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ENVIRONMENTAL FRIENDLY CROSSBANDED BOARD FORM JUTE STICK

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DECLARATION

I, Tahsina Tasmin, Student ID- Ms-150510 declare that the thesis is based on my own work except for quotation and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Khulna University or any other institutions.

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Name of the candidate: Tahsina Tasmin

Dedicated To

My Parents and late Grand Father

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At the very beginning, I would like to express my gratitude to almighty God for his blessings upon me for the successful completion of this thesis paper.

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ABSTRACT

The study was conducted to develop jute stick cross-banded board without using any binding agent therefore; the effect of temperature on physical and mechanical properties of these boards was evaluated. Board made at 200^{0}C showed higher physical (WA: 54.77%, TS: 30.54%) and mechanical properties (MOE: 12765.34 N/mm^2, MOR: 85.46 N/mm^2, IB: 0.74 N/mm^2) than other boards and UF bonded cross board showed lower physical (WA: 99.76%, TS: 87.74%) and mechanical properties (MOE: 6862.5 N/mm^2, MOR: 52.61 N/mm^2, IB: 0.37 N/mm^2) than binderless boards. Hence, it can be concluded that Jute stick can be a potential raw material for manufacturing cross banded board.

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1.1 General Introduction

The population of world is increasing rapidly day by day. As a result the natural resources of world mainly forest resources are decreasing continuously to meet the demand of increasing population (Adger and Brown, 1994). There is a greater awareness of the need for materials in an expanding world population and increasing affluence (Pijus *et at*, 2011) The cost of raw material is also increasing day by day. For all this reasons, the technology is advancing in the sense of being able to produce cheaper materials from residues. In this context, new raw materials that reduce the production costs and which do not damage the environment have been an important aspect of technological development.

In recent years, effective utilization of fast-growing non wood lignocellulosic materials and agro-wastes has been of great interest owing to a drastic fall in forest resources. Lignocellulosic biomass exploitation mainly wood is focused in pulp and paper fabrication, building and carpentry, but there is a part of this lignocellulosic biomass from which no profit is taken. Now a days the feasibility of using lignocellulosic residues as alternative raw material for particleboard, fiber board or plywood production has been explored by a number of researchers (Youngquist *et al*., 1993). Lignocellulosic residues offer interesting potential applications as raw material in general, in addition to its possible uses with energetic purposes. They are abundant, renewable and recyclable. Most of the non-wood lignocellulosic materials have very low densities, which make them extremely bulky. The collection, transportation and storage of these materials call for special attention due the bulky nature of these. Among the nonwoodlignocellulosic materials, bagasse, jute, kenaf, cereal straw has attracted special interest because of its rapid growing speed. Jute is cultivated almost exclusively in developing countries of East Asia and in some parts of Latin America. Bangladesh, India and Thailand account for over 90 percent of world production and among them Bangladesh is in the second position (FAOSTAT-Crops, 2017). Jute stalk contains two types of fiber: outer "bast" and an inner "core." Jute bastfibers are using extensively as automotive nonwoven material (Moreau *et al.* 1995; Parikh *et al.* 2002a; Parikh *et al.* 2002b). The core however, has no utility in the automotive applications and is often discarded and these are mainly used for fuel wood purposes. Thus, Jute core is considered to be one of the new sustainable lignocellulosic raw materials if we use it efficiently. A good number of research works has been done on the effective utilization of jute making board. In this context the main target of this thesis is effective utilization of jute core.

Now-a-days researchers are conducting their research on plywood, particle boards, and fiber boards by using nonwoodlignocellulosic materials. Synthetic thermosetting resins such as phenol–formaldehyde, urea formaldehyde resins are generally used as adhesives to manufacture such boards. However, these resins have some negative impacts on health and environment due to the emission of volatile organic compounds from the resin and these resins are derived from petrochemicals and also production of these resins is not economically feasible. Researchers are now interested to make adhesive free boards (Angles *et al.* 1999, 2001; Suzuki *et al.* 1998; Van Dam *et al.* 2004). In this context, binderless boards have attracted great interest as environment-friendly products, because they can be manufactured from fragments of lignocellulosic materials without the addition of any adhesives. The self-bonding strength is improved only by activating the chemical components of the board constituents during steam/heat treatment. The main reason of self-bonding mechanism is mainly activation of chemical components of the board constituents, mainly hydrolysis of hemicellulose, degradation of part of cellulose to produce simple sugars and other decomposition products and thermal softening of cell wall matrix, crosslinking between carbohydrate polymers and lignin and an increase in cellulose crystallinity (Van Dam *et al.* 2004, Laemask and Okumura 2000; Ellis and Paszner 1994; Widyorini *et al* 2005; Shen, 1991; Rowell *et al.*,2002; Inoue *et al.*, 1993; Suzuki *et al.*, 1998; Tanahashnie*et al.*, 1989). Jute core is deemed to be a suitable raw material for making binderless boards because of its high hemicellulose content. Making of high performance environmental friendly Cross banded board from jute stick (core) is the main target of this thesis.

1.2 Objective of the study

- To develop binderless cross banded board from jute stick.
- To evaluate physical and mechanical properties of binderless cross banded board from jute stick.

Chapter Two

Literature review:

2.1General Information about jute:

2.1.1 Introduction:

The word 'jute' is probably coined from the word jhuta or jota, an Oriya word. Jute is one of the most affordable natural fibers and it is second only to cotton in amount produced and variety of uses of vegetable fibers. Jute fibers are composed primarily of the plant materials cellulose and lignin. It falls into the bast fiber category (fiber collected from bast, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc. The industrial term for jute fiber is *raw jute*. The fibers are off-white to brown, and 1–4 metres (3–13 feet) long. Jute is also called the *golden fiber* for its color and high cash value (Indian jute: Medicinal use/Herbal Use of Jute, 2015). **Jute** is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. It is produced primarily from plants in the genus *Corchorus*, which was once classified with the family Tiliaceae, and more recently with Malvaceae. The primary source of the fiber is *Corchorusolitorius*, but it is considered inferior to *Corchoruscapsularis*. "Jute" is the name of the plant or fiber that is used to make burlap, hessian or gunny cloth. *Corchoruscapsularis* was used for this research.

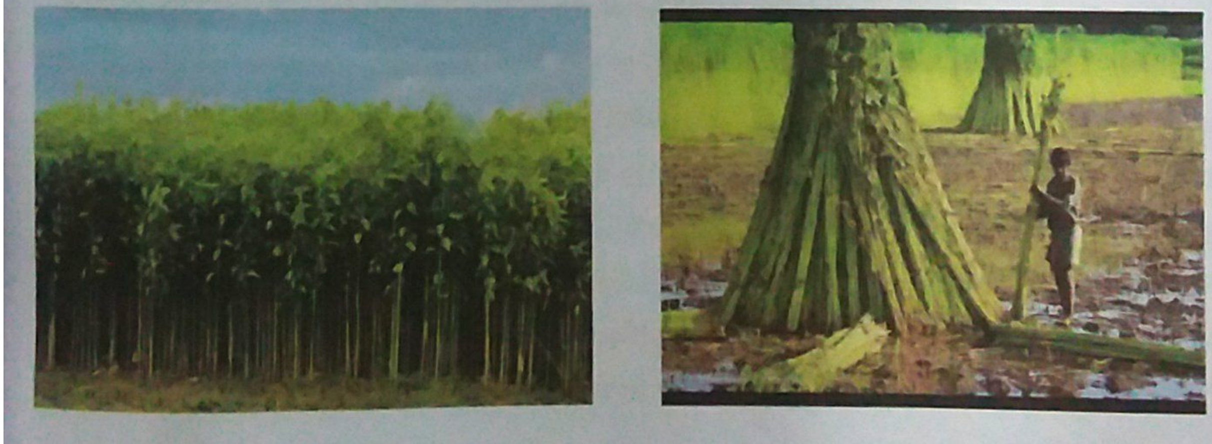


Fig: 2.1 Jute Plantation

Jute is a natural fiber with numerous environmental advantages. It is an annually renewable resource with a high biomass production per unit area, and Jute products being biodegrable decompose in the soil at the end of product life-cycle. Towards global warming, a concern of much importance in the present world, while the synthetic materials are being considered as the root of many problems, the natural fiber products are proven to be absolutely harmless.

