Khulna University
Life Science School
Forestry and Wood Technology Discipline

Author(s): Sabuj Majumder

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Supervisor(s): Dr. Md. Nazrul Islam, Professor, Forestry and Wood Technology Discipline, Khulna University

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EFFECT OF PARTICLE SIZE AND MAT FORMATION TECHNIQUE ON PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL LATEX RUBBER BONDED PARTICLEBOARD

Sabuj Majumder
Student ID: 130519

This thesis paper has been prepared for the partial fulfillment of the requirements of Four years B. Sc. (Hons.) degree in Forestry from Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh.

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Dedicated to

My Beloved Mother and Father

DECLARATION

I, Sabuj Majumder, declare that this thesis is the result of my own works and it has not been submitted or accepted for a degree in any other university.

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Sabuj Majumder

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Supervisor

Dr. Md. Nazrul Islam
Professor
Forestry and Wood Technology Discipline
Khulna University
Khulna, Bangladesh.

Submitted By

Sabuj Majumder
Student ID: 130519
Forestry and Wood Technology Discipline
Khulna University
Khulna, Bangladesh.

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ABSTRACT

This thesis paper represents the effect of particle size and mat formation on physical and mechanical properties of natural latex bonded particleboard. The particle board was made from natural latex, starch, jute particle and formic acid. The particleboard is made by hot press at 180°C and 5 M Pa pressure is used. The physical and the mechanical properties of fine, course, mixture & layer particle board were measured and compared .The course particleboard exhibits lower density (882 kg/m3), moisture content and water absorption than the other particle board but shows higher mechanical properties (MOR-14.88 and MOE-2995.07).

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Chapter one : Introduction

1.1 BACKGROUND OF THE STUDY

The demand for glued-wood composite products, such as particleboard, medium-density Wberboard and plywood, has recently increased dramatically throughout the world, especially for housing construction and furniture manufacturing (Sellers, 2000; Youngquist, 1999). The Food and Agricultural Organization (FAO) of the United Nations reported that the worldwide consumption of particleboards was 56.2 million cubic meters in 1998 (Youngquist and Hamilton, 2000). The 76 particleboard mills in North America produced 11 million cubic meters of particleboards, which accounted for 19% of the total wood composites produced (Sellers, 2000, 2001). According to a report from Kozlowski and Helwig (1998), the wood used for particleboard production was a signiWcant portion of the 0.36 billion cubic meters of the wood that was consumed annually and the annual wood consumption is expected to reach about 0.47 billion cubic meters by 2010. The large amount of wood consumption could mean a high worldwide deforestation rate that can cause negative impacts on the environment. Therefore, increased interest has been seen in the production of particleboards from other biomass, such as grass, straw, plant, and agricultural residues. Agricultural residues provide renewable and environmentally friendly alternative biomass resources for easing the high demand for woody materials (Kozlowski and Helwig, 1998; Sampathrajan et al., 1992). As a result , research has been focused on making particleboards using rice straw, cotton stalks, sugar cane bagasse, jute sticks (Heslop, 1997; Pan and Cathcart, 2004),

For particle board production particle geometry plays an important role on physical and mechanical properties. Two types of particles are used in this study. Fine and course particle and the mixture of the both are used for preparing boards. Also the previous study of particle board shows that the mat formation technique has an effect on density, MOR and MOE

1.2. OBJECTIVES

- To assess the effect of particles size and mat formation technique on mechanical & physical properties of the board.

Chapter two : Literature review

2 Literature review

2.1 General information about particleboard

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. (Shrivastava, 1997). It may be classified as a 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).

2.1.1 Brief history and development of particleboard

Particleboards are not more than a few decades old production. Before particleboard, modern plywood, as an alternative to natural wood, was invented in the 19th century, but by the end of the 1940s there was not enough lumber around to manufacture plywood affordably. By that time particleboard was intended to be a replacement (Sheng, 2004). But before that scarcity in raw materials of plywood, first efforts were made in the early 1920's for manufacturing of particleboard. But it was unsuccessful as for the lack of suitable adhesives. Then new techniques introduced in the 1930's in resin applications with the growing demand paved the way for the industrial production of particleboard in the early 1940's (Moslemi, 1985). The first commercial piece was produced during World War II at a factory in Bremen, Germany. It used waste material such as planer shavings, off-cuts or sawdust, hammer-milled into chips, and bound together with a phenolic resin. Today's particleboard manufacturer provides high-quality products that consumers require due to up gradation of manufacturing techniques (Moslemi, 1985; Sheng, 2004).

