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FEASIBILITY STUDY OF PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT BONDED BOARD FROM *Lannea coromandelica*

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TO

MY BELOVED PARENTS

DECLARATION

I, Sohana Zafar Bristi, declare that this thesis paper is my own works and it has not been submitted or accepted for a degree in any other university.

I, herby, give consent for my thesis, if accepted, to be available for any kind of photocopying and for inter-library loans.

Signature:

Sohana Zafar Bristi

APPROVAL

Project thesis submitted to the Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, in partial fulfillment of the requirements for the professional M.Sc (Masters) degree in Forestry. I have approved the style and format of the project thesis.

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ABSTRACT

Jeol (*Lannea coromandelica*) is a member of Anacardiaceae family. It is generally found in tropical and sub-tropical regions all over the world. Jeol is locally used as folk medicine. The study has been conducted to evaluate the properties of cement bonded board made from *Lannea coromandelica* stem. In this study, two types of ratios (1:2.5 and 1: 2.75) have been used and three types of particles such as coarse, coarse-fine and fine particles. The density of CBP for fine, fine-coarse and coarse particles (Ratio-1: 2.5) are 0.810, 0.817 and 0.856 respectively. In case of ratio (1: 2.75), the density for fine, fine-coarse and coarse particles are respectively 0.830, 0.853 and 0.867. It has been found that the moisture content of CBP for fine, coarse-fine and coarse particle (Ratio- 1:2.5) are 14.62%, 15.58% and 16.62% respectively. Moisture content of (Ratio-1:2.75) for fine, coarse-fine and coarse particles are 13.35%, 13.94% and 15.56% respectively. Water absorption of water by cement bonded board for fine, coarse-fine and coarse particles (Ratio-1:2.5) are 26.54%, 25.23% and 25.12% respectively. In case of (ratio-1:2.75), it has been found that water absorption of water is 25.43%, 22.18% and 21.54% respectively after 24 hours immersion in water. It has been found that thickness swelling of CBP for fine, coarse-fine and coarse particles of ratio-1:2.5 are 2.25%, 2.21% and 2.18% respectively. In case of ratio-1:2.75, CBP for fine, coarse-fine and coarse particles are respectively 2.17%, 2% and 1.93% after 24 hours immersion in water. The linear expansion of CBP of ratio-1:2.5 for fine, coarse-fine and coarse particles are 3.63%, 3.39% and 3.38% respectively. For ratio-1:2.75, the linear expansion of CBP is 3.20%, 2.90% and 2.73% respectively after 24 hours immersion in water. Modulus of elasticity of CBP for fine, coarse-fine and coarse particles (Ratio-1:2.5) are found to 231.78 N/mm^2, 234.67 N/mm^2 and 260.23 N/mm^2 respectively. In case of ratio-1:2.75, Modulus of elasticity of CBP are 238.22 N/mm^2, 259.55 N/mm^2 and 266.67 N/mm^2 respectively. Modulus of Rupture of CBP for fine, coarse-fine and coarse particles (Ratio-1:2.5) are 3.12 N/mm^2, 3.24 N/mm^2 and 3.49 N/mm^2 respectively. In case of ratio-1:2.75, Modulus of rupture of CBP is 3.46 N/mm^2, 3.48 N/mm^2 and 3.59 N/mm^2 respectively. From the entire particle boards the ratio of 1: 2.75 of coarse particles show highest performance. Hence it can be concluded that cement bonded board from *Lannea coromandelica* tree can be alternative raw material for manufacturing of cement bonded particle board.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER: 1

INTRODUCTION

1.1 Background and justification of the study:

Wood is one of the earth's treasured renewable resources. It is a wonderful gift of nature and the only working material that is self-generating. Because of its unique properties, availability in large quantity, renewability and adaptability, wood may be chosen not only as a material of wide usage, but also as an important buffer against shortage of other materials (Anon, 1970). Wood is always been a pre-eminent construction and industrial material. It's low cost and availability in various forms and sizes, together with such properties as relatively great strength with respect to weight, ease of shaping, low heat conductivity and sound quality made it an outstanding material (Shrivastava, 1997).

Increasing pressure on forests from multiple sectors presents significant challenges to forest and Environmental managers who must strike a balance between demand and the need to protect this important renewable resource. Maser (1994) suggested that the past abundance of forest products has evolved into present-day limitations, and if changes are not made, present limitation will become future scarcities. Forests in Bangladesh are deteriorating at an alarming rate due to various socio-economic menaces, biotic pressure and competing land uses. Estimated forest area of the country is about 2.53 million ha (0.02 ha person-1) which is about 17.49% of the total land mass. Of the total forest land, the Forest Department (FD) directly controls 1.53 million ha. The District Administration controls 0.73 million ha and the remaining 0.27 million ha are privately owned village forests (Muhammed et al., 2008). Wood composites are widely used as alternatives to solid wood for utilizing wastage, reducing environmental hazardous and making desired shaped furniture.

Over the last years promising cement bonded wood composites for structural purposes have acquired. Durability, toughness, high dimensional stability, resistance against environmental influences such as biodegradation or weathering but also availability of raw material as well as economic factors are features which can make cement-bonded composites superior to conventionally bonded composites (Flybort et al., 2008). In Europe, South America and Asia, cement has been used as bonding agent for wood excelsior board, particle board, fiber board and other wood cement composite products for nearly 50 years (Lee and Short, 1989). Lee (1984) concluded that cement excelsior board (CEB) was very stable dimensionally when subjected to water soaking, the water absorption and residual water absorption are much less than those of ply wood. Wood-cement panels are currently used in many countries for roof decking, flooring, exterior walls, partitions, and wall paneling in houses, school and industrial buildings (Moslemi, 1974).

Especially in warm and humid climates, where high resistance against termites and fungal decay is demanded for constructive materials (Eusibeo, 2003; Wolfe and Gjinolli, 1996ab). Cement-bonded Composites show a high potential as a building material. Further benefits of CBCs are easy machining with conventional wood working tools and simple fabrication (Wolfe and Gjinolli, 1996ab), which make this materials interesting for less developed countries. However, the production and use of CBCs in these countries is small because of a lack of information and the limited economic sales potential (Ramirez-coretti et al., 1998). Now-a-days, these countries show a big interest in these composite materials, whereas industrial countries mainly use CBCs, especially cement-bonded wood wool board, for insulation purposes. The increasing interest of less developed countries in CBCS can be explained by low costs and availability of raw materials (Flybort et al., 2008).

Bangladesh is a densely populated country. The problem of housing is now a mostly sensitive issue due to increase in its population. Moreover, natural disasters like flood are very frequent and humid weather prevails in most part of the year. The situation, therefore, demands low cost housing for the teeming millions that would very likely promote the use of CBP panels as cheap constructional material. In this context, the present study was under taken to evaluate the suitability of *Lannea coromandelica* (Jeol) in the fabrication of cement bonded wood composites. National Forest and Tree Resources Assessment 2005 – 2007 of Bangladesh explained that there is about 70% tree volume of the forest in Bangladesh where Lannea species are grown in association with other species. Besides, in Bhawal National Park (Gazipur), it is listed as a common species. In Modhupur region, Garo families use it's bark for medicinal purposes. In Moulovibazar, Lalmonirhat district Lannea speacies are available (Rahmatullah, 2011; Uddin, and Hassan, 2010). It is used as fencing, medicine in southern region generally (Faysal, 2008). So Jeol is an easily obtainable species in different region. Its value is within the limit of local people. If we can utilize it for making cement board, then it will recover our wood crisis.

1.2 Objectives of the study:

1. To develop the manufacturing technology of cement bonded board from *Lannea coromandelica* particle.
2. To evaluate the physical and mechanical properties of cement bonded board from *Lannea coromandelica.*

CHAPTER: 2
REVIEW OF LITERATURE

2.1 General information of cement bonded board:

2.1.1 Definition of cement bonded board:

A particleboard is a board (or sheet) constituted from fragments of wood and/or other lingo-cellulosic materials (chips, shavings, flakes, splinters, sawdust etc), bonded with organic binders with the help of one or more agents like heat, pressure, humidity, catalyst etc (Anon, 1970). It may be classified as panel product manufactured under pressure and heat from particles of wood or other lingo-cellulosic materials bonded entirely with a binder, generally a synthetic resin, to which other chemicals (e.g. fire retardant, fungicide, water retardant etc) may be added to improve certain properties (Salehuddin, 1992).

Cement bonded wood has been investigated for more than one hundred years, whereas the industrial utilization of cement bonded particleboard started in the 1930's. However, most of the innovation have been done in the last 40 years (Moslemi, 1999). Furthermore, the shortage of resources in general is a fact which forces the utilization of recycled wood (Wei et al., 2003). The decline of wood quality partly caused by increased use of small dimensioned wood influences production and quality of engineered wood products (EWP). In order to reduce in homogeneities, solid wood is disintegrated and bonded to form wood products. Different method have investigated (e.g. sliding, crushing, steam explosion etc), besides cutting technologies, to disintegrate wood particles for the manufacture of wood composites with distinctive properties.

Cement boards are mainly cement bonded particle boards and cement fiber. Cement bonded particle boards have treated wood flakes as reinforcement, whereas in cement fiber boards have cellulose fiber, which is a plant extract as reinforcement. Cement acts as binder in both the cases. The fire resistance properties of cement bonded blue particle boards and cement fiber boards are the same. In terms of load-bearing capacity, cement-bonded particle boards have higher capacity than cement fiber boards. Cement particle boards can be manufactured from 6 mm to 40 mm thickness making it extremely suitable for high load bearing applications. These boards are made of a homogeneous mixture and hence are formed as single layer for any thickness. Cement fiber boards are more used in decorative applications and can be manufactured from 3 mm to 20 mm thickness. Fiber boards are made in layers of very thin thickness, making it extremely difficult to manufacture high thickness boards. Many manufacturers use additives like mica, aluminium stearate and cenospheres in order to achieve certain board qualities (Wikipedia, 2011).