The worldwide awareness on environment is the reason for the opportunities of jute, due to environment friendly characteristics. Jute, a natural fiber that can be used in many different areas, supplementing or replacing synthetics, has been receiving increasing attention from the industry. The usage of jute are not only traditional uses, but also on the production of other value added products such as pulp and paper, geo- textiles, composites and home textiles. The roots of jute plants play a vital role in increasing the fertility of soil. Jute plants have carbon dioxide assimilation rate and it clean the air by consuming large quantities of carbon dioxide (IJSG, 2011).

2.1.2 Jute Cultivation:

To grow jute, farmers scatter the seeds on cultivated soil. When the plants are about 15–20 cm tall, they are thinned out. About four months after planting, harvesting begins. The plants are usually harvested after they flower, before the flowers go to seed. The stalks are cut off close to the ground. The stalks are tied into bundles and soaked in water for about 20 days. This process softens the tissues and breaks the hard pectin bond between the bast and Jute hurd (inner woody fiber stick) and the process permits the fibres to be separated. The fibres are then stripped from the stalks in long strands and washed in clear, running water. Then they are hung up or spread on thatched roofs to dry. After 2–3 days of drying, the fibres are tied into bundles. The suitable climate for growing jute is a warm and wet climate, which is offered by the monsoon climate during the fall season, immediately followed by summer. Temperatures ranging from 70–100 °F and relative humidity of 70%–90% are favorable for successful cultivation. Jute requires 2–3 inches of rainfall weekly with extra needed during the sowing period.

2.1.3 Major Types of Jute:

White jute (Corchorus capsularis)

Historical documents (including *Ain-e-Akbari* by AbulFazal in 1590) state that the poor villagers of India used to wear clothes made of jute. Simple handlooms and hand spinning wheels were used by the weavers, who used to spin cotton yarns as well. History also suggests that Indians, especially Bengalis, used ropes and twines made of white jute from ancient times for household and other uses. It is highly functional in carrying grains or other agricultural products.

Tossa jute (Corchorus olitorius)

Tossa jute (*Corchoru solitorius*) is a variety thought to be native to India, and is also the world's top producer. It is grown for both fiber and culinary purpose. It is used mainly for its fiber in Bangladesh, in other countries in Southeast Asia, and the South Pacific. Tossa jute fiber is softer, silkier, and stronger than white jute. This variety astonishingly shows good sustainability in the climate of the Ganges Delta. Along with white jute, tossa jute has also been cultivated in the soil of Bengal where it is known as *paat* from the start of the 19th century. Coremantel, Bangladesh is the largest global producer of the tossa jute variety.

Fig: 2.2 White Jute

Fig: 2.3 Tossa Jute

2.1.4 Parts of Jute Stalk:

Fig: 2.4 Bundle of jute stick

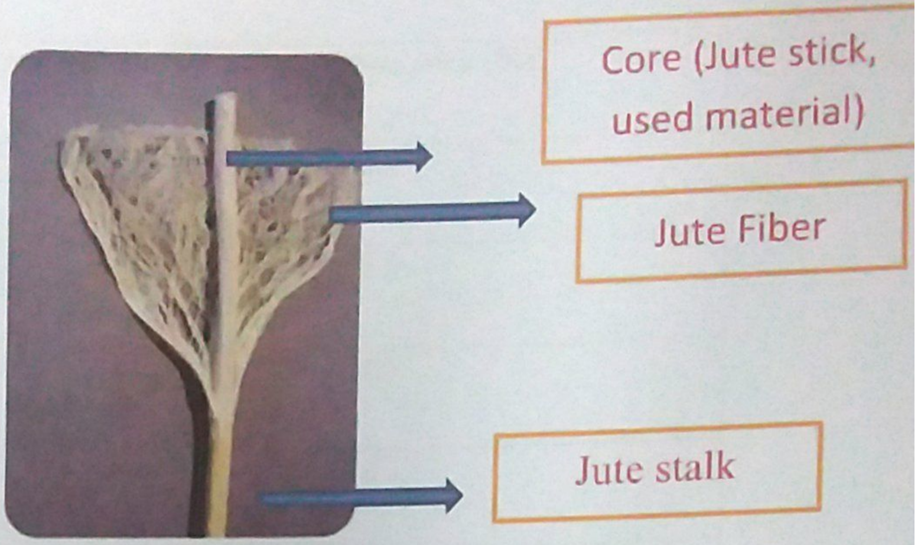


Fig: 2.5 Jute Stalk

Jute stalk contains two types of fiber: outer "bast" and an inner "core." Jute bast fibers are using extensively as automotive nonwoven material (Moreau *et al.* 1995; Parikh *et al.* 2002a; Parikh *et al.* 2002b). The core however, has no utility in the automotive applications and is often discarded. This core is mainly called jute stick which has no utility except fuelwood purposes. Thus, Jute sticks are considered to be one of the new sustainable lignocellulosic raw materials if it can be used efficiently.

2.1.5 Properties of Jute:

Chemical composition of Jute

Yield component research with five jute cultivars showed averaged 26% leaves and 74% stalks by weight. In the same research the jute stalk's average composition was 35% bark and 65% woody core by weight. The bark of the jute stalk contains the long fiber strands that are composed of many individual smaller fibers, normally called bast fibers. These individual bast fibers, held together by lignin, are the building blocks of the bark fiber strands, which historically were used to make the cordage products. The woody core material of the stalk, the portion remaining when the bark is removed, contains core fibers. The individual bast fibers are longer and thinner than the individual shorter, thicker core fibers. Oil in seed and crude protein in jute leaves and stalks are also present.