2.1.2 Types of particleboard

There are different types of particleboards depending on:

2.1.2.1 Types of particles used

Flakeboard: A particleboard in which the wood is largely in the form of flakes, giving the surface a characteristic appearance (Shrivastava, 1997). A small wood particle of predetermined dimensions specifically produced as a primary function of specialized equipment of various types, with the cutting action across the direction of the grain (either radially, tangentially, or at an angle between), the action being such as to produce a particle of uniform thickness, essentially flat, and having the fiber direction essentially in the plane of the flakes, in overall character resembling a small piece of veneer (Shrivastava, 1997).

Chipboard: A particleboard made from chips. It is made in varying thickness and may be surfaced with paper, veneers, plastic materials, etc. (Shrivastava, 1997). Gluing together wood particles with an adhesive, under heat and pressure makes chipboard. This creates a rigid board with a relatively smooth surface. Chipboard is available in a number of densities: -normal, medium and high-density. It is often used for kitchen tops (which are laminated with melamine) and fire doors. Medium density is somewhere between normal and high density. There are exterior grades of chipboard available but most are only suitable for internal use. Chipboard with a veneered surface is widely used for flat-pack furniture and work surfaces. High-density chipboard is often used as the carcass for kitchen units and worktops and flooring. This type of chipboard is hardwearing, rigid and heavy (Salehuddin, 1992).

Shavings board: A particleboard in which wood shavings are the chief constituents. (Shrivastava, 1997). Shavings are produced from various kinds and sizes of trees being converted to lumber of different dimensions. Often instigated by the need for reducing costs of disposal of materials that clog production, or by the desire to get some return from material that in the log form has represented a considerable outlay of money. Shavings ordinarily come from air-dried or kiln-dried wood. Shaving produced from machining dry wood of a single species afford their producer the best prospects for marketing waste material. Uniform particle sizes (achieved by screening) are needed for some uses. For most uses only fresh material is acceptable. Shavings, when exposed to the weather, deteriorate very rapidly and lose much of their value (Salehuddin, 1992).

Waferboard: It is a structural material made from rectangular wood flakes of controlled length and thickness bonded together with waterproof phenolic resin under extreme heat and pressure (Salehuddin, 1992). Waferboard is a widely used, versatile structural wood panel. Manufactured from waterproof heat-cured adhesives and rectangular shaped wood strands that are arranged in cross-oriented layers, Waferboard is an engineered wood panel that shares many of the strength and performance characteristics of plywood. Waferboard's combination of wood and adhesives creates a strong, dimensionally stable panel that resists deflection, delamination, and warping; likewise, panels resist racking and shape distortion when subjected to demanding wind and seismic conditions. Relative to their strength, waferboard panels are light in weight and easy to handle and install (Shrivastava, 1997).

Oriented trand board: Oriented strand board, or OSB, or Sterling board (UK) or Smart Ply (UK and Ireland) is an engineered wood product formed by layering strands (flakes) of wood in specific orientations (Salehuddin, 1992). Oriented strand board is manufactured in wide mats from cross-oriented layers of thin, rectangular wooden strips compressed and bonded together with wax and synthetic resin adhesives. The resin types typically used include phenol formaldehyde (PF), melamine fortified urea-formaldehyde (MUF) or isocyanate, all of which are moisture resistant binders. In Europe, it is common to use a combination of binders, typically PMDI would be used in the core and MUF in the face layers and this has the advantage of reducing press cycles whilst imparting a bright appearance to the surface of the panel (Shrivastava, 1997).

2.1.2.2 Particle size distribution in the thickness of board

Single layer or homogeneous board: Single-layer particleboards are made from pressing together wood particles of similar sizes to form a flat, dense board. This type of particleboard is suitable as a base for plastic lamination and veneering, but not for painting. Single-layer particleboards are used commonly for interior applications. They have some water-resistance capabilities, but are not fully waterproof (Shrivastava, 1997).

Three layer board: A three-layer particleboard is made from sandwiching a layer of larger wood particles between two layers of high-density, finer wood particles. The outer layers have a higher amount of resin adhesive than the inner layer. Three-layer particleboards have smooth outer layers that are suitable for painting. These boards are not as dense as single-layer boards and tend to split easily (Shrivastava, 1997).

Graded-density boards: Graded-density particleboards are similar to three-layer particleboards. They have an inner core of coarse wood particles sandwiched between two outer layers of finer particles. However, unlike a three-layer particleboard, the transition between the coarse surfaces to the finer ones is gradual. Graded-density particleboards are used in cabinet construction and for furniture components (Salehuddin, 1992).

2.1.3 Raw materials for particleboard manufacturing

2.1.3.1 Ligno-cellulosic materials

Woody materials, planer savings, sawmill residues, such as slabs, edging, trimmings, etc. Residues from timber cutting in furniture and cabinet manufacturing plants, residues from match factories, veneer and plywood plant residues, saw dusts, Logging residues, such as short logs, broken logs, crooked logs, small tree tops and branches, forest thinning , etc. and bark (Salehuddin, 1992).