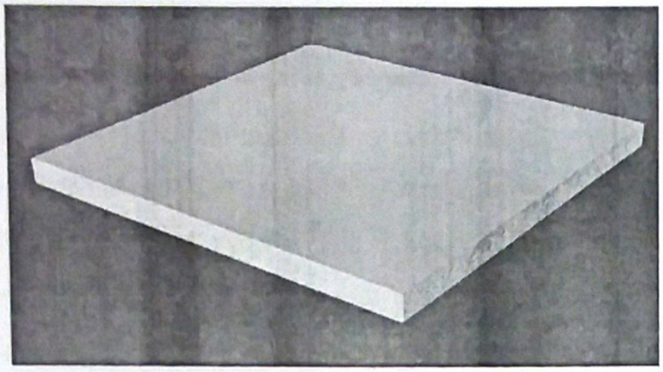

Figure 2.1: Cement bonded board

2.1.2 Brief history of mineral-bonded wood composites:

The first mineral-bonded wood composite panels utilized a magnesite binder and were developed in Austria in the early 1900s. These products still exist today mainly for interior applications, and are currently manufactured in Europe and the U.S. by Heraklith (now Knauf Insulation) and Tectum, respectively. In Europe and the U.S., these low-density panels (approximately 400 kg/m^3) are often used as insulation boards because of their excellent thermal and acoustic properties. Soon after, cement-bonded wood composites became popular with the development of Wood-Wool Cement Board (WWCB). WWCBs are used for internal applications and for exposed decorative ceilings and roof decks, and because Portland cement bonded WWCBs are fully moisture-resistant, they are also used successfully for permanent shuttering of concrete floors and walls, and most recently for thick and very Large Wall Elements in Scandinavia and Russia. The worldwide demand for these Large Wall Elements is expected to increase because of increasing heating and cooling costs and greater demand for personal comfort. Sophisticated and automated turn-key plants that are capable of producing several types of WWCB, Wood Strand Cement Board (WSCB), and Large Wall Elements on one combined manufacturing line are now available. Cement- bonded Particle Board (CBPB) is a high-density product that was developed in the 1970s to replace asbestos-cement board for structural applications. Common uses of CBPB in Europe are facades, electrically-heated and raised floors, permanent shuttering of concrete floors and walls, and fire- and moisture-resistant furniture. The applications of CBPB have been restricted by its high density (approximately 1,250-1,400 kg/m^3), reduced flexibility and strength, relatively high expansion and shrinkage when exposed to moisture, and the need to pre-drill pilot holes when attaching screws. Therefore, manufacturers, builders, and architects were interested in developing a product that could better meet structural requirements and overcome these hurdles – this was attained with the development of the new wood Strand Cement Board (WSCB), which accepts screws without pre-drilling, and exhibits lighter weight, greater bending strength, more flexibility, and less expansion and shrinkage due to moisture than CBPB. For a more detailed description of the history of mineral-bonded wood composites, the author refers the reader to Gerry van Elten's paper "History, Present, and Future of Wood Cement Products" presented at the 9th International Inorganic-Bonded Composite Materials Conference in Vancouver, BC, Canada (Aro, 2008).

Chart showing history of cement bonded board-

Year	History
1900	The first mineral bonded board was produced by an Austrian carpenter using wood shavings and gypsum
1920	The first Wood Wool Cement Board (WWCB) is produced in Austria. Several others in Europe followed.
1930	Wooden lath reinforced WWCB roofing boards produced in Holland, along with the first Cement Bonded Wood Chips (Durisol) boards.
1950	Velox boards produced in Austria from course wood particles and cement.
1970	The first Cement Bonded Particle Board (CBPB), called Duripanel, was produced in Switzerland.
2000	Eltomation developed a fully automatic plant for Wood Strand Cement Board with approx. 1100 kg/m^3, called EltoBoard

(www.unbc.ca/woodconcrete)

2.1.3 Types of cement bonded particleboard:

There are three main types of wood-cement board which are Wood wool cement board (WWCB), Cement bonded fiber board and Cement-bonded particle board (CBP). Each type of the composites gives different type of characteristics and properties. Moreover, the technology involved in the manufacture of each of these types of composites is different (Maloney, 1977).

a) Wood wool cement board (WWCB):

The production of WWCB had already spread over Europe in the thirties, several years after wood wool gypsum boards and wood wool magnesite boards were successfully produced and applied in Austria. After 1950 WWCB has spread world-wide. In industrialized countries automatic plants were installed, in developing countries usually only certain essential sections to reduce the investment and to employ people. Until recently no fully automatic WWCB plant could be supplied, since all wood wool shredding machines were manually operated. Besides being unhealthy and dangerous for the operators these machines produce wood wool of an inconsistent quality, while the capacity is relatively low (Elten, 1996).

Traditionally wood wool cement boards have been applied in Europe as a base for gypsum plaster or cement stucco and for permanent shuttering and insulation of concrete. Later in some countries (Scandinavia, Holland) non coated, spray painted acoustic ceiling boards have proven to be very successful and are now increasingly being used in several other countries as well. In the sixties so called Sandwich or Composite Boards were introduced, offering higher insulation values. These boards consist of one or two outer layers of WWCB with a core of rigid foam of polystyrene or polyurethane. To further improve the fire resistance also composite panels with mineral wool are produced. For an increased span of roofing boards, wooden laths (Holland) or poles (Sweden) embedded in the boards allow for a free span of up to 1, respectively 2 meters and with steel channels at the edges (UK) up to 4 meters. In case of a special shape of the board and channels according to our UK Patent 1,094,689 a free span of up to 6 meters is obtained. In developing countries various systems were developed for mass production of low income houses. For the description of these systems I refer to my earlier lectures for the Food agriculture organization of the United Nations (FAO) and the World Association for Element-Building and Prefabrication (WAEP) (Elten, 1996).

b) Cement bonded fiberboard:

Cement bonded fiber board is produced from fiber which we can get from either wood or non woody materials. Wood fiber reinforced cement bonded boards are manufactured from wood fiber (7-8.5%), sand (60%), cement (30%) and aluminium tri-hydrate (3-4%). The wood fiber is usually obtained from softwood chemical pulp. They act as a reinforcing agent in the boards, a role previously played by asbestos fibers in an older generation of building materials. The manufacture involves washing the sand and reducing it to a fine powder using a ball mill. Fibers are then refined or beaten twice in conical refiners to make the ability to interact with sand and cement higher. The proportions outlined above are combining the cement, sand, fibers and additives and diluted to form slurry with a solids content of 10% (Shakri, 2008).

c) Cement bonded particleboard:

Cement bonded particleboard (CBPB) was first commercially manufactured in the early nineteen seventies and has continued to be manufactured in relatively small quantities satisfying the requirements of specialized end-use applications. There are perhaps only about fifty of these mills world-wide each of which produces on average only about 200 m3/day. CBPB is readily identified from its mid grey somewhat polished appearance. The surface is very smooth, cementitious and devoid of wood chips; however, when heavily sanded the surface can appear very similar to that of resin-bonded particleboard. In cross section the chips, particularly in the middle layer of the panel, can be clearly seen: there are very few holes to be seen with the cement encasing the wood chips. Primarily because of its lay up, composition and mass, CBPB is mainly used for specialized applications in construction. Thus, its outstanding merits, especially in terms of reaction to fire, durability, sound insulation and stiffness, render the product most suitable for internal wall construction in public places, lining of lift shafts, construction of cabling ducts, soffits, motorway acoustic fencing and cladding of prefabricated house units (http://www.wpif.org.uk/uploads/PanelGuide/41_%20Annex%202c%20BRE%20V3%2021_04.pdf).

It is composed of mineralized wood particles and Portland cement. It is light gray in color and is flat and smooth on both surfaces. CBCP combines the workability of wood with the strength & durability of cement. During the manufacturing and curing process, the wood content in CBCP is mineralized with non-toxic chemical agents to render it fire resistant. These treated mineralized wood elements combine with the Portland cement matrix to add strength and flexibility (www.architecturalproducts.com/downloads/Versaroc%20Catalog.pdf).

2.1.4 Technological process:

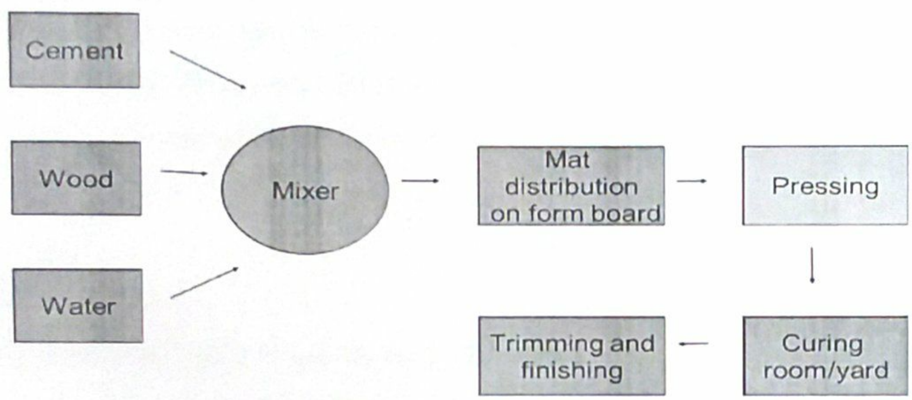

Figure 2.2: Flow chart of technological process (www.unbc.ca/woodconcrete).