Table 2.1 Chemical constituents in Jute fiber and jute stick

Constituents	**Jute fiber (%)**	**Jute stick (%)**
Alpha Cellulose	61	40.8
Lignin	11.5	23.5
Hemicellulose	24	32.9
Ash	1.6	0.8
Others	1	1.0

(Jute Technology Mission: Design & Development of JDPS, Final Report)

Table 2.2 Close view of chemical contents of jute stick,

Constituents	**Quantity (%)**
Major constituents	
Alpha- Cellulose	40.8
Pentosan	22.1
Uronic anhydride	7.5
Acetyl content	4.5
Lignin	2.5
Minor Constituents	
Fat and wax	1.9
Nitrogen	1.1
Ash	0.8
Monosaccharide Constituents	
Glucose	43.2
Xylose	18.7

Constituents	Quantity (%)
Mannose	1.6
Galactose	1
Arabinose	0.6
Rhammose	0.4

(Jute Technology Mission: Design & Development of JDPS, Final Report)

Physical Properties of jute fiber:

Table 2.3 Physical properties of jute fiber

Ultimate cell length	2.50 mm
Ultimate cell breadth	18 micro meter
Density	1.46 gm/cc
Moisture Retain at 65% RH	13.8%
Transverse Swelling in water (Diameter wise)	20%
Water holding capacity	500%
Heat of combustion	17.5 j/g
Ignition Temperature	193^0 C

(Jute Technology Mission: Design & Development of JDPS, Final Report)

Jute absorbed the Carbon dioxide from the air, which helps the ozone layer from destruction. It also emits oxygen to the atmosphere, which is helping the livelihood. Jute as a fiber crop is a fast growing one that takes only 4 to 5 months to mature. The production of the fastest growing wood plant needs at least 10 to 14 years from the plantation to harvest. The usages of jute in place of wood to make boards will reduce the cost of production. So following this feasibility of jute I tried to make cross banded board to reduce the cost of wood.

2.1.6 Status of jute production in the world:

Jute is a rain-fed crop with little need for fertilizer or pesticides, in contrast to cotton's heavy requirements. Production is concentrated mostly in Bangladesh, as well as India's states of

Assam, Bihar, and West Bengal (OJC, 2013) India is the world's largest producer of jutebut mported approximately 162,000 tones of raw fiber and 175,000 tones jute products in 2011 , (IJSG, 2014). India, Pakistan, and China import significant quantities of jute fiber and products from Bangladesh, as do the United Kingdom, Japan, United States, France, Spain, Ivory Coast, Germany and Brazil.

Table 2.4 Top ten jute producers in the world,

Country	**Production (Tones)**
India	1,968,000
Bangladesh	1,349,000
People's Republic of China	29,628
Uzbekistan	20,000
Nepal	14,890
South Sudan	3,300
Zimbabwe	2,519
Egypt	2,508
Brazil	1,172
Vietnam	970
World	**3,393,248**

(FAOSTAT- Crops, 2017)

Above table shows that Bangladesh is the second producer of jute in the world. Every year huge amount of jute produced in Bangladesh and fulfilling country's need Bangladesh exported jute fibers in other countries. After use of fibers a lot of jute sticks remain unused as wastage. That's why the main target of this thesis was proper utilization of this remaining unused wastage (Jute stick).

2.1.7 Major Drawback of Uses of Jute stick:

The major disadvantages of jute sticks are to their coarseness, stiffness, low extensibility, wash shrinkage, ready susceptibility to microbial attack and poor abrasion resistance. In order to minimize or even eliminate some of the major disadvantages attempts have been made to reduce such problem (Sarkar and Adhikari, 2001).

2.2 Information about Binderless board:

2.2.1 Binderless Board

Binderless board is a wood panel made without the use of synthetic adhesive. It is manufactured by hot pressing of wood particles that involves a self-bonding process (Workshop on Technology Transfer, 2014). A process, which converted the lignocellulosic materials into panel boards without using of synthetic resin binders, has been developed and patented by Shen in the mid-eighties. Studies on manufacturing process of binderless board have been conducted for years. It is also self- bonding board.

2.2.2 Binderless board manufacturing process:

Non-wood lignocellulosic materials have been considered to produce various composite products for their physical and chemical characteristics. Non-wood raw materials which are usually rich in hemicelluloses, are supposed to be potential materials for binderless boards production. Binderless composites production using non-wood lignocellulosic materials are summarized, as reported by several researchers in Table.

Table: 2.5 Binderless composites production using non-wood lignocellulosic materials

Lignocellulosic materials	Types	Reference
Plantain	Fiberboard	Alvarez *et al.* 2011
Kenaf	Particle board	Okuda *et al.* 2006a
Bagasse	Fiberboard	Shen 1986; Widyorini *et al.* 2005a
Coconut Husk	Fiberboard	Van Dam *et al.* 2004
Bamboo	Fiberboard	Shao *et al.* 2009
Rice straw	Particleboard	Luo and Yang, 2012
Wheat straw	Fiberboard	Halvarsson *et al.* 2009
Miscanthussinensis	Fiberboard	Salvado *et al.* (2003)
Banana bunch	Fiberboard	Quintana *et al.* (2009
Seed cake	Fiberboard	Hidayat *et al.* (2014)
Cotton stalks	Fiberboard	Fahmy and Mobarak (2013)
Vitisvinifera	Fiberboard	Mancera*et al.* (2011)
Cynaracardunculus	Fiberboard	Mancera *et al.* (2008)

There are two distinct processes: wet-forming and dry-forming used for binderless board production. Wet-forming process is the distribution of cellulosic materials into water that form hydrogen bonds and create thermosetting adhesive behavior of lignin during heating and drying process. On the other hand, dry forming process is the basic for industrial manufacturing process that reducing moisture content of cellulosic materials by drying and it distribute into mat by pre-pressing and finally undergoes hot-press (Lee and Hunt, 2013).Common processes such as hot pressing, steam explosion before hot pressing and steam injection pressing and hot water boiling have been developed to increase the performance of binderless board (Zhang *et al.*, 2015). Pre-treatment processes such as hot water boiling and grinding processes are simpler processes. In summary, poor dimensional stability of binderless fiberboards made from non-woody materials was one of the biggest drawbacks resulting from high hemicelluloses content. The extension of steam pretreatment seemed to be an option to overcome this drawback, but correspondingly, the energy consumption has to be considered.

2.2.3 Self- bonding mechanism of Binderless composite:

The self-bonding strength is improved only by activating the chemical components of the board constituents during steam/heat treatment. The main reason of self-bonding mechanism is mainly activation of chemical components of the board constituents, mainly hydrolysis of hemicellulose, degradation of part of cellulose to produce simple sugars and other decomposition products and thermal softening of cell wall matrix, crosslinking between carbohydrate polymers and lignin and an increase in cellulose crystallinity (Van Dam *et al.* 2004, Laemask and Okumura 2000; Ellis and Paszner 1994; Widyorini *et al* 2005; shen, 1991; Rowell *et al.*,2002; Inoue *et al.*, 1993; Suzuki *et al.*, 1998; Tanahashnie*et al.*, 1989, 2000). Hydrolysis of hemicelluloses produces water-soluble components and some extractives and volatile degradation products during the process where steam-pressure and pressing is important to the degree of degradation (Xu *et al.*, 2005). During hydrolysis process, acetic acid, formic acid, cinnamic acid and some sugar are liberated and these are hydrolyses hemicelluloses produce some furfural products.