2.1.3.2 Non-woody materials

Jute sticks, bagasse, bamboo, flax shaves, cotton stalks, cereal straw, almost any agricultural residue (such as husks, coconut coir etc.) after suitable treatment (Youngquist, 1999).

2.1.3.3 Chemicals

Binder or adhesive

Adhesives or binders are the materials used in the fabrication of timber structures and components offers a neat and efficient method of bonding together the separate pieces of wood, or of board products such as plywood, chipboard, or fiberboard, which comprise the finished product. The bond attained must meet the strength requirements for the structure as a whole and this bond must remain unaffected by the condition to which it will be exposed throughout its life (Youngquist, 1999).

There are mainly two types of adhesive. One originated from natural sources known as natural adhesive and another is synthetic adhesive.

Natural adhesive

Adhesives of natural origin- such as animal, casein, soybean, starch and blood glues are still being used to bond wood in some plants and shops, but are being replaced more and more by synthetics (Vick, 1999).

Synthetic adhesive or Synthetic resin adhesive

Synthetic adhesives are man-made polymers which resemble natural resins in physical characteristics but which can be tailored to meet specific woodworking requirements. Synthetic adhesives can be categorized into two groups, namely thermosetting adhesives and thermoplastic adhesives (Dunky and Pizzi, 2002).

Other additives

Additives are mainly used to improve the certain properties of particleboard such as moisture repellency, fire retardancy etc.

Paraffin wax or wax emulsion: Wax is added as a water repellent in the production of wood-based manufactured composite boards such as particleboard, medium density, oriented strand and other board products.

Fire retardants: The most common and best known fire retardance methods for wood are based on changing the pathway of pyrolysis. In this simple and inexpensive method, wood is treated with a substance that enhances the pyrolysis reaction of cellulose through the pathway leading mainly to char formation. A fire retardant may also slow down pyrolysis reactions and stabilize the chemical structures of wood against decomposition. For instance, aluminium sulphate added to wood creates bonds between cellulose molecules in increased temperatures, thus preventing thermal decomposition (Dunky and Pizzi, 2002).

Curing agents and hardeners: Deliver a complex combination of performance attributes that can vary from high bond strength to good insulating properties depending on end-use application. Provide unique benefits to adhesives such as fast and low temperature cure, excellent thermal shock resistance, and low viscosity for solvent-free systems, hydrophobicity, and good overall chemical and mechanical properties (Lee, 1991).

Chapter Four: Materials and Methods

3.1 EQUIPMENT

3.1.1 CHIPPER

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

3.1.2 HOT PRESS

A digital hydraulic hot press was used to press the mat into particleboard. It has multi layer plate. The both platen were movable up and down.

3.1.3 HYDRAULIC UNIVERSAL TESTING MACHINE (UTM)

An analogue hydraulic Universal Testing Machine (UTM),was used to determine the mechanical properties of the particleboards.

3.1.4 OVEN

A lab scale ventilated oven was used to determine the moisture content (%) of raw materials as well as the particle boards. A digital indicator outside the oven indicated the inside temperature.

3.1.5 ELECTRIC BALANCE

An air tight digital balance was used to measure the weight of the raw materials as well as particle boards and also used to measure the weight of different ingredients of the adhesive.

3.2 MATERIALS

3.2.1 Particles

Particles are made using jute sticks. There are two types of particle. Course is 2.5 mm & fine is 1mm.

3.2.2 Natural latex

Latex is a stable dispersion of polymer micro particles in an aqueous medium. It is found in nature. It is used as a binder of the board in this research. This binder is very environmental friendly because there is no synthetic agent.

3.2.3 Formic acid

Formic acid is the simplest carboxylic acid. The chemical formula is HCOOH . It is used as a curing agent. Natural latex usually takes 2 hours to coagulate but due to adding formic acid the prepared board cured within a very short time.

3.2.4 Starch

Starch is a polymeric carbohydrate consisting of a large number of glucose units joined by glycoside bonds. Pure starch is a white, tasteless and odorless powder. Starch generally contains 20% to 25% amylase and 75% to 80% amylopectin by weight. It is a good adhesive for particleboard. Starch provides hydroxyl groups that can react with the carboxyl group in formic acid.