Working with CBPB

Cement bonded board should be cut by power saw and machined (routed, spindled, planed and bored) with normal woodworking machinery fitted with tungsten carbide cutting edges. Dust extraction equipment must be employed in enclosed spaces.

a) Mechanical joints and fixings

Wherever possible, fittings that depend upon face fixing should be selected; fittings that depend upon the expansion of a component inserted into the panel edge should be avoided. Conventional woodworking fixings and techniques can be applied to CBPB which provides good holding power for screw fixings into the panel faces. Edge screwing is possible; in panels >16mm in thickness, pre-drilled holes are required. Countersunk parallel core screws should be used in both edge and face fixings because they have greater holding power than conventional wood screws.

A high ratio of overall diameter to core diameter is desirable. Because of the high alkalinity of the panel, stainless steel or galvanized screws with a diameter up to 4.2mm should be used. Drill pilot holes for all screw fixings. Typically, the holes should be 85 to 90% of the screw core diameter. Fixings into the panel face should not be within 15mm of edges of panels up to 16 mm in thickness (20 mm for panels up to 22 mm in thickness) and within 40mm of the corners. Manual nailing of serrated or twisted nails up to 3.1 mm in diameter is possible in panels up to 12 mm in thickness. Above 12 mm, either predrilled manual insertion or non-predrilled pneumatic fixing should be used. Nails must be flat headed and galvanized, sheradised or of stainless steel. Panels can also be fitted together using galvanised or stainless steel clips. Further information on working with CBPB is included in Section 4.4 of PanelGuide. (http://www.wpif.org.uk/uploads/PanelGuide/41_%20Annex%202c%20BRE%20V3%2021_04.pdf).

b) Adhesive-bonded joints

A wide variety of jointing methods can be used, provided the following simple guidelines are observed:

- The joint parts should be accurately machined.
- Use sharp cutters to avoid tearing or burnishing the surfaces to be bonded.
- Use a high solids content adhesive with low flowing properties such as cold setting formaldehyde.
- Locate mating pieces accurately and hold them under pressure while the adhesive sets
- The width of grooves machined in CBPB should be limited to about one-third of the thickness of the board. The depth of groove is typically about one-half of the board thickness.
- Allow adhesive-bonded joints to condition for several days before sanding and finishing; this avoids the appearance of sunken joints and is essential with high-gloss finishes.
- A tongue and groove joint is very efficient, provided the fit of the joints is not too tight to cause a split along the edge.
- When attaching lippings, the tongue should be machined on the solid wood piece.

c) Finishing

Where very smooth surfaces are required pre-sanded panels should be specified. Further information on finishing CBPB is provided in Section 4.7 of Panel Guide.

Health and safety

a) Dust: Cement bonded board will generate large quantities of very fine dust when it is machined and is a potentially hazardous substance and must be controlled. Dust from cutting operations can be controlled adequately by complying with the Control of Substances Hazardous to Health (COSHH) Regulations 2002. Under these regulations wood cement dust has a Workplace Exposure Limit (WEL) of 5mg/m2 expressed as an 8-hour time-weighted average. Exposure must be reduced as far as possible below this limit, usually with properly designed and maintained dust extraction equipment fitted to woodworking machines. Extraction equipment is often not practicable or even available when using portable or hand-held tools, so a suitable dust mask (for example, Type FFP2 to EN 149) should be worn. If possible, work in a well-ventilated place. Further information on dust is given in Section 6.3 of Panel Guide.

b) Formaldehyde

Uncoated Cemented board manufactured using Portland cement does not require to be tested for formaldehyde and is automatically rated as E1. Uncoated panels produced in the UK therefore, have an E1 rating.

c) Hazards and control

In sheet or processed form, CBPB is non-classifiable under the COSHH regulations. However, there may be handling hazards, especially so on account of its high density. COSHH Regulation 6 requires an assessment to be made (and normally recorded) of health risks associated with wood dust or formaldehyde together with any action needed to prevent or control those hazards. The table below gives the most common hazards and identifies control methods to minimize the risk of harm actually occurring.

Common hazards and methods of control

Activity	Hazard	Control
Manual handling (in full sheet form)	Large sheet sizes present a risk of strain or crush injuries if not handled correctly.	Store carefully in uniform stacks on a flat level base. Use mechanical handling equipment Adopt correct manual handling procedures.
Carpentry work Activities likely to produce high dust levels include: · Sanding by machine · Sawing, routing and turning · Hand assembling machined or sanded components	Wood cement dust in general (including dust from CBPB) may cause dermatitis and allergic respiratory effects.	Off site: preparation under exhaust ventilated plant. On site: enclosure and exhaust ventilation. Dust extraction on portable tools. Good ventilation. Respiratory protection equipment. *Note*: Any health hazards arising from the use of CBPB at work can and should be controlled by compliance with the requirements of the Control of Substances Hazardous to Health (COSHH) Regulations 2002.

(http://www.wpif.org.uk/uploads/PanelGuide/41_%20Annex%202c%20BRE%20V3%2021_04.pdf).

2.1.5 Applications of cement bonded particle board:

Successful new applications in Western Europe, different from that of asbestos boards, are amongst others:

- Flooring with tongue and grooved boards;
- Large size prefabricated elements for permanent shuttering of concrete walls and floors
- The production of complete prefabricated houses.

Depending on cultures and building codes, the developments in the market since 1970 for CBPB are very different in various countries, which is also depending on price and quality of the boards. Amroc in Magdeburg, Germany, which company has Eltomation mixing, dosing and distributing equipment for narrow thickness tolerances, recently reported the distribution of their standard CBPB Class B1 and high fire resistant boards Class A2 in Western Europe as follows:

Approximate distribution for the following applications:

15% - (raised) Floors

20% - Office containers, influenced by new governmental fire and moisture regulations

15% - Supply to prefabricated house manufacturers

25% - Various supplies to the industry, amongst others for kitchens, bathrooms and furniture.

5% - Facades

20% - Various, including high fire resistant Class A2 boards (Elten, 1996).

General properties of low density cement wood fabricated using excelsior-type particles (Eusebio, 2003)-

Property	From	To
Bending strength	1.7 MPa	5.5MPa
Modulus of elasticity	621 MPa	1241 MPa
Tensile strength	0.69 MPa	4.1 MPa
Compression strength	0.69 MPa	5.5 MPa

2.1.6 Advantages & attributes of cement-bonded wood composites:

A unique feature of mineral-bonded wood composites is that their manufacture is adaptable to either end of the cost and technology spectrum. This means that manufacturing plants with varying levels of automation are available – from full automation to low levels of automation (which rely more on manual labor and hand operated equipment). This is especially true with Portland cement-bonded composites because no heat is required to cure the cement binder. These composites also exhibit manufacring versatility; with a small investment, the products can already be manufactured on a small scale using simple tools, and as the market has grown, automated equipment for their manufacture has been developed and is readily available for implementation. In contrast to conventional urea- and phenol-formaldehyde resin-bonded wood composite panels, cement bonded wood composites possess much higher fire, insect, and fungal resistance, in addition to good weather ability and acoustic absorption. Also, the increasing cost of resins and machinery necessary for the production of resin-bonded boards is another point in favor of mineral-bonded composites (Ahn and Moslemi 1980; Simatupang and Geimer 1990; Simatupang et al., 1991; Oyagade 1994; Badejo 1999; and Ajayi 2000). In summary, the general attributes of mineral-bonded wood composites are:

- High fire resistance
- Wet and dry rot resistance
- Freeze-thaw resistance
- Termite and vermin resistance
- Excellent workability
- Exceptional insulation and acoustic performance (WWCB)
- Low cost and ease of manufacture

2.1.7 Disadvantages:

One major disadvantage of cement board is the weight per square foot. It is approximately twice that of gypsum board, making handling by one person difficult. Cutting of cement board must also be done with carbide-tipped tools and saw blades. Due to its hardness, pre-drilling of fasteners is often recommended. Finally, cement board is initially more expensive than water resistant gypsum board but may provide better long term value (Wikipedia, 2011).

2.2 General information of *Lannea coromandelica* :

2.2.1 General description:

The family Anacardiaceae consists of about 77 genera and 700 species of trees, shrubs, woody climbers and, very rarely, herbs. In India, the family is represented by 20 genera and 60 species of trees and 3 genera and 8 species of shrubs. Anacardiaceae is distributed in the tropical and subtropical regions of the world with a few extending into the temperate zones. The family is of considerable economic value (Singh *et al.* 2000). *Lannea coromandelica* L. is a one kind of Anacardiaceae species. Plants belong- ing to this genus are used in folk medicine (Islam, T; Tahara, S, 2000). It is upto 15-20 m tall. Bark is ash coloured, smooth. Leaves are 8.0-13.0 cm long, crowded at ends of branches, leaflets green, membranous, 3-5 pairs 1.0-4.2 × 0.3-2.1 cm, ovate, elliptic-oblong, glabrous, base oblique.

Figure 2.3: Bark of *Lannea coromandelica.*

Flowers are purplish, appearing when tree is base of leaves, male racemes are compound, female is simple; pedicels are very short. Calyx is 4-5 lobed, hairy, ciliate. Petals are 4, ovate-oblong. Stamens are as many as petals. Drupes are smooth glabrous, 0.6-1.0 cm long, reniform, compressed, red (Patel, K. C; Patel, R. S; Shah, R. B and Jangid, M. S, 2010). Usually the tree flowers in months between February and April. The fruiting season is between May to July. The tree when injured exudes a brown gum that turns black on drying. It also has been noted to be glassy white in colour. *L. coromandelica* is strongly irritant. All the plant parts, gums, stems, leaves, flowers and bark were investigated for the chemical constituents. The plant was reported to contain various compounds like Carbohydrates including Gums, Proteins, Glycosides, Terpenoids, Polyphenols. Preliminary phytochemical analysis of the bark revealed the presence of Terpenoids and Flavonoids (Reddy et al., 2011).