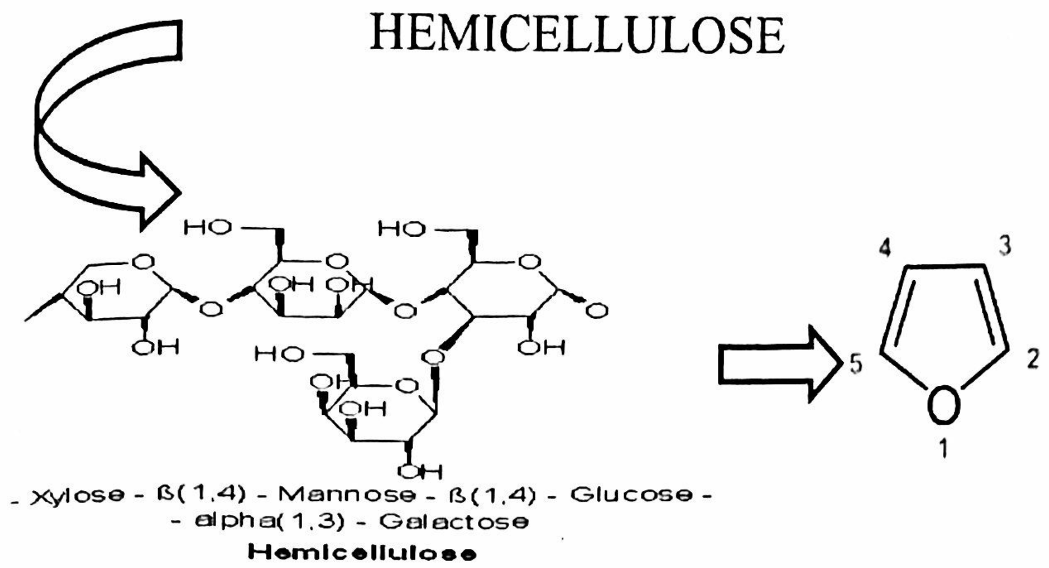


Fig: 2.6 Hydrolysis of hemicellulose (Widyorini *et al.*, 2005)

Some of the pentoses and hexoses also produced that are dehydrated to furfural and hydro-oxymethyl furfural respectively. Then part of the lignin carbohydrate bond cracked by those acids. It causes explosion of functional groups that seems a slower hydrolysis and the recondensation of the activated lignin molecules like phenol at high temperature (Mobarok and Fahmy, 2013).

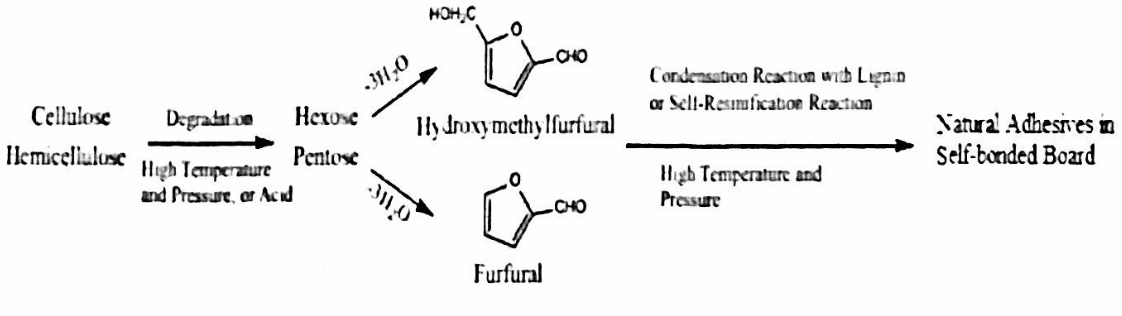


Fig: 2.7 Potential self-bonding mechanism in the production of binderless board (Suzuki *et al.*, 1998; Mobarak and Fahmy 2013).

Chapter Three

Materials and Method:

3.1 Materials:

The used raw material for this thesis was Jute (*Corchoruscapsularis*)stick.

Fig: 3.1 Jute Stick

3.2.1 Methods and Procedure:

Collection of raw material:

Bundles of Jute sticks were collected from Gopalganj district.

Preparation of raw material:

After collection of raw material it was air dried for seven days. Then fibers on the sticks were separated manually. Then sticks were cut into desirable sized by using conventional hand tool.

Assembling of Sticks:

Assembling of sticks was the major concentration to manufacture this board. 31 cm sized sticks were assembled one after another the length wise to make face layer. Then 21 cm sized sticks were assembled one after another the width wise to make alternate layer. Then again 31 cm sized sticks were assembled to make another layer and simultaneously assembled the other width wise layer by 21 cm sized sticks. Finally the other face layer was made by 31 cm sized sticks. The sticks were assembled into a rectangular 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.

Hot Pressing:

Aftter assembling the assembled sticks were hot pressed at different temperatures (160^0C ,180^0C, 200^0C) temperature at air dried condition at 2.5 Mpa pressure for 10 mintes. Bords made with Urea formaldehyde was hot pressed at 140^0C at 2.5 Mpa pressure for 7 minutes. Density of the boards was controlled at 0.7 gm/cm^3. Then press was switched off but prssure was not released at that time.Then the board was allowed to cool for 10 minutes. Then pressure was removed and broght the board out.

Fig: 3.2 Hot Press

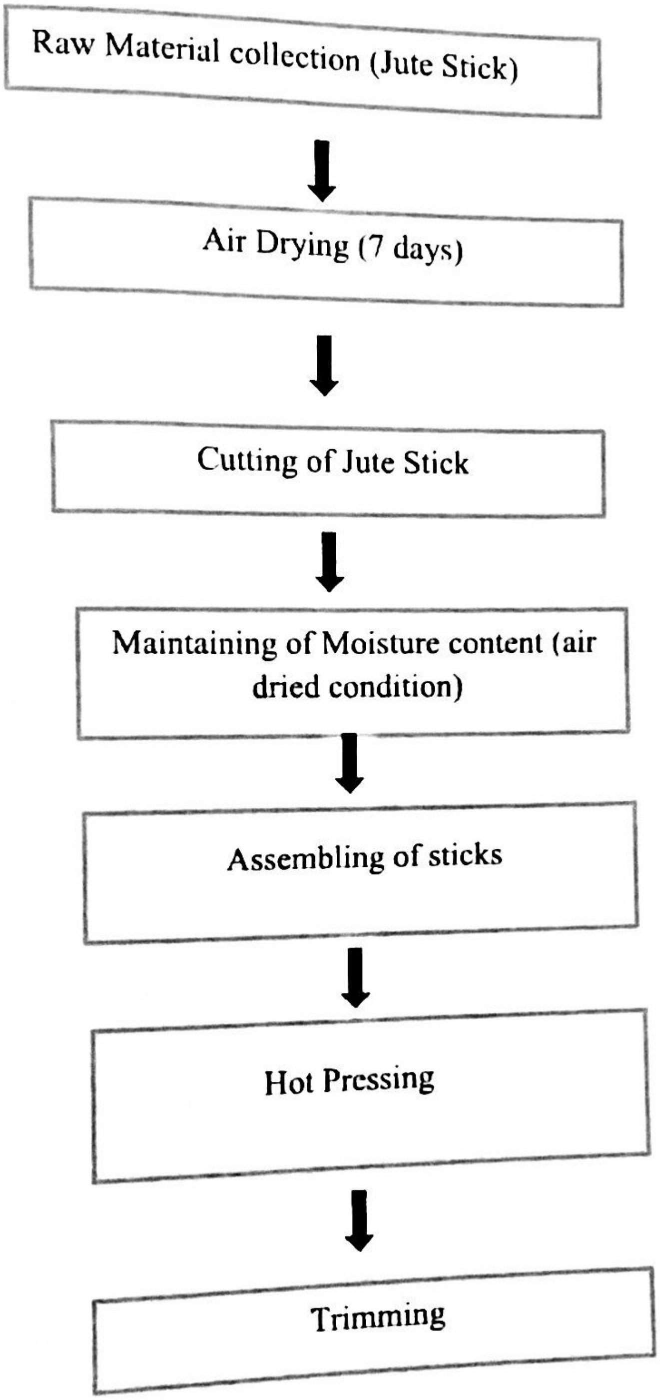
Trimming:

After the boards of each type were produced separately, these were trimmed at edges with the fixed type circular saw. The dimentions of each type of boards were 30x 20x 0.7 cm.