3.3 METHODOLOGY

Firstly jute sticks are broken into small particles using grinder. Then the particles are categorized to fine & course particles by screening. The particle are weighted . After taking weight the particle are oven dried at 103 +/- 2 degree centigrade for 12 hours. Then it is re-weighted. Mixing the particle , starch, formic acid & natural latex and made mat of random mixing(50% fine & 50% course) & by layer of fine, course & fine. Then pressed using Pressing machine at 180 degree centigrade temperature, 5 MPa pressure for 5 minutes. After pressing the board is cooled using fan. At last the board is sized by sizing using saw. The process is shown below by a flow chart-

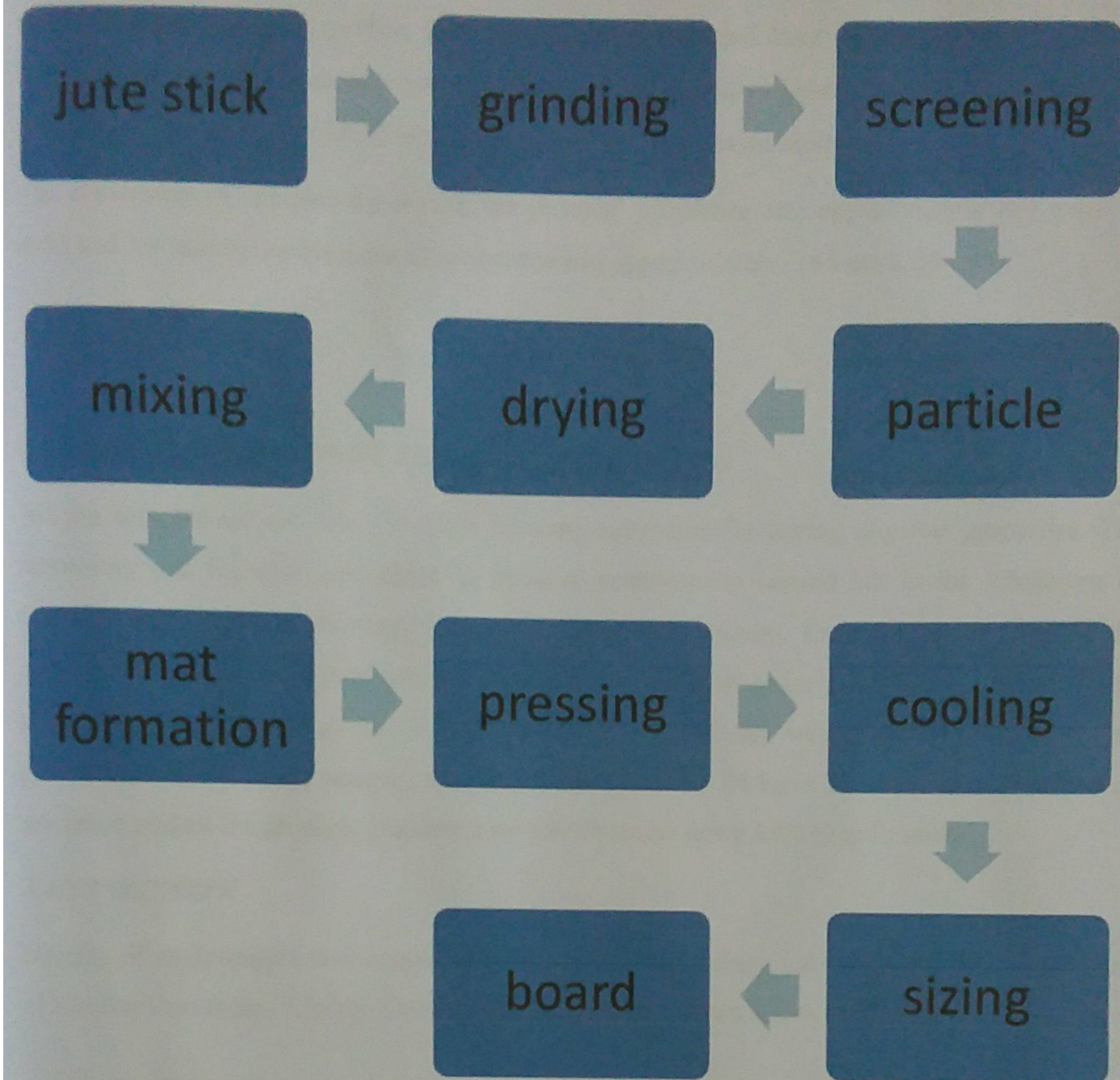

Fig : Manufacturing method

3.4 TESTING

3.4.1PREPARATION OF SAMPLES FOR TESTING

For testing physical properties, three samples were collected from each board of each type. So the total number of sample was nine 9 for each type of particleboard for testing of physical properties. The Density and Moisture Content were determined on the same nine (9) samples.

For testing mechanical properties, three samples were collected from each board of each type. So the total number of sample was nine (9) for each type of particleboard for testing of mechanical properties. The MOR and MOE were determined on the separate samples.

The dimension of samples for testing the physical properties was approximately (50 mmx 35 mm) and for testing the mechanical properties was approximately (180 mmx 35 mm).