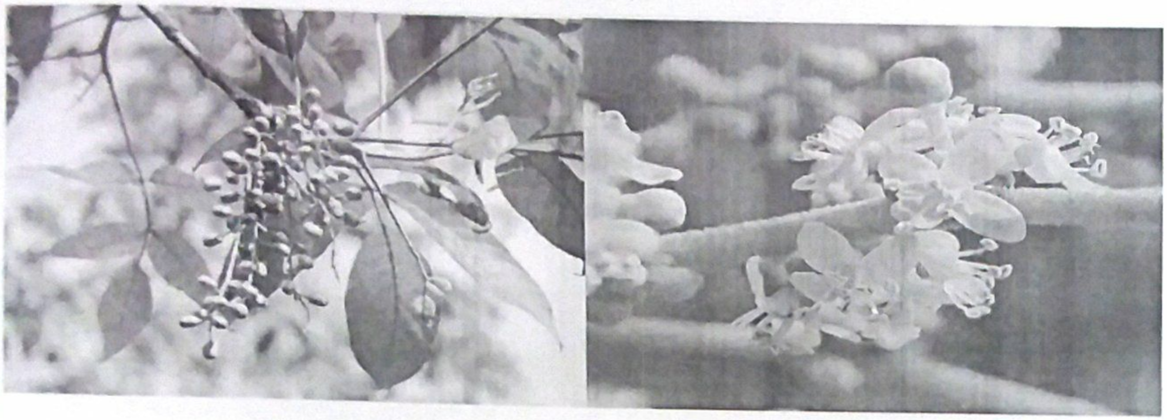

Figure 2.4: Fruits and flowers of *Lannea coromandelica*

2.2.2 Scientific classification:

Table 2.1: Scientific classification of *Lannea coromandelica.*

Kingdom	Plantae
Unranked	Angiosperms
Unranked	Eudicots
Unranked	Rosids
Order	Sapindales
Family	Anacardiaceae
Genus	Lannea

(Wikipedia, 2011)

2.2.3 Different identification of *Lannea coromandelica:*

- **Preferred Scientific Name**: Lannea coromandelica (Houtt.) Merr.
- **Other Scientific Names:** *Lannea grandis (Dennst.) Engl, Haberlia grandis Dennst, Odina wodier Roxb, Lannea wodier (Roxb.) Adelb, Dialium coromandelicum Houtt*

- **Common Names**: In Bangladesh the following common names are used-

  Bangladesh: bhadi, jial bhandi, jigor, jail, kasmala, jiol , jir, jival , bohar , ghadi, lohar ,jiga.

  (http://www.cabicompendium.org/NamesLists/FC/Full/LANNCO.htm)

2.2.4 Wood characteristics:

- A diffuse-porous wood.
- Growth rings very faint, demarcated by darker bands of fibres.
- Vessels 6–28/mm2, solitary or in radial multiples of 2–5 and few clusters, round, average tangential diameter 214 (128–300) µm, average length of vessel members 520 (235–749) µm.
- Intervessel pits alternate, polygonal, 8–11 µm in diameter with slitlike apertures. Vessel-ray pits with reduced borders, round to oval. Tyloses present. Fibres septate, 1257 (695–1819) µm long, average diameter 25 µm, wall thickness 4–5 µm, thin- to thick-walled, with simple pits mainly confined to the radial walls.
- F/V ratio 2.5. Parenchyma scanty vasicentric, in 2–4-celled strands.
- Rays 3–5/mm, 1–5-seriate, heterocellular: with body ray cells procumbent and 1–2 rows of upright or square marginal cells. ray height 497 (192–802) µm or 5 to 33 cells. Radial canals present with 2–3 layers of partly lignified thin-walled epithelial cells, in some rays two radial canals present.
- Silica bodies present in ray cells. Prismatic crystals present in procumbent and marginal ray cells and idioblasts. Pearson and Brown (1932) used the term aggregate crystals for silica bodies (Singh et al., 2000).

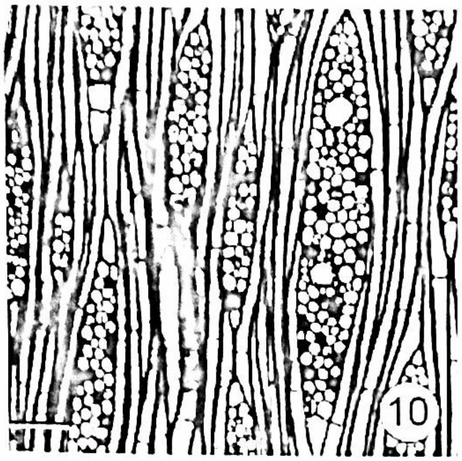

Figure 2.5: *Lannea coromandelica*: Tangential section showing septate fibres and radial canal.

2.2.5 Distribution of *Lannea coromandelica*:

The genus Lannea constitutes about 40 species of trees, shrubs, and undershrubs. They are widely distributed in Africa, but only one species *Lannea coromandelica* is a deciduous tropical tree widely distributed in Bangladesh, India and some other tropical countries where annual rainfall is below 150cm and at comparatively low elevations. This plant is commonly cultivated beside road sides, borderline of houses and grounds and also man-made forests. These forests are characterized by seasonal leaf shedding and profuse flowering of the trees (Reddy et al., 2011).

The Garos were once a nomadic tribe of the Bodo group of Mongoloids now living in different areas of Bangladesh and in the adjacent s tates of India. Garos are very conservative in their outlook. Among Garo, the people who treat and cure patients by folk medicines are considered persons with supernatural power and therefore, enjoy respect and honor in the community. The names of 65 plants dis tributed in to 43 families were obtained from the tribal healers inhabiting the Madhupur region in Bangladesh. Among these Bark of Lannea coromandelica is used for seminal problem (Mia et al., 2009). In the National Forest and Tree Resources Assessment of 2005– 2007, T 15 species are listed in following Figure represent 70% of the total tree volume in Forest of Bangladesh. The most common species in Forest are *Heritiera fomes* and *Dipterocarpus turbinatus*, representing together 25% of the total gross volume in Forest. Other important species are *Gmelina arborea*, *Albizia procera* and *Lannea coromandelica*.

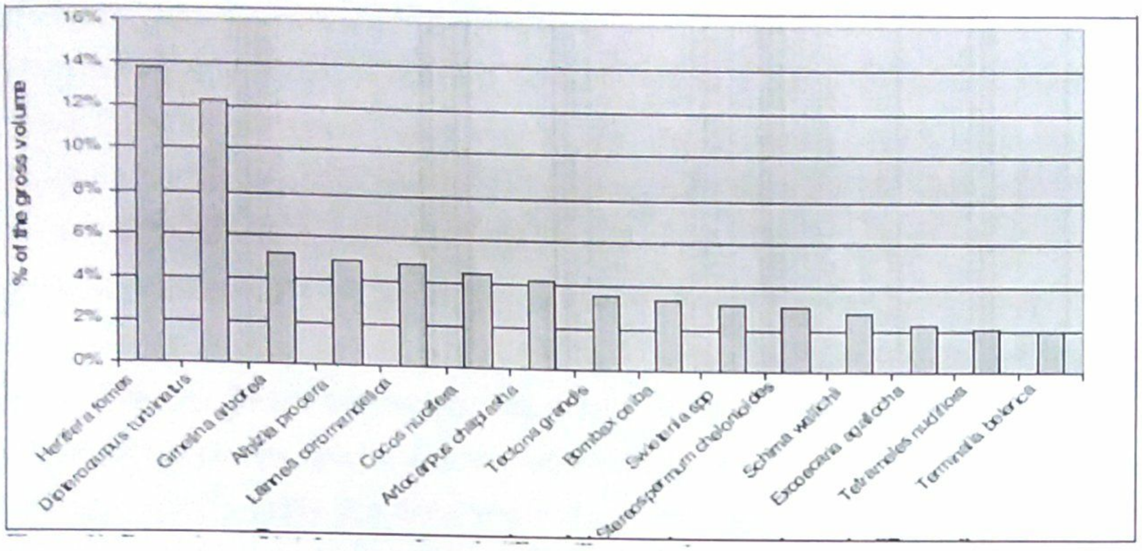

Figure 2.6: Percentage of total gross volume in "Forest" per species .
(http://www.fao.org/forestry/15464-08f7605c2c73c077460d884f8cc11856c.pdf)

Tree species	Total	Low	Medium	High
Cocos nucifera	17,925	63	114	17,747
Samanea saman	12,276	7	68	12,201
Mangifera indica	8,899	19	148	8,732
Areca catechu	8,882	13	26	8,843
Heritiera fomes	8,301	110	1,335	6,855
Borassus flabellifer	7,571	4	86	7,482
Dipterocarpus turbinatus	6,978	181	-	6,797
Phoenix sylvestris	6,942	34	94	6,815
Swietenia spp	6,498	7	29	6,462
Albizia procera	5,676	12	41	5,623
Artocarpus chaplasha	5,272	9	11	5,252
Bombax ceiba	4,343	2	17	4,324
Artocarpus heterophyllus	4,077	27	120	3,930
Lannea coromandelica	3,612	28	45	3,539
Gmelina arborea	2,969	3	5	2,960
Tectona grandis	2,078	0	31	2,048
Syzygium cumini	1,901	4	14	1,882
Anthocephalus chinensis	1,453	-	2	1,451
Stereospermum chelonioides	1,442	-	6	1,436
Excoecaria agallocha	1,383	19	63	1,301
Schima wallichii	1,242	2	2	1,237
Albizia richardiana	1,131	3	16	1,112
Trewia polycarpa	987	10	18	959
Terminalia belerica	977	1	-	977
Tetrameles nudiflora	959	40	-	919

Figure 2.7: Commercial volume per stem quality class for the most important timber species for the total area of Bangladesh (1000 m^3) (http://www.fao.org/forestry/15464-08f7605c2c73c077460d884f8ec11856c.pdf).