Fig: 3.3 Board before trimming

Fig: 3.4 Board after trimming

3.2.2 Flow Diagrams of Cross banded Board



3.2.3 Board Evaluation:

Preparation of sample for testing

Two replications of each type of boards were manufactured for testing physical and mechanical properties; two samples were collected from each board of each type. The dimension of samples for testing the physical properties was approximately (5 cm × 5 cm) and for testing the mechanical properties was approximately (21cm × 5 cm).

Determination of Mechanical Properties

All the samples are cut into required dimension for testing mechanical properties. The laboratory test for characterization of mechanical properties was carried out in Akij Particle Board industry.

Determination of Physical Properties

All the samples are cut into (5cm × 5cm) dimension for testing physical properties. The laboratory test for characterization of physical properties was carried out in the laboratory of Forestry and Wood Technology Discipline, Khulna University, Bangladesh. At first all the specimens were weighted and green dimension are taken at room temperature. Then weight and dry dimension were measured. Next, the samples were soaked into water for 2 hour. Then wet dimension was taken and all the physical properties are calculated by using formula. Then the samples were again soaked into water for 24 hour. Then finally, the wet dimension was taken and all the physical properties are calculated by using following formula,

Water Absorption

Water absorption was calculated by the following formula-

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

Where,

Aw=Water absorption (%)

m_1=Weight of the sample before immersion in water (gm.)

m_2= Weight of the sample after (24 hr.) immersion in water (gm.)

Thickness Swelling

Thickness swelling was calculated by the following formula-

$$G_t = \frac{t_2 - t_1}{t_1} \times 100 \text{(ASTM, 1997)}$$

Where,

Gt=Thickness swelling (%)

t_1= Thickness of the sample before immersion in water (gm.)

t_2= Thickness of the sample after (24 hr.) immersion in water (gm.)

Chapter Four

Result and Discussion:

Effect of Temperatures on Board properties

4.1 Mechanical Properties

Modulus of Elasticity (MOE):

Fig: 4.1 showed modulus of elasticity of cross banded board at different temperature. The result showed that MOE (12765.34 N/mm^2) at 200^{0}C is comparatively higher than 160^{0}C and 180^{0}C. Literature showed that board treated with higher temperature showed higher MOE because at higher temperature hemicellulose starts to degrade and the degraded hemicellulose, the monosaccharides are transformed into hydroxymethyl furfural and that could further participate in forming new browning compounds that are responsible for the bonding phenomenon (Carmen, 2015).

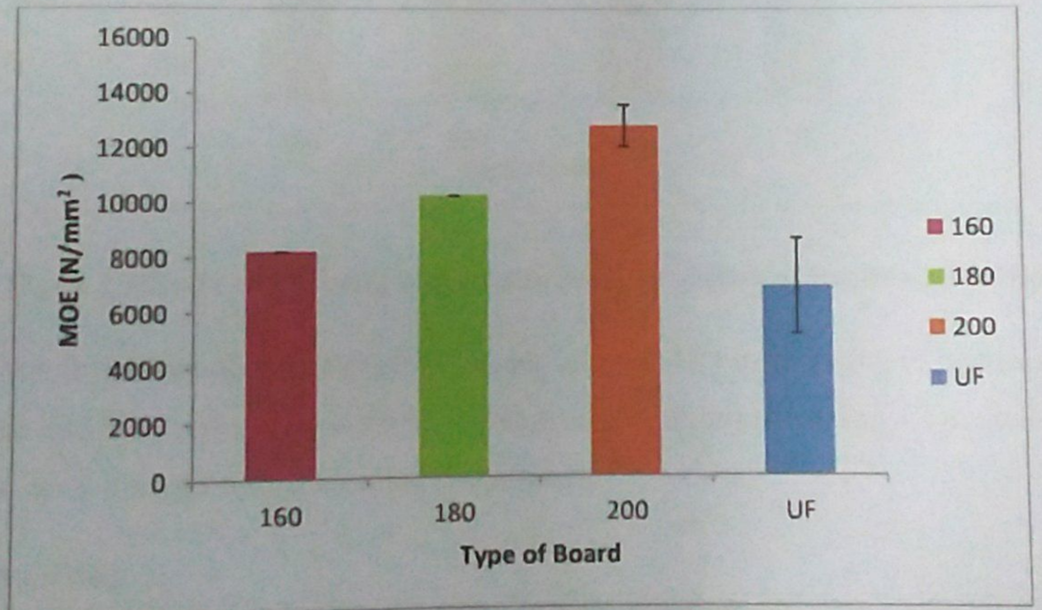


Fig: 4.1 Effects of pressing temperatures on Modulus of Elasticity (MOE)

MOE of UF board showed decreasing result than binderless boards. UF was brushed only on the surface of the sticks but it was not penetrate into the holo space of the sticks so may be UF

Bonded the sticks at outer binding line and no inner bonding line was created (Ceman, 2015). This could be a probable reason of decreasing MOE of UF board than binderless board.

Modulus of Rupture (MOR):

Fig: 4.2 showed modulus of rupture of cross banded board at different temperature. The result showed that MOR (85.46 N/mm^2) at 200^0C showed higher value than 160^0C and 180^0C and UF bonded cross board showed lower MOR than other boards. The Graphical presentation showed that MOR of cross bonded board is increasing by increased temperature.