3.4.2 DETERMINATION OF PHYSICAL PROPERTIES

All the samples are cut into (50 mmx 35 mm) dimension for testing physical properties. The laboratory test for characterization of physical properties is carried out in the laboratory of Forestry and Wood Technology Discipline, Khulna University, Bangladesh. At first all the specimens are weighted and green dimension are taken at room temperature. Then all the samples are kept into oven for 24 hours. After drying oven dry weight and dry dimension are also measured. Next, the samples are soaked into water for 24 hour. Finally, the wet dimension are taken and all the physical properties are calculated by using following formula-

3.4.2.1 DENSITY

Density of each sample was measured in the Wood Technology Laboratory of FWT Discipline of Khulna University, Khulna. Density was calculated with the following formula-

$\rho = \frac{m}{v}$ (Deschand Dinwoodie, 1996)

Where, ρ = Density in gm/cm^3; m = Mass of the sample in gm and v = Volume in cm^3.

3.4.2.2MOISTURE CONTENT

The moisture content was determined, from the differences in weights before and after the sample has been drying in the oven. Initial and final weight of the samples was measured by electric balance. It was calculated by the following formula-

$$MC\ (\%) = \frac{m_{int} - m_{od}}{m_{od}} \times 100 \quad \text{(Deschand Dinwoodie, 1996)}$$

Where, MC = Moisture content (%), m_{int}= Initial mass of the sample (gm), m_{0d}= Oven-dry mass of the sample (gm).

3.4.2.3WATER ABSORPTION

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

$$A_w = \frac{m_2 - m_1}{m_1} \times 100 \text{ (ASTM, 1997)}$$

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).

3.5 DETERMINATION OF MECHANICAL PROPERTIES

All the samples are cut into required dimension for testing mechanical properties. The laboratory test for characterization of mechanical properties is carried out in the laboratory with the Universal Testing Machine (UTM), in Khulna university laboratory.

3.5 .1MODULUS OF RUPTURE (MOR)

Modulus of rupture (MOR) was measured with the Universal Testing Machine (UTM), in Khulna university laboratory .The MOR was calculated from the following equation-

$$MOR = \frac{3PL}{2bd^2}$$ (Desch and Dinwoodie, 1996)

Where, MOR is the modulus of rupture in (N/mm^2), P= Load in N, L= Span length in (mm), b= width of test sample in (mm), d= Thickness of test sample in (mm).

3.5.2 MODULUS OF ELASTICITY (MOE)

Modulus of rupture (MOR) was measured with the Universal Testing Machine (UTM), in Khulna university laboratory. The modulus of elasticity (MOE) was calculated from the following equation-

$$MOE = \frac{P'L^3}{4\Delta bd^3}$$ (Desch and Dinwoodie, 1996)

Where, MOE is the modulus of elasticity in (N/mm^2), P' is the load in N at the limit of proportionality, L is the span length in (mm), Δ is the deflection in mm at the limit of proportionality, b is the width of sample in (mm), d is the thickness/depth of sample in (mm).

3.6 ANALYSIS OF DATA

All the data, produced during the laboratory tests for characterization of physical and mechanical properties of each type of particle boards, were analyzed by using Microsoft Office Excel 2007 and SPSS software ANOVA (Analysis of Variance) and LSD (Least Significant Difference) were done to analyze the data.

Chapter Four: Result and Discussion

4.2.1 PHYSICAL PROPERTIES

4.2.1.1 DENSITY

Density is quantity that is used to describe the mass of a material per unit volume (Irle and Barbu, 2010). It has been found that the density of the board made from fine particle is 998 Kg/m^3 , course particle is 882 Kg/m^3 , miuxture board is 953 Kg/m3 & layer board is 974 Kg/m3. From the following (Fig-4.2.1.1), we have seen that impact on density.

