire and water resistant , Kerala, India , 2017: Indian International coir fair conference paper , Coir Research Institute.