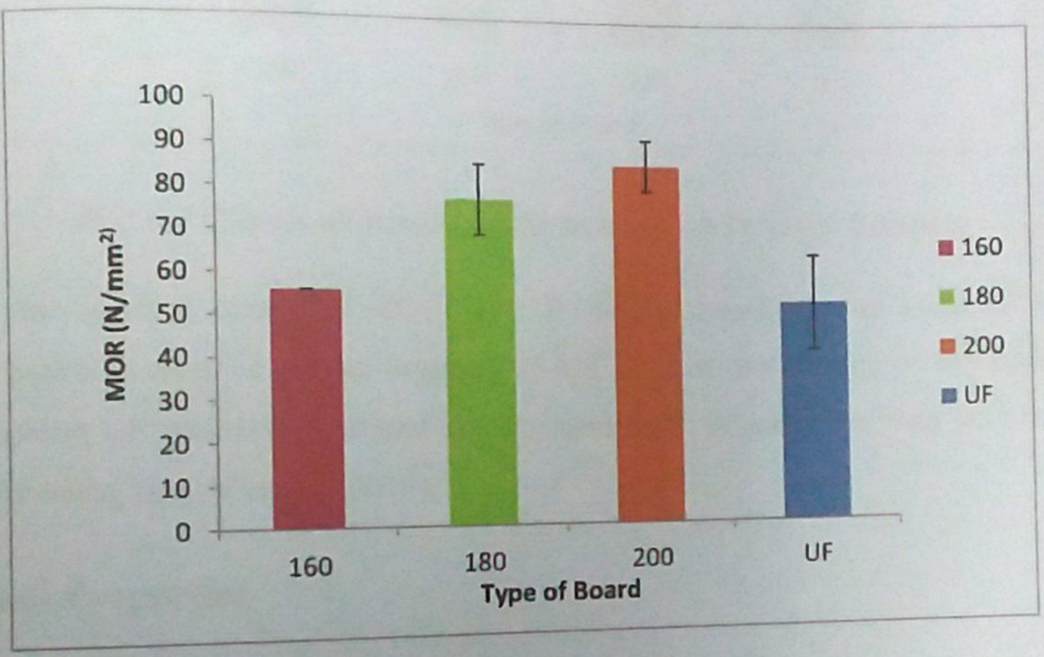


Fig: 4.2 Effects of pressing temperatures on Modulus of Rupture (MOR)

It may be due to self-bonding ability of the boards increased by degradation of hemicellulose and transformed into hydroxyl methayl- furfural which creates stronger bonding Cerman, 2015). This bonding became stronger with increasing temperature.

Internal Bond (IB):

Fig: 4.3 showed modulus of rupture of cross banded board at different temperature. IB (0.74 N/mm^2) at 200^0C board showed higher IB than 160^0C and 180^0C boards. Like MOE and MOR Internal bonding of cross banded board increased with increasing temperature.

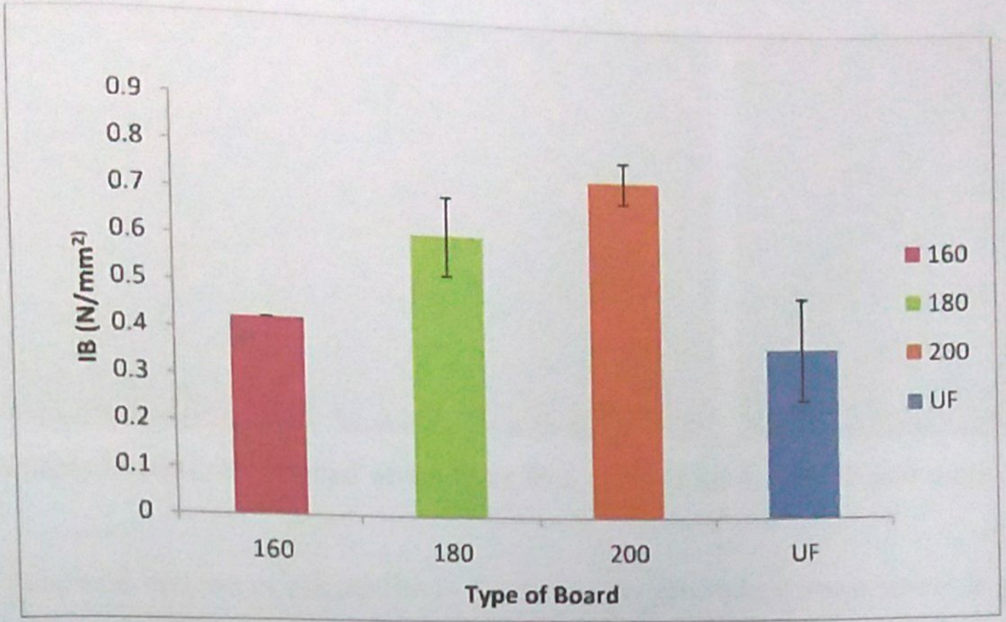


Fig: 4.3 Effects of pressing temperatures on Internal Bonding

It may be due to same reason of MOR. But UF bonded board showed lower IB value than binderless board. It may be due to brushing of UF only on the surface of the sticks. Due to surface brushing UF was not penetrated into the holo space of sticks and may be it was created only outer bonding line. (Cerman, 2015).

4.2 Physical Properties

Water Absorption

Fig: 4.6 showed Water absorption of cross banded board at different temperature, after two hour and 24 hour submersion in water. Board made at 200^0C showed lower WA (WA: 54.77%) after 24 hrthan 160^0C and 180^0C. But after 24 hr submersion in water, UF bonded cross board showed almost two times higher Water absorption than binderless boards.

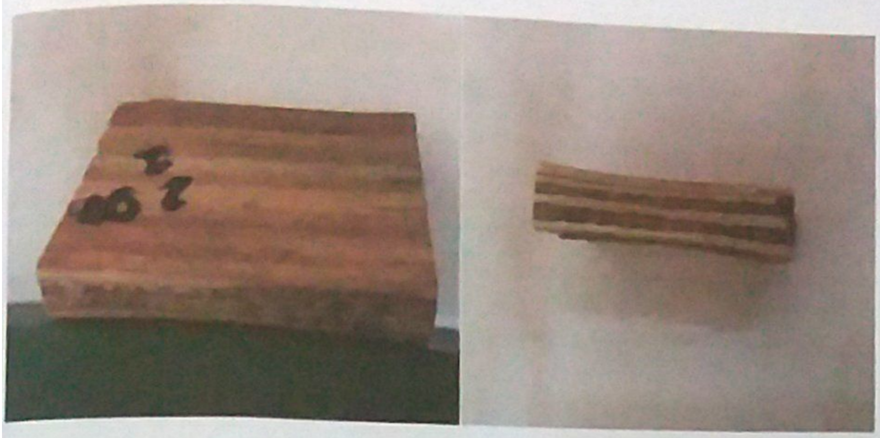


Fig: 4.4 Sample of binerless board after 24 hr WA

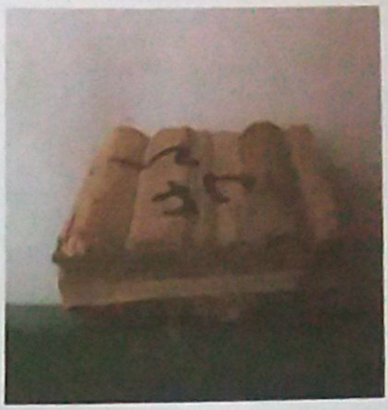


Fig: 4.5 UF board after 24 hr WA

This result showed that water absorption is decreasing by increasing temperature. It may be due to degradation of hemicellulose. Because during heating the degradation of hemicelluloses significantly reduces the amount of free reactive hydroxyl groups, and thus decreases the ability to bind water (Inari et al., 2007). On the other hand, (Hill, 2006) notes that during thermal treatment the possibility of cross-link formation in the lignin increases, and this can also be a factor contributing to water repellence. The decrease in hydrophilic character and that increased with increasing temperature. The presence of β-ether structures and methoxyl groups in lignin was higher in the bond-line, supporting the hypothesis of a migration of lignin and possibly a condensation reaction occurring at higher temperatures, explaining the water-resistance property acquired by the boards (Carmen, 2015)