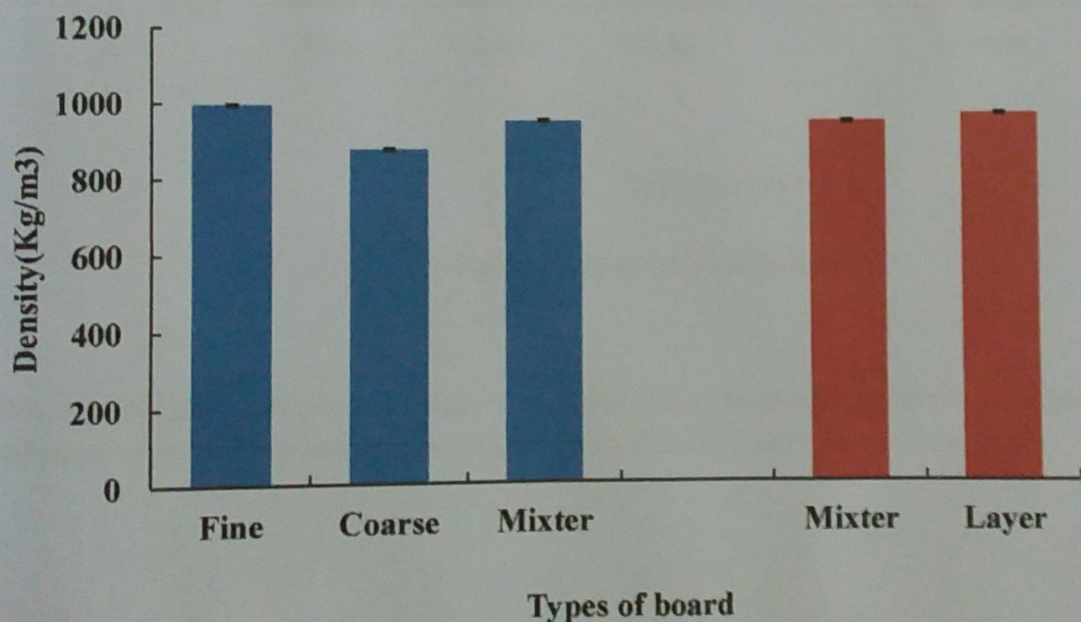

Fig: Impact on density

From the analysis of variance (Table A-1), it has been observed that there was significant difference ($P < 0.01$) in density among the different types of boards.

4.2.1.2 WATER ABSORPTION

It has been found that the water absorption of the board made from fine particle is 51.23%, course particle board is 43.18%, mixture particle board is 34.15% & layer particle board is 27.22%. From the following (Fig-4.2.1.2), we have seen that impact on water absorption.

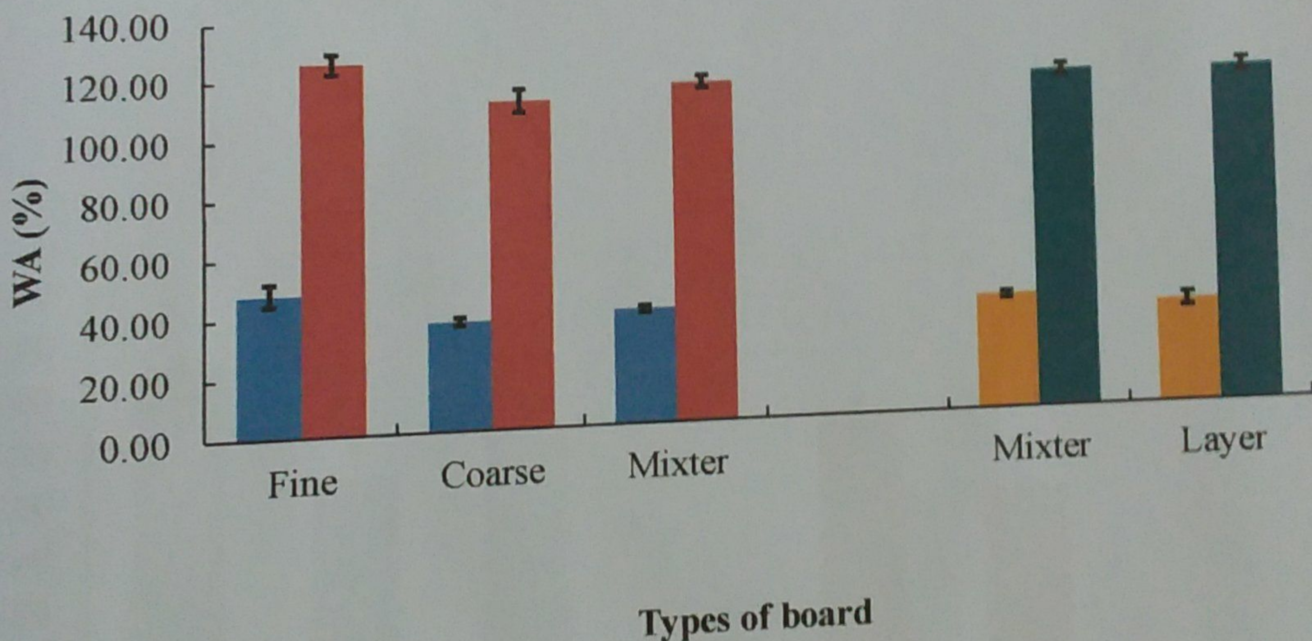

Fig: Impact on water absorption

From the analysis of variance (Table A-2), it has been observed that there was significant difference ($P < 0.01$) in water absorption among the different types of boards.

4.2.1.3 MOISTURE CONTENT

It has been found that the moisture content of the board made from fine particle is 51.23%, course particle board is 43.18%, mixture particle board is 34.15% & layer particle board is 27.22%. From the following (Fig-4.2.1.3), we have seen that impact on moisture content.