Lawachara National Park under Kamalganj upazila of Maulvi Bazar district is a part of West Bhanugach reserve forest, which was declared reserve in early nineteenth century as per the Forest Act 1878, the Assam Forest Manual 1898 and the Forest Act 1927. The Park is located nearly 160 km northeast of Dhaka and approximately 60 km south of Sylhet city. It lies between 24°30′-24°32′ N latitude and 91°37′-91°39′ E longitude. In this park 374 species are recorded, herbs are represented by148, shrubs by 71, trees by 90 and climbers by 65 species here. *Lannea coromandelica* is listed as tree here (Uddin and Hassan, 2010). In tropical deciduous forest of India, Girth size (mean and range), tree density, leaf size, wood density and saturation water content of sub-canopy species *Lannea coromandelica* are accordingly 67cm, 38 number/ha, 84 cm2, 0.513gcm^{-3}, 128% dry mass where the above characteristics of canopy species *Shorea robusta* are 62 cm, 63 number/ha, 144 cm2, 0.719 gcm^{-3} and 72% dry mass (Kushwaha and Singh, 2004).

2.2.6 Importance of *Lannea coromandelica*:

Due to abundance of this tree, it is available very easily. The logs of *Lannea* is preferably cut in abundance, because It is used as support pillar of houses and agricultural implements. Different parts of the tribal hut especially pillars are made up from the woods of *Lannea*. as these woods are strong and sturdy. It is used for construction of huts. It is used as firewood by the tribes and sold in local market also. Having dried the log of *Lannea* is carved and forms like a water tub. It is used as water reservoir and kept adjacent to wells, hand pumps and other such water resources. Sometimes, it is also used as canal for supplying water to fields. This log is water resistant and lasts for a decade. In some houses the stand for water pot is found trichotomously branched which is made from the trunk/branches of this species, embedded into the ground at the corner of the hut. Stand for the support of arrow is made from the log of such plant. The high structures are made from the woods of *Lannea*. It is used to dry fodder and grains in the sunlight.

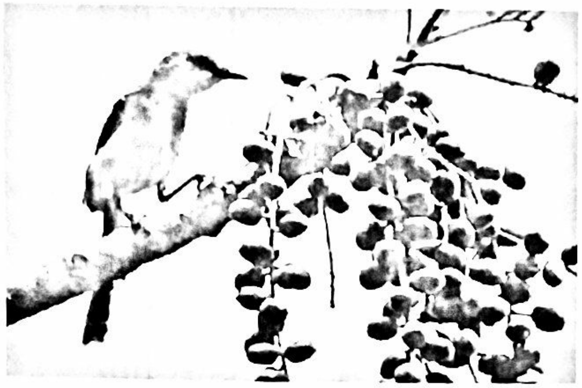

Figure 2.8: Fruits are used as the food of bird.

Some Musical instruments like Drum, Tanpura and Tambura, etc. are generally made from the wood of this plant. Wood is lightweight and durable, so it is used for making stand for a flour mill. Pillars for houses are made from its wood. Dried branched are used as fuel. Leaves & stem bark is crushed in one liter of water and taken half a cup thrice a day to cure fever. Fresh stem bark paste warmed with coconut oil is applied externally for ulcers and wounds. Leaf paste is applied on muscular swellings. Gum is applied on wounds. Fresh leaves are used as fodder. The gum, extract from the stem of such plant is widely used to cure injuries and other skin diseases (Patel et al., 2010).

CHAPTER: 3

MATERIALS AND METHOD

3. Materials and method

3.1 Methods and procedures

a) Manufacturing of cement bonded particleboards

Different types of single-layer cement bonded particleboards from Lannea coromandelica stem was manufactured in the wood Technology Laboratory of Forestry and Wood Technology Discipline of Khulna University, Khulna, Bangladesh.

b) Collection of raw materials:

Lannea coromandelica stem was used to manufacture cement bonded particle board. *Lannea coromandelica* was collected from Rupsha Upozilla in Khulna. The age of the tree was approximately 10-15 years. Ordinary Portland cement, Akij was used as a bonding agent, purchased from local market. Cost of raw materials is given bellow-

Cost of raw materials:

Raw materials	**Cost**
Lannea coromandelica (10-15) years old)	200 tk per cft
Cement	10 tk per kg

The price of *Lannea coromandelica* bellow the following age is 100 tk per cft. In compare to other species *Lannea coromandelica* is a less expensive species. Prices of some species is also given here-

Species	Cost (Tk per cft)
Teak	1000-1500
Gamar	700-850
Garjan	750-900
Chapalish	800-1000
Kadam	700-800
Pinus	500-600

(www.smef.org.bd/functions/dl_file.php) And (www.housingnepal.com/.../prices-of-ply-woodper-q-ft-and-wood-species-per-cubic-feet).

c) Manufacturing procedure

1. Preparation of raw materials

The bark of the sample tree stems was removed by sawing with 36-inch band saw. Then the stem was cut into lumbers of 60cm×21cm dimension after which lumbers were cut into small pieces by circular saw to feed into the chipper and kept under open sun for 30 days for drying.

2. Particle preparation

To produce particles, chipping was done with the chipper machine. The small pieces of stem were inserted into the Chipper machine. The holes in the perforated mesh that were used in Chipper machine were approximately 8mm in diameter. From the chipper machine the particles were collected manually. The particles were differentiated into two categories such as fine and coarse. Then these were dried to 12-14% moisture content. A cold water solubility performed on the chips which shows that they contained 2.97% soluble ingredients that have inhibited the curing of cement (Akhter, 1995). These substances generally include tannins, gum, sugars, organic salts, cyclitons, glactons and pectin like materials present in wood (Browning, 1967; Biblis and LO, 1968).

3. Screening of particles

The particles were then screened manually by sieve no. 16. The fines were under the sieve and the remaining particles on the sieve were separated. Generally less than 5mm particle size was considered as fine and more than 6mm was considered as coarse particle (Eusebio, 2002).

4. Final drying of screened particles

After screening the particles of each type were kept under open sun for 20 days for drying. After 20 days under open sun, the moisture content of particles was approximately 11.5%.

5. **Mixing**

Three types of boards were prepared during the study such as fine, coarse and coarse-fine mixed particle board. These particles were mixed with cement in two different ratios, 1:2.5 and 1:2.75. So six types of boards were produced in two different ratios. The replicate number was 3 for each type of board. For every board, 45% water was used for mixing. To obtain a uniform distribution of cement, particle and water, the mixing procedure was carried out systematically in a pan by mixing cement and particles with required amount of water into the particles. Mixing continued until the particles was covered completely with cement.

6. **Assembly**

Each mixture were hand-formed into a square of iron mould on a stainless steel plate lined with a superior quality polythene sheet to prevent the consolidated mat from sticking to the platen during pressing.

7. **Cold pressing**

Hand formed mats measuring 250×250 mm were cold pressed. They were kept in pressing condition for 24 hrs (Eusebio et al., 1994)

8. **Curing**

The cement bonded particle board were cured in the conventional process. After pressing they are kept at room temperature for 14 to 30 days. Water is sprayed frequently for proper curing of the cement bonded particle board (Nagadomi et al., 1996).

9. **Trimming**

After the boards of each type are produced separately, these are trimmed at edges with the fixed type circular saw. The dimensions of each type of boards are 20cm×20cm.

3.2 Materials and equipment

a) Chipper

A locally made small lab scale chipper was used to chip the raw materials.

b) Cold press

A single daylight hydraulic cold press was used to press the mat into particleboard. The cold press has two platens. The lower platen is fixed with the body of the cold press and upper platen is moveable up and down. The moveable upper platen is used to measure the load given by the manual hydraulic jack. The cross-sectional area of the platens was 35×35 cm.

c) Hydraulic universal testing machine (UTM)

An analogue Hydraulic University Testing Machine (UTM) (model: WE-100, made by Time Group Inc) was used to determine the mechanical properties of the particleboards. There are two units of this machine, one is control unit and another is working unit. A meter is attached with the working unit to measure the deflection. The length of the span, on which the samples are laid, is 200mm. Another part of the working unit is used to determine the tensile strength, which works vertically.

d) Electric oven

A lab scale ventilated oven (Name: Gallennkamp, size1, made in UK) is used to determine the moisture content (%) of raw materials as well as the particle boards and also used in other purposes. A digital indicator outside the oven indicates the inside temperature.

e) Moisture meter

An analogue moistur meter (Model: RC-1E, made by Delmhorst Instrument Co, USA) is used to measure the moisture content of particles.

f) Electric balance

An air tight digital balance (Model: AB 204, made in Switzerland) is used to measure the weight of the raw materials and also used to measure the weight of cement.

d) Specifications of manufactured cement bonded particleboards

Table 3.1: Specifications of manufactured cement bonded particleboards

Dimensions (mm)	250×250
Thickness (mm)	15
Layer	Single
Board types (fine, coarse, coarse-fine)	6
No of samples	36
Ratios (particle: cement)	(1:2.5/1:2.75)
Bonding agent	cement

e) Laboratory tests

The laboratory tests for characterization of physical properties and mechanical properties for each type of particleboards were carried out respectively in the Wood Technology laboratory of Forestry and Wood Technology Discipline of Khulna University, Bangladesh and in the Laboratory of Mechanical Engineering Department of Khulna University of Engineering and Technology, Khulna, Bangladesh. All the tests were carried out according to the Malaysian Standard for wood cement board, MS 934:1986. The testing specifications according to this standard were almost identical to the International specification for CBP, ISO 8335:1987 (Anon, 1985).