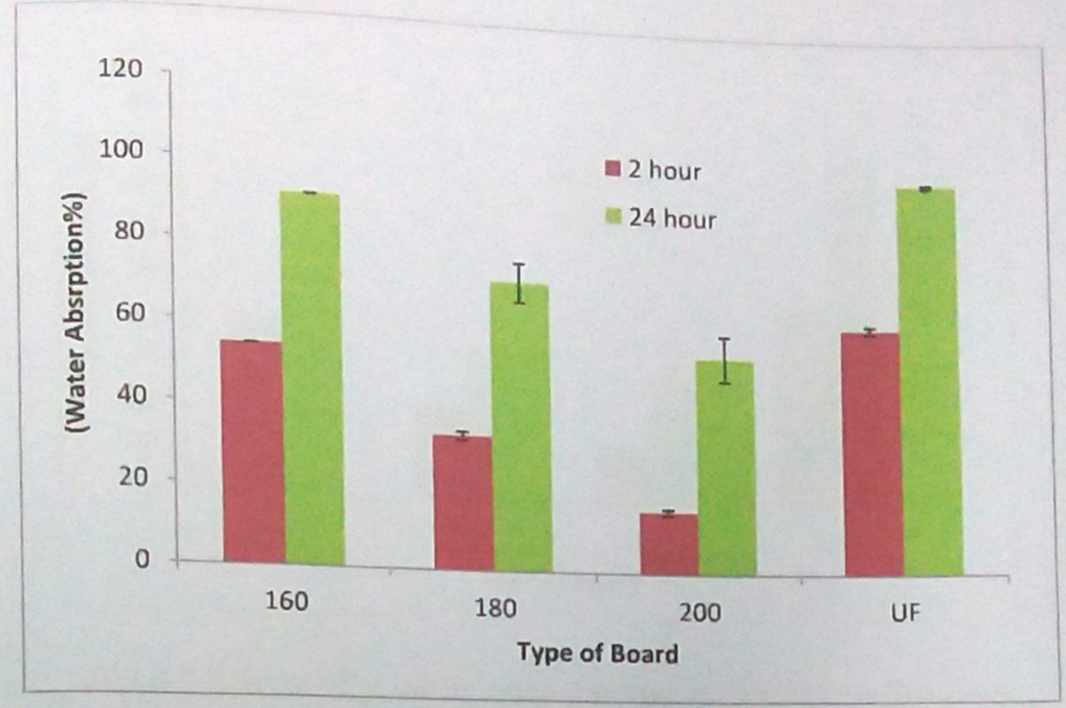


Fig: 4.6 Effects of pressing temperatures on Water Absorption (WA)

Another literature showed that manufacturing temperature has a positive effect on reducing wood hydrosgopicity as well as water absorption. Under heat, the pores start to collapse due to the action of unalterable hydrogen bonding among adjoining pore walls, which is termed as hornification (Park et al. 2006). Hornification suppresses and prevents the opening of previously exist polar sites for water absorption on rewetting (Crawshaw and Cameron, 2000). But board made with UF Showed higher water absorption. Because UF resin is less resistant to water and go through decomposition in the presence of amino methylene linkage resulting spring back of particleboard after immersion in water (Nemli, 2006). So it increases water absorption.

Thickness swelling:

Fig: 4.7 showed thickness swelling of cross banded board at different temperature, after two hour and 24 hour submersion in water. After 24 hr submersion in water 200^0C board showed lower TS (30.54%) than other boards. This result showed that thickness swelling is decreased by increasing temperature. Due to lower water absorption thickness swelling is become less. In other words When boards are pressing at high temperatures appreciably reduces the swelling (Stamm 2006).

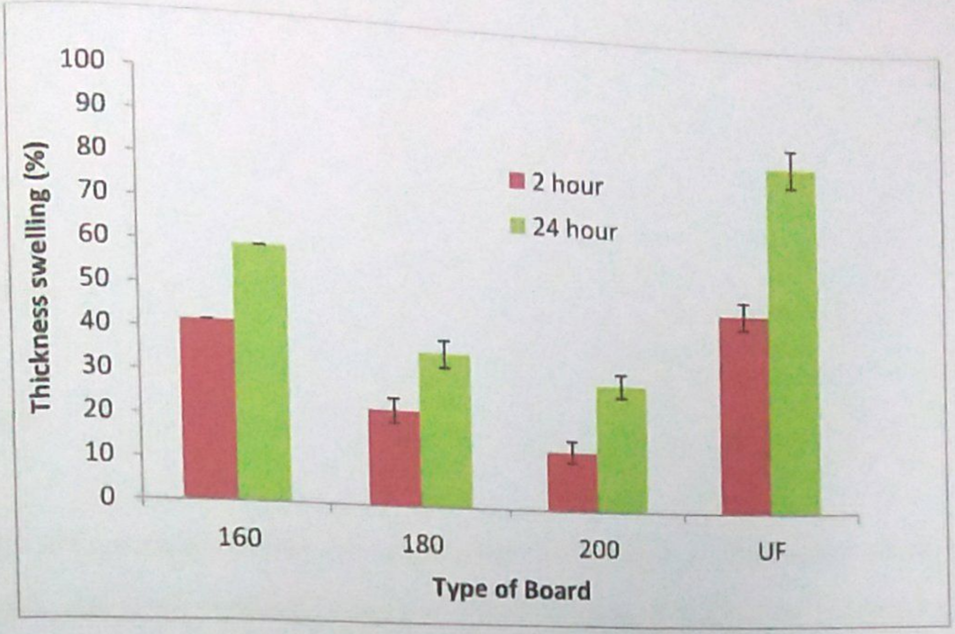


Fig: 4.7 Effects of pressing temperatures on Thickness Swelling

At higher temperature dimentional stability will increase due to decomposition of hemicelluloses into different types of sugars that further react between themselves, forming a water-insoluble polymer that reduce water absorption as well as thickness swelling.(Navi and Heger 2005). Structural modification and chemical changes of lignin also play a vital role to reduce thickness swelling (Carmen, 2015). Boards made with UF resin showed highest thickness swelling and the reason behind this is the same as water absorption.

Chapter Five

Conclusion:

- From the above result it can be concluded that a high performance cross banded can be made from jute stick without using any binding agent, which is environmental friendly.
- There is a significant effect of temperature on cross-banded board. Board made at 200^0C temperature showed higher mechanical and physical properties than other boards.
- Further study is needed to improve dimensional stability of cross banded jute stick board.

Chapter six

References

1. Adgre W.N., and Brown K., 1994. Landuse and causes of global warming. John Wiley and sons, Chichester, UK, pp: 271-273

2. Angles MN, Reguant J, Montane D, Ferrando F, Farriol X, Salvado J. 1999Binderless composites from pretreated residual softwood. J ApplPolymSci 73 pp:2485–2491

3. Angles MN, Ferrando F, Farriol X, Salvado J 2001. Suitability of steam exploded residual softwood for the production of binderless panels. Effect of the pre-treatment severity and lignin addition. Biomass Bioenerg 21 pp:211–224.

4. Alvarez, C. Rojano, B. Almaza, O. Rojas, O.J. and Ganan, P. (2011) Self-bonding boards from plantain fiber bundles after enzymatic treatment: adhesion improvement of lignocellulosic products by enzymatic pre-treatment. J Polym Environ 19(1) pp:182–188.