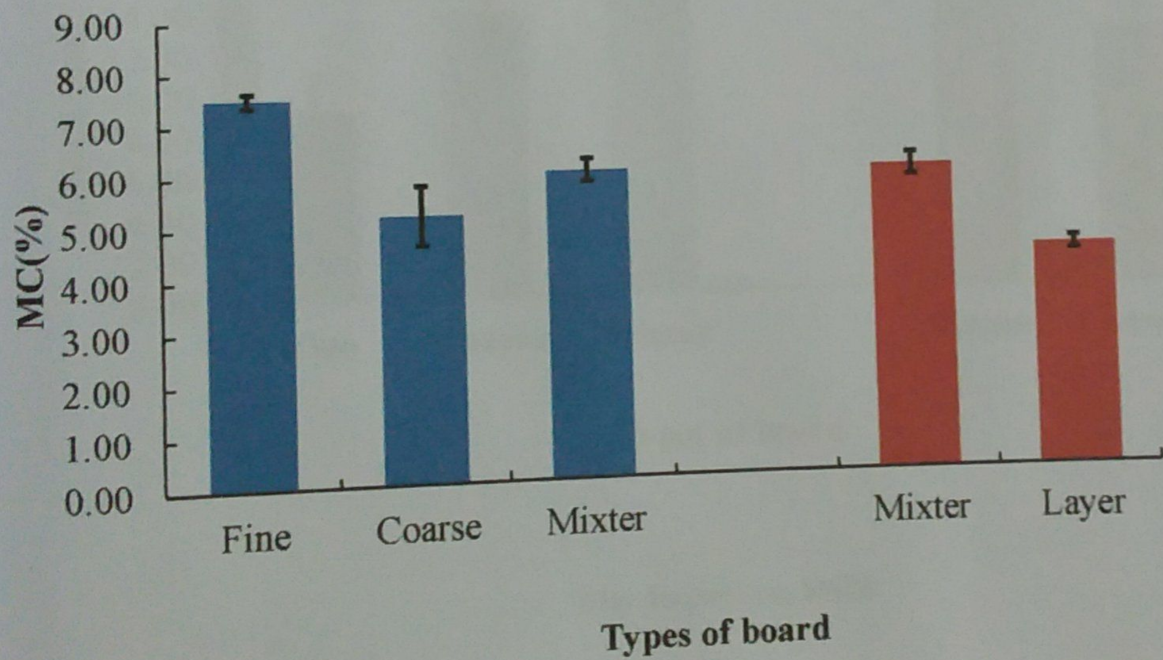

Fig: Impact on moisture content

From the analysis of variance (Table A-3), it has been observed that there was significant difference ($P < 0.01$) in moisture content among the different types of boards.

4.2.2 MECHANICAL PROPERTIES

4.2.2.1 MOR

It has been found that the MOR of the board made from fine particle is 9.30953, course particle board is 14.1182, mixture particle board is 14.8832 & layer particle board is 12.9359. From the following (Fig-4.2.2.1), we have seen that impact on water absorption.

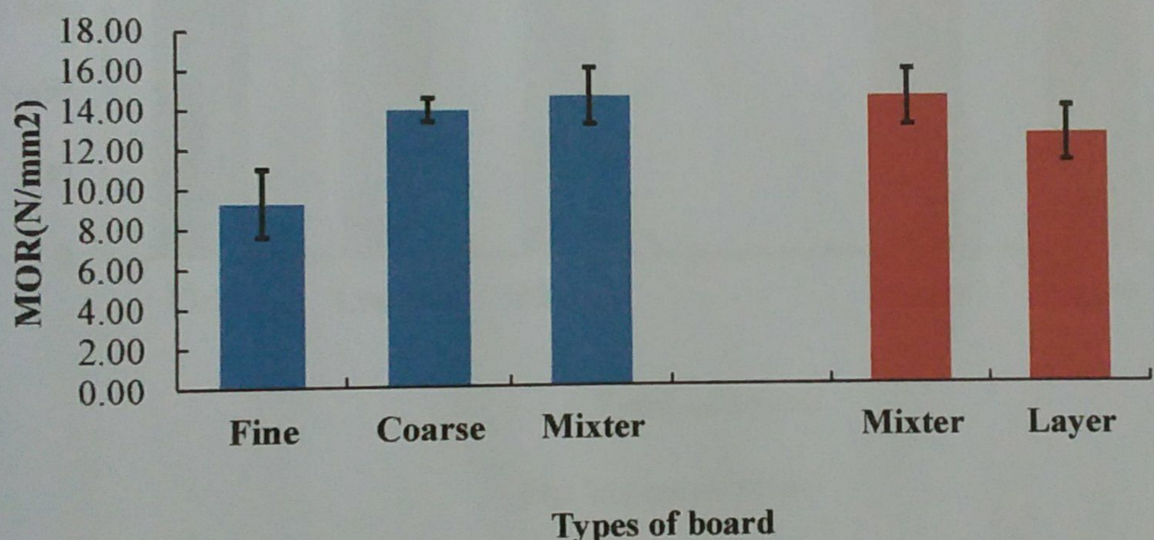

Fig: Impact on MOR

From the analysis of variance (Table A-4), it has been observed that there was significant difference ($P < 0.01$) in MOR among the different types of boards.