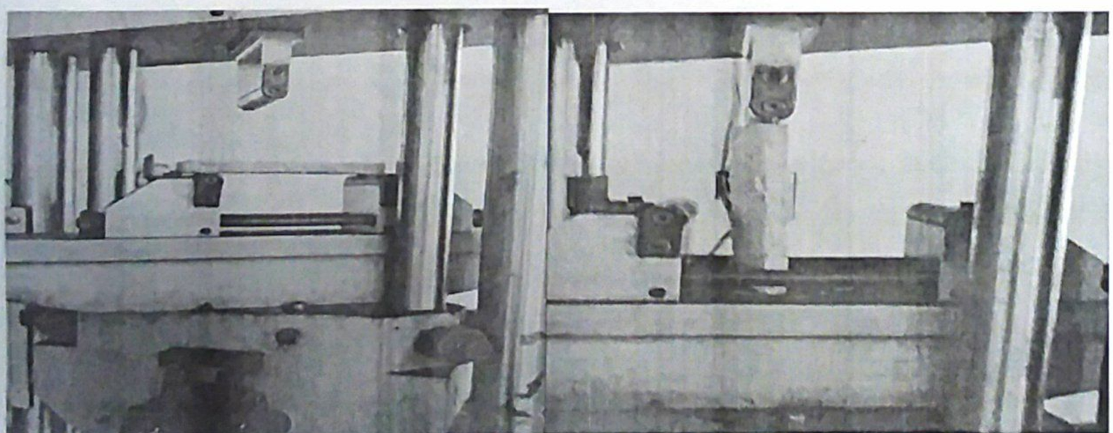

Figure 3.1: Mechanical testing by universal testing machine in KUET laboratory.

f) Preparation of samples for testing

For testing physical properties, three samples are collected from each board of each type. So the total number of samples was 18 for each type of particleboard for testing of physical properties. The density and moisture content were determined on the same 18 samples and the water absorption, Thickness swelling and Linear Expansion were determined on the same samples.

For testing mechanical properties, three samples are collected from each board of each type. So the total number of samples was 18 for each type of particleboard for testing of mechanical properties. The MOR and MOE were determined on the same samples.

The dimension of samples for testing the physical properties was approximately 5.5cm×5.5cm and for testing the mechanical properties was approximately 18cm×5cm.

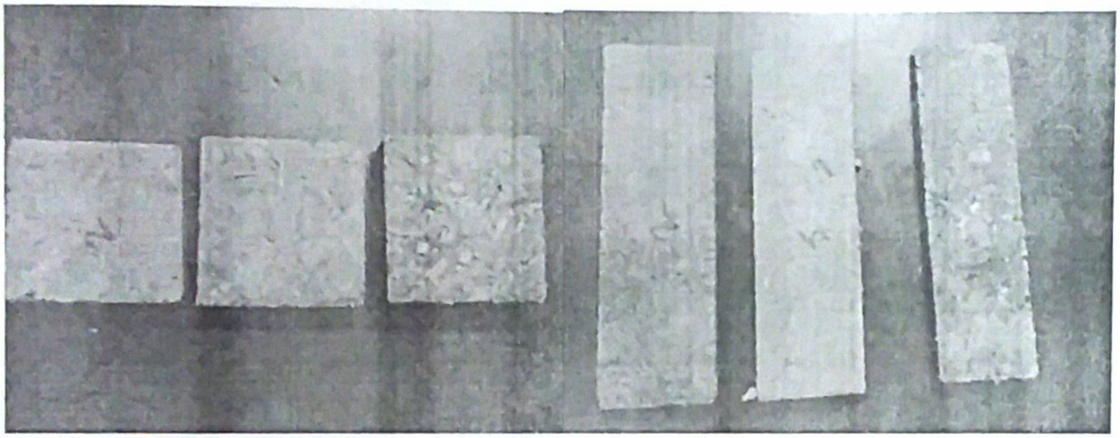

Figure 3.2: Sample for testing physical and mechanical properties.

g) **Board Evaluation**

Density:

For density study, the weight measurement was taken in an electric balance. Density was determined in green wood and oven dried wood. The following formula was used to calculate the density of wood (ASTM,1983).

$D = M / V$

Where, D = Density in gm/cm^3

M= Mass or weight in gm

V= Volume in cm^3.

Moisture content:

The amount of water in wood is normally expressed as percentage. Moisture content was generally determined by oven-dry method. For the measurement of moisture content, the samples were weighted first in an electric balance immediately after one day of felling. Then the samples were placed in an electric oven maintained at 60°c for 24 hours and gradually raised at 100 ± 2°c in order to avoid shrinking defects. Then the samples were again weighted at 1 hour interval and the data were recorded until constant weight was obtained. The moisture content of the samples was determined by the following formula (Shivastava, 1997).

$MC (\%) = [(W_w - W_o) \times 100] / W_o$

Where, MC = Moisture content

W_w = Weight of samples in green condition

W_o = Weight of samples in oven dry condition.

Water absorption:

Water absorption is defined as the differences in weight before and after immersion in water and expressed in percentage. The water absorption was calculated by the following formula-

$A_w = (M_2 - M_1) / M_1 \times 100$ (http://www.imal.it.)

Where, A_w = Water absorption (%)

M_2 = The weight of the sample after (24 hr.) immersion in water (gm)

M_1 = The weight of the sample before immersion in water (gm)

Thickness swelling

Thickness swelling was calculated by the following formula-

$G_t = (T_2 - T_1) / T_1 \times 100$ (http://www.imal.it.)

Where, G_t = Thickness swelling (%)

T_2 = Thickness of sample after (24 hr.) immersion in water (mm)

T_1 = Thickness of sample before immersion in water (mm).

Linear expansion

The linear Expansion was calculated by the following formula-

$LX (\%) = (L_A - L_B) / L_B \times 100$ (http://www.imal.it.)

Where, L_A = Length of sample after (24 hr.) immersion in water (mm)

L_B = Length of sample before immersion in water (mm).

Modulus of Elasticity:

The modulus of elasticity was calculated from the following equation –

$MOE = P'L^3 / 4\delta bd^3$ (Desch and Dinwoodie, 1996)

Where, *MOE* = Modulus of elasticity in MPa

P' = Load in N at the limit of proportionality.

L = Span in mm.

δ = deflection in mm at the limit of proportionality

b = width in mm

d = depth in mm

Modulus of Rupture:

The MOR in the point of bending was calculated from the following equation,

$MOR = 3PL / bd^2$ (Desch and Dinwoodie, 1996)

Where, MOR = Modulus of Rupture

P = Load in N

L = Span in mm

b = Width in mm

d = Depth in mm.

h) Analysis of Data

Factorial experimental design such as SPSS- 11.01 was used in the experiment and all the data produced during the laboratory tests for characterization of physical and mechanical properties of each type of boards.

CHAPTER: 4

RESULTS AND DISCUSSION

4.1 Results

The results of different physical and mechanical laboratory tests are described here. Two types of ratios were used for physical and mechanical tests such as 1: 2.5 (Ratio-1) and 1: 2.75 (ratio-2).

4.1.1 Physical Properties

4.1.1.1 Density

The density of CBP for fine, fine-coarse and coarse particles with ratio-1: 2.5 were 0.810, 0.817 and 0.856 respectively. In case of ratio (1: 2.75), the density for fine, fine-coarse and coarse particles are respectively 0.830, 0.853 and 0.867 (Figure-4.1). The variation in density among the different types of cement bonded particle boards may be due to the variation in density of the different types of particles itself. Moreover, the weight of the raw materials for different types of board is different.

In case of ratio-2, coarse particles shows highest value and fine particles of ratio-1 shows the lowest value. Ratio-2 shows the highest value between two ratios.

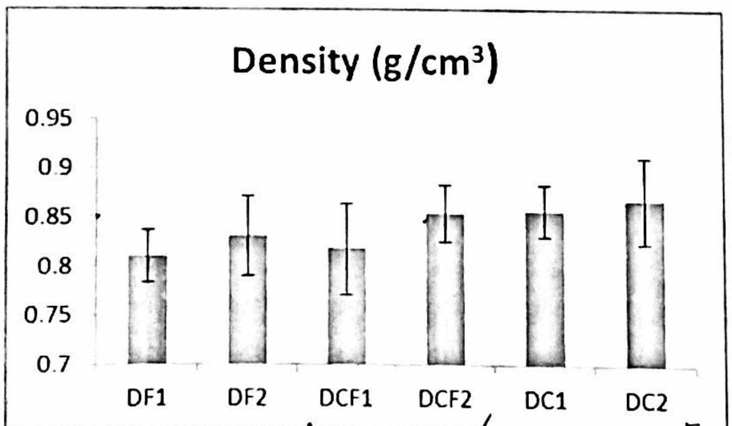

Figure 4.1: Density of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1, and 2 means Ratio 2.