5. Anon, 2015. Indian Jute : Medicinal use/Herbal Use of Jute (Jute Leaves, etc.).

6. Anon. 2017. Food and Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division.

7. Anon, 2011. International Jute Study Group (IJSG). Report of the Twelfth Session of Council of IJSG.

8. Anon, 2013. Office of the Jute Commissioner - Ministry of Textiles".www.jutecomm.gov.in.

9. Anon, 2013 Statistics — World production of Jute Fibres from 2004/2005 to 2010/2011". International Jute Study Group (IJSG).

10. Anon, 2014. Workshop on Technology Transfer: Binderless particleboard and compressed panels.

11. Carmen C. 2015 Influence of pressing parameters on mechanical and physical properties of self- bonded laminated beech boards. Lula University of Technology, Department of wood science and engineering.pp: 1-10

12. Crawshaw J, Cameron RE. 2000 A small angle X-ray scattering study of pore structure in Tencel cellulose fibres and the effects of physical treatments. Polymer 41(12). pp:4691–4698

13. Ellis S, Paszner L 1994 Activated self-bonding of wood and agricultural residues. Holzforschung 48. pp: 82–90

14. Fahmy, T.Y.A. and Mobarak, F. (2013). Advanced self-bonded board-like green nanocomposites from undebarked cotton stalks and mechanism of self-bonding, Cellulose, 20(3).pp: 1453–1457.

15. FAOSTAT – Crops" (Query page requires interactive entry in four sections: "Countries"–Select All; "Elements"–Production Quantity; "Items"–Jute; "Years"–2014). Food and Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division. 2017-02-13. Retrieved 2017-02-17

16. Handbook of Pulp and Paper Processing. (By NPCS Board of Consultants & Engineers).

17. Halvarsson, S. Edlund H. and Norgren, M. 2009. Manufacture of non-resin wheat straw fibreboards. Ind Crops Prod. 29. pp:437–445.

18.Hidayat, H. Keijsers, E.R.P. Prijanto, U. van Dam, J.E.G. and Heeres, H.J. 2014. Preparation and properties of self-bonded boards from Jatrophacurcas L. seed cake, Industrial Crops and Products, 52, pp. 245–254.

19. Hill, C. A. S. 2006. Wood modification: chemical, thermal and other processes. (Chichester: John Wiley and Sons). Pp: 1-5

20. Inari, G. N., Petrissans, M., and Gerardin, P. 2007. Chemical reactivity of heattreated wood.Wood Science and Technology, 41(2), pp: 157-168.

21. Inoue M., Norimoto M., Tanahashi M., Rowell R.M., 1993. Steam or heat fixation of compressed wood.Wood Fiber Sci. volume 25(4).Pp: 224-235.

22. Jute Technology Mission: Design & Develpoment of JDPS (Final Report). Develpoment of Jute- Bamboo Composites for Applications in Rural Areas.

23.. Laemsak N, Okuma M, 2000. Development of boards made from oil palm frond II: properties of binderless boards from steamexploded fibers of oil palm frond. J Wood Sci 46. pp:322–326.

24. Lee, C.M. and Hunt, J.F. 2013. Self-bonded panel made from wood particles and cellulosic fibers,United States patent 8936699.

25. Luo, P. and Yang, C.M. 2012. Production of Self-bonded Particleboard Using Rice Straw Pretreated with Liquid Hot Water, in Applied Mechanics and Materials, Vol. 200. Pp: 159-169.

26. Moreau JP, BelBerger P, Tao WY. 1995 Mechanical processing of kenaf for nonwovens.TAPPI J 78(2).Pp: 96–105.

27. Mobarak, F. Fahmy, Y. and Augustin, H. 1982. Self-bonded lignocellulose composite from bagasse and mechanism of self-bonding, Holzforschung-International Journal of the Biology, Chemistry, Physics and Technology of Wood, 36(3), pp. 131–136.

28. Mancera, C. Ferrando, F. and Salvado, J. 2008. *Cynara cardunculus* as raw material for the production of binderless fiberboards: Optimization of pretreatment and pressing conditions, Journal of Wood Chemistry and Technology 28. Pp: 207-226.

29. Mancera C, Mansouri NEE, Ferrando F, Salvado J. 2011. The suitability of steam exploded Vitisvinifera and alkaline lignin for the manufacture of fiberboard. BioResources 6(4).pp:4439–4453

30. Mobarak, F. Fahmy, Y. and Augustin, H. 1982. Self-bonded lignocellulose composite from bagasse and mechanism of self-bonding, Holzforschung-International Journal of the Biology, Chemistry, Physics and Technology of Wood, 36(3), pp: 131–136.

31. Nemli G, O ¨ ztu¨rk I˙ 2006. Influences of some factors on the formaldehyde content of particleboard. Build Environment 4. pp:770–774.

32. Navi, P. and Heger, F. 2005. Comportement Thermo-Hydromécanique du Bois: Applications TechnologiquesetDans les Structures (Thermohydro-Mechanical Behaviour of Wood: Technological and Structural Applications), (Lausanne: PPUR Presses Polytechniques) 2. Pp: 28-31.

33. Okuda, N. Hori, K. and Sato, M. 2006. Chemical changes of kenaf core self-bonded boards during hot pressing (I): influence of the pressing temperature condition. Journal of Wood Science, 52(3), pp. 244-246

34. Park S, Venditti RA, Jameel H, Pawlak JJ. 2006 Changes in pore size distribution during the drying of cellulose fibers as measured by differential scanning calorimetry. CarbohydrPolym 66. pp:97–103

35. Parikh DV, Calamari TA, Sawhney APS, Blanchard EJ, Screen FJ. 2002.Thermoformable automotive composites containing kenaf and other cellulosic fibers. Text Res J 72. pp:668–672.

36.Parikh DV, Calamari TA, Sawhney APS, Blanchard EJ, Screen FJ (2002) Improved chemical retting of kenaf fibers. Text Res J 72. pp:618–624

37. Pijus K*, Sibaprasad M, Gora D, Sadhu C, Subhash B. 2011. Modified flush door shutter using jute composite - A natural substitute of wood.International Journal of Soft Computing and Engineering (IJSCE)1.pp: 9-11

38. Quintana, G. Velasquez, j. Betancourt, S. and Ganan, P. 2009. Binderless fiberboard from stem exploded banana bunch. Industrial Crops and Products.29(1). pp:60-66.

39. Rowell R., Lange S., Mc Sweeny J., Davis M., 2002. Modification of fiber using steam. In: Proceedings of the 6th pacific rim bio-based composites symposium, Oregon 2.Pp 606-615.

40. Suzuki S, Shintani H, Park SY, Saito K, Laemsak N, Okuma M, Iiyama K. 1998. Preparation of binderless boards from steam exploded pulps of oil palm (ElaeisguneensisJaxq.) fronds and structural characteristics of lignin and wall polysaccharides in steam exploded pulps to be discussed for self-bonding. Holzforschung 52. pp:417–426.

41. Shen K.C., 1991. Method of making composite products from lignocellulosic materials.United States Patent 5017319.

42. Suzuki S., Shintani H., Park SY., Saito K., Laemsak N., Okuma M., Iiyama K., 1998. Preparation of binderless boards from steam exploded pulps of oil palm fronds and

structural characteistics of lignin and wall polysaccharides in steam exploded pulps to be discussed for self- bonding. Volume: 52. Pp: 417-426.

43. Sur and Amin., 2010. Physics and Chemistry of