4.2.2.2MOE

It has been found that the MOE of the board made from fine particle 1982.01, course particle board is 2819.69, mixture particle board is 2995.07 & layer particle board is 2456.24. From the following (Fig-4.2.2.2), we have seen that impact MOE.

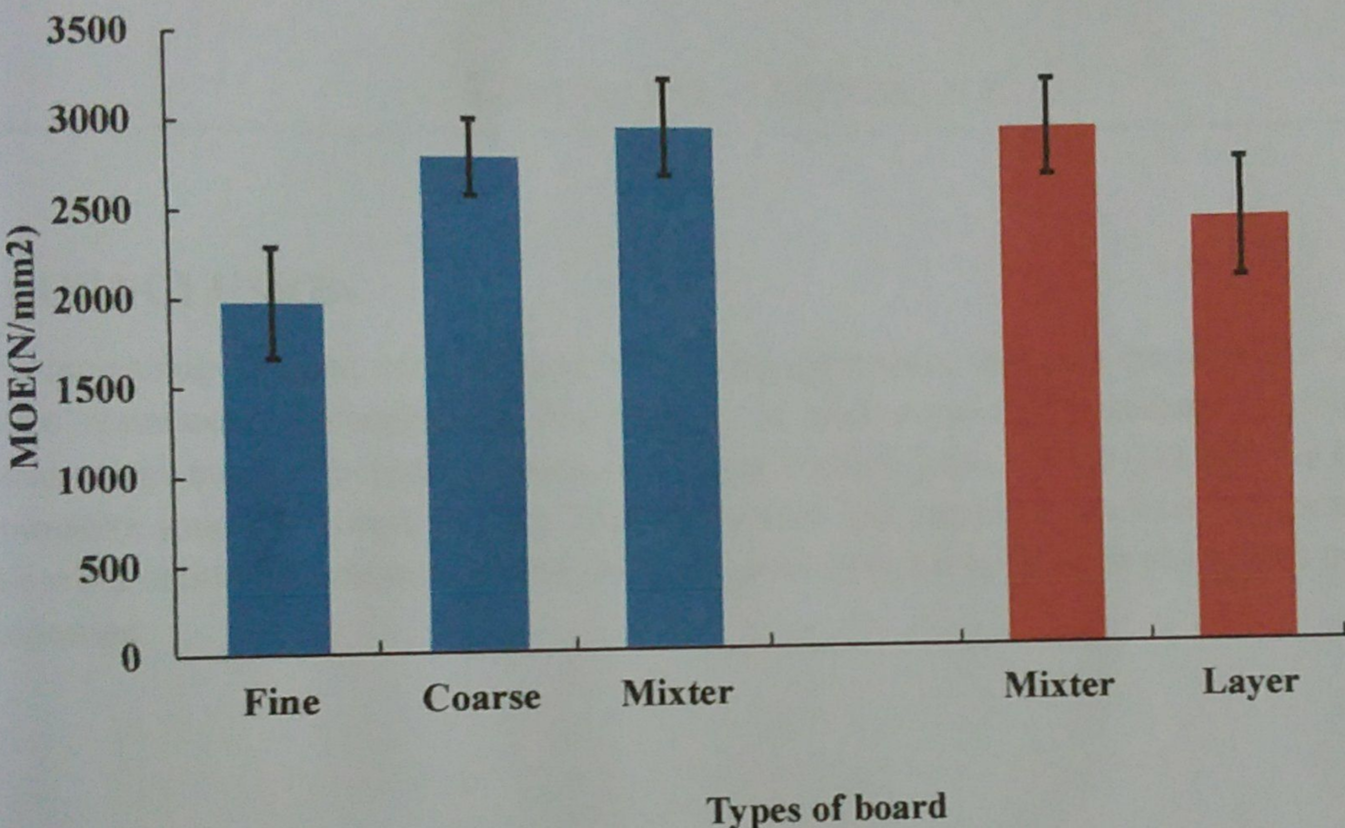

Fig: Impact on MOE

From the analysis of variance (Table A-5), it has been observed that there was significant difference ($P < 0.01$) in MOE among the different types

Chapter Five: Conclusion

5.1 CONCLUSION

The increasing demand of wood and wood products creates immense pressure on the limited forest resources of Bangladesh. Therefore, it is now especially important to utilize forest resources in more effective and economic ways. Natural latex bonded jute particle board is a alternative source of forest product. This thesis work will also show the best one for utilization. The work shows that mixture of fine & course particle board is better in physical & mechanical properties.

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