From analysis of data (Table 4.1), there is no significant difference between two ratios of fine, fine-coarse and coarse particles for density but there is no significant difference among fine, coarse-fine and coarse particles.

4.1.1.2 Moisture content

It has been found that the moisture content of CBP for fine, coarse-fine and coarse particle (Ratio- 1) are 14.62%, 15.58% and 16.62% respectively. Moisture content of Ratio-2 for fine, coarse-fine and coarse particles are 13.35%, 13.94% and 15.56% respectively. Figure- 4.2 shows that coarse particles of Ratio-1 have the highest value and fine particles of ratio-2 have lowest value.

Ratio-2 shows the lowest amount of moisture content due to the use of highest amount of cement and free from spongy particles.

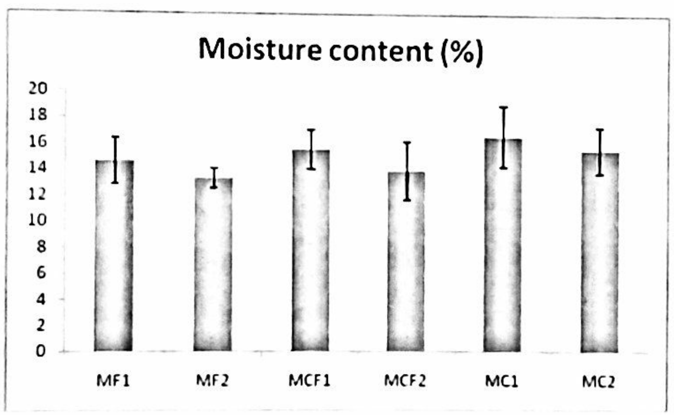

Figure 4.2: Moisture content of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1 and 2 means Ratio 2.

From analysis of data (Table 4.1), there is no significant difference between two ratios of fine, coarse-fine and coarse particles for moisture content there is no significant difference among fine, coarse-fine and coarse particles.

4.1.1.3 Water absorption

Water absorption of water by cement bonded board for fine, coarse-fine and coarse particles (Ratio-1) are 26.54%, 25.23% and 25.12% respectively. In case of ratio-2, it has been found that water absorption of water is 25.43%, 22.18% and 21.54% respectively after 24 hours immersion in water. Figure- 4.3 shows that fine particles of ratio-1 have the highest value of water absorption and coarse particles of ratio-2 absorb the lowest amount of water.

Particles of ratio-2 absorb lower amount of water than ratio-1 because of the use of the highest amount of cement and free from spongy particles.

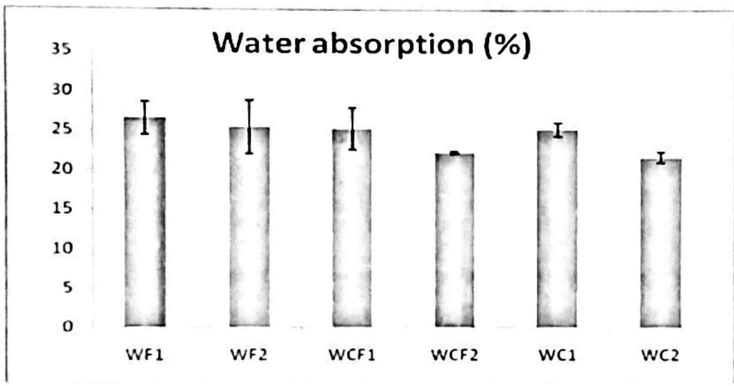

Figure 4.3: Water absorption of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1 and 2 means Ratio 2.

From the analysis of data (Table 4.1), it has been found that there is significant difference between two ratios of fine, coarse-fine and coarse particles for water absorption but there is no significant difference among fine, coarse-fine and coarse particles.

4.1.1.4 Thickness swelling

It has been found that thickness swelling of CBP for fine, coarse-fine and coarse particles of ratio-1 are 2.25%, 2.21% and 2.18% respectively. In case of ratio-2, CBP for fine, coarse-fine and coarse particles are respectively 2.17%, 2% and 1.93% after 24 hours immersion in water (Figure-4.4). The variation in the thickness swelling among the different types of CBP may occur due to the variation in wood: cement ratio and different types of particles. Among the different types of CBP, fine particles of ratio-1 show the highest value of thickness swelling and coarse particles of ratio-2 show the lowest value of thickness swelling. Ratio-1 has the highest value than the lowest value.

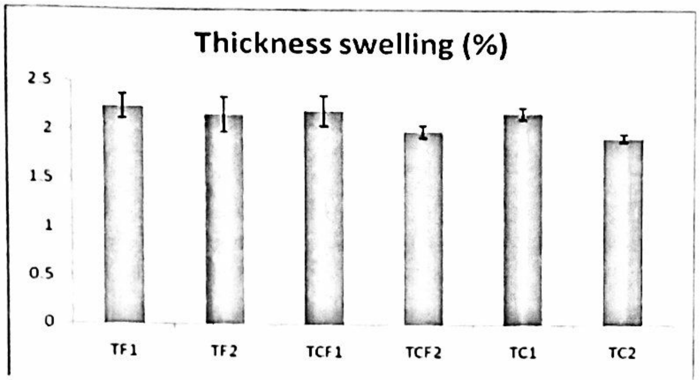

Figure 4.4: Thickness swelling of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1 and 2 means Ratio 2.

From the analysis of data (Table 4.1), It has been found that there is significant difference between two ratios of fine, coarse-fine and coarse particles for thickness swelling but there is no also significant difference among fine, coarse-fine and coarse particles.

4.1.1.5 Linear expansion

The linear expansion of CBP of ratio-1 for fine, coarse-fine and coarse particles are 3.63%, 3.39% and 3.38% respectively. For ratio-2 the linear expansion of CBP is 3.20%, 2.90% and 2.73% respectively after 24 hours immersion in water (Figure-4.5). The variation in the linear expansion among the different types of CBP may occur due to the variation in wood: cement ratio and different types of particles. Fine particles of ratio-1 between the two ratios show the highest value of linear expansion and coarse particles of ratio-2 show the lowest value of linear expansion. Figure-4.5 indicates that Ratio-1 has the highest value than ratio-2.

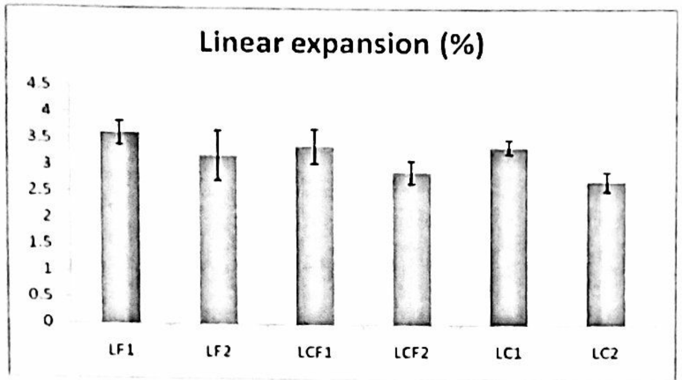

Figure 4.5: Linear expansion of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1 and 2 means Ratio 2.

From the analysis of data (Table 4.1), it has been found that there is significant difference between two ratios of fine, coarse-fine and coarse particles for linear expansion but there is no significant difference among fine, coarse-fine and coarse particles.

Table 4.1: Summary for different test results of physical properties.

Source of variation	**MC**	**Density**	**Water absorption**	**Linear thickness**	**Thickness swelling**
Particle size	NS	NS	NS	NS	NS
Ratio	NS	NS	*	*	*

*= Significant at $p<0.05$

NS= Not significant

4.1.2 Mechanical properties

4.1.2.1 Modulus of elasticity (MOE)

Modulus of elasticity of CBP for fine, coarse-fine and coarse particles (Ratio-1) are found to 231.78 N/mm^2, 234.67 N/mm^2 and 260.23 N/mm^2 respectively. In case of ratio-2 Modulus of elasticity of CBP are 238.22 N/mm^2, 259.55 N/mm^2 and 266.67 N/mm^2 respectively (Figure-4.6). Coarse particles of ratio-2 show the highest value for MOE and fine particles of ratio-1 show the lowest value for MOE. Here ratio-2 has the higher value than ratio-1.

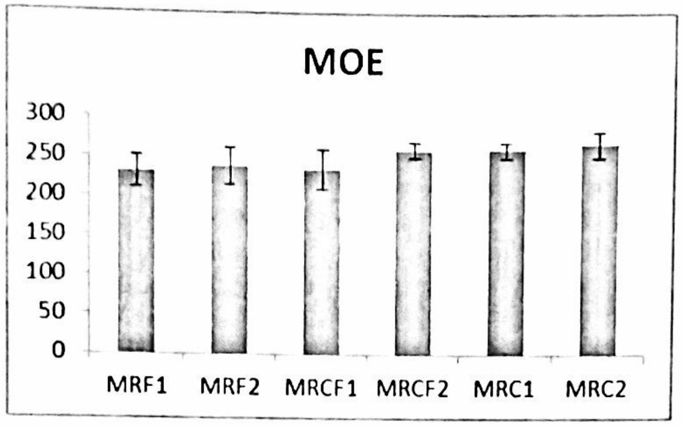

Figure 4.6: Modulus of elasticity of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1 and 2 means Ratio 2.

From analysis of data (Table 4.2), it has been found that there is no significant difference between two ratios of fine, coarse-fine and coarse particles for Modulus of elasticity and there is no significant difference among fine, coarse-fine and coarse particles.

4.1.2.2 Modulus of Rupture (MOR)

Modulus of Rupture of CBP for fine, coarse-fine and coarse particles (Ratio-1) are 3.12 N/mm^2, 3.24 N/mm^2 and 3.49 N/mm^2 respectively. In case of ratio-2 Modulus of rupture of CBP is 3.46 N/mm^2, 3.48 N/mm^2 and 3.59 N/mm^2 respectively (Figure-4.7). Coarse particles of ratio-2 show the highest value for MOE and fine particles of ratio-1 show the lowest value for MOE. Here ratio-2 has the higher value than ratio-1.

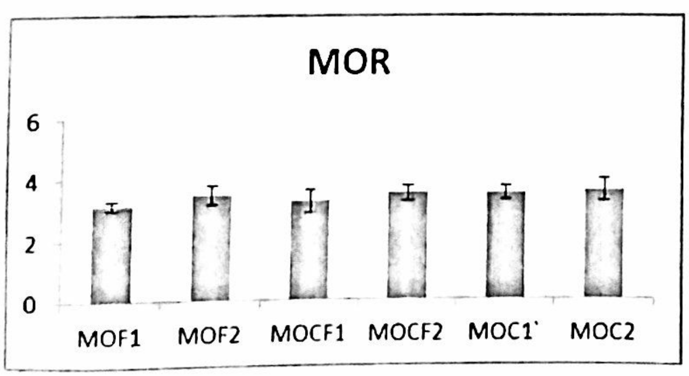

Figure 4.7: Modulus of Rupture of cement bonded board made from *Lannea coromandelica* (F=Fine, CF=Coarse-fine and C=Coarse). Here 1 means Ratio- 1 and 2 means Ratio 2.

From analysis of data (Table 4.2), it has been found that there is no significant difference between two ratios of fine, coarse-fine and coarse particles for Modulus of Rupture and there is also no significant difference among fine, coarse-fine and coarse particles.

Table 4.2: summary for different test results of Mechanical properties.

Source of variation	MOE	MOR
Particle size	NS	NS
Ratio	NS	NS

*= Significant at $p<0.05$

NS= Not significant

4.2 Discussion

In the study it has been found that the average density of *Lannea coromandelica* particles is 0.84 gm/cm^3. The used amount of cement is responsible to increasing density of particles. In the observation, coarse particles show higher density. In Nigeria, Cement bonded particle board from only pine (*Pinus caribaea* M.) saw dust 1.79 gm/cm^3 (Erakhrumen et al., 2008). It is found that cement: sawdust-coir ratio of 2:1 had 1.54gm/cm^3 and in case of 2:2 ratio, density was 1.13 gm/cm^3 lower than sawdust. Biswas et al., 1997 shows that density for cement bonded particle board of *Albizia falcataria* wood in Bangladesh is about 976 kg/m^3. The average density of CBP from saw dust in bison factory was 1250 kg/m^3 (Anon, 1975).

In this study, it has been found that coarse particles of ratio-1 show higher moisture content and fine particles of ratio-2 show lower moisture content among all particles. In bison factory in china found that the cement boarded particle from saw dust, moisture content range from 3% to 9% at factory point (Anon, 1975).

In this study, water absorption of cemented board particle board made from *Lannea coromandelica* ranges from 20-30%. Water absorption (WA) is lower in ratio-2 for treated coarse particles. In bison factory (Anon, 1975) in china found that the cemented bonded particle from saw dust, water absorption of the board of the board was 27%. The WA of

various board specifications were higher where there were reduced proportion of cement inclusion. This pattern of WA variation is in conformity with the observation of many researcher such as Badejo, 1987; Oyagade, 1995. CBP made from *Bambusa vulgaris* of wood-cement ratio (1:2.5), (1:2.75) and (1:3) show water absorption respectively 37.81%, 26.10% and 20.39% (Chew et al., 1992). Lower amount of cement in the composite manufacture might lead to a large quantity of exposed particle and free internal spaces which are almost always associated with the low density boards, a possible contributing factor to this WA pattern and likely instability of the board. Compared to low density particle board, high density particle board has lower porosity so that the particle and the cement can interact each other more easily to form a crosslink (Zheng et al., 2007).
Cemented bonded particle board of *Albizia falctaria* wood in BFRI shows that water absorption of the board was 27.8% after 24 hours submerging into water (Biswas et al., 1997). It was observed that 23.4%, 30.6% and 54.0% water absorption for only pine (*pinus caribaea M*) saw dust: coir ratio (2:1) and sawdust : coir ratio(2:2) for cement bonded particle board (Erakhurumen et al., 2008). This result is at variance with some studies that have identified coconut husk as a material with high lignin content with low affinity for moisture but consistent with outcome of study such as Rahman and Khan (2007) which identified coconut husks fibers as being hydrophilic due to presence of hydroxyls groups from cellulose and lignin components.

Lannea coromandelica is low density species. Thickness swelling in this study ranges from 1.8% to 2.5% and linear expansion 2.36% to 4%. Given the same socking period, a particle (bonded with urea formaldehyde glue) was found to swell only 21% Cement bonded particle board of *Albizia falcataria* wood shows 2.87% thickness swelling after 24 hours immersing into water (Biswas et al., 1997). CBP made from *Bambusa vulgaris* of wood-cement ratio (1:2.5), (1:2.75) and (1:3) show thickness swelling 1.94%, 1.16% and 1.27% respectively (Chew, sudin and kasim, 1992). Thickness swelling for cement bonded board of coconut coir is less than 1.2% (Aggarwal, 1992). In bison factory China found that thickness swelling for CBP was 1% (Anon, 1975). Erakhrumen et al., (2008) observed 12.3%, 4.6% and 2.9%

thickness swelling for only pine (*pinus caribaea M*) saw dust: coir ratio (2:1) and sawdust : coir ratio (2:2) for cement bonded particle board.

In this study, it has been found that MOE of Cement bonded particle board made from *Lannea coromandelica* species ranges from 192 to 288 N/mm^2 and MOR of CBP ranges from 2.86 to 3.98 N/mm^2. Coarse particles of Ratio-2 show higher value of MOE and MOR where Ratio-1 shows lower value than ratio-2. MOE of coconut coir cement bonded particle board is 2500-2400 MPa (Aggarwal, 1992). MOE of cement bonded board made from the mixture of coconut coir, cement and water with boiled and washed fiber length 1-13cm, 1-6cm and 1-4mm were 286.54MPa, 498.70MPa and 169.30 MPa respectively and MOR of such boards were respectively 2.71MPa, 4.04MPa and 1.53MPa (Asasutjarit et al., 2005). CBP made from *Bambusa vulgaris* of wood-cement ratio (1:2.5), (1:2.75) and (1:3) show bending strength 2.19 Mpa, 3.64 Mpa and 5.15 Mpa respectively (Chew, sudin and kasim, 1992). In bison factory , china found that MOE of cement bonded particle board was 3000 N/mm^2 (Anon, 1975). Abdalla (1998) said that the increase of MOR for Sunt wood-cement mixture was associated with increase of cement: wood ratio. Albizia Falcataria wood for cement bonded particle board shows that the average bending strength was observed to be 59 kg/cm^2 with the maximum being the 66 kg/cm^2 and the minimum 51 kg/cm^2 (Biswas et al., 1997). Aggarwal (1992) found that MOR of coconut coir cement bonded board is 9 to 11 MPa and MOR of CBP in bison factoty of China was found 9 N/mm^2 (Anon, 1975).

The strength properties were also influenced by board density (kwon and Geimer, 1998; Ajayi, 2000 and Zheng et al., 2007). The reduction in the values of MOE and MOR obtained as a result in the cement component in the mixing ratios is in conformity with similar studies on cement reinforced lingo-cellulosic composites. The result also showed that boards with higher cement content had higher density values (Eusebio et al., 1998; Zhou and Kamdem, 2002). Stable low-density cement bonded composites with reduced cement to particle ratio can be made because high density boards are difficult to handle, cut, nail and transport (Zhou and Kamdem, 2002) coupled with the cost implication associated with higher content of cement component for its production. It has been noted that higher cement contents do not always result in continuous further property increase in composite boards (Del Meneeis et al., 2007).

Researcher have found the use of chemical additives in wood-cement-water systems as a means of enhancing cement setting. Additives such as calcium chloride ($CaCl_2$), Ferric chloride ($FeCl_3$), Ferric Sulphate ($Fe_2(So_4)_3$), Magnesium Chloride ($MgCl_2$) and Calcium hydroxide ($Ca(OH)_2$) have been reported to reduce the inhibitory effects of wood on the setting of Portland cement. Magnesium chloride was added to the composites in the range of 1-10% to accelerate the curing of cement. Mechanical properties of bamboo-cement boards increased as the $MgCl_2$ content increased up to a level of 5%. At higher $MgCl_2$ contents, board properties decreased slightly. The board produced at a bamboo: cement ratio of 1: 2.5 and $MgCl_2$ content of 5% had the best dimensional stability and mechanical properties (Moslemi et al., 1985; rahman and Khan, 2007).

Chapter: 5

CONCLUSION

- Jeol (*Lannea coromandelica*) is found all over the country and it is used as cheaper product. Jeol can be manufactured in a conventional process. Due to its cheaper rate in the market and its availability, it can solve our dwelling problem.
- Density and strength properties value of coarse particles are comparatively higher than coarse-fine and fine particles. Ratio (1:2.75) shows higher strength properties than ratio (1:2.5).

- Density and strength properties value of coarse particles are comparatively higher than coarse-fine and fine particles. Ratio (1:2.75) shows higher strength properties than ratio (1:2.5).
- Further study is needed to improve the mechanical properties of cement bonded board made from *Lannea coromandelica*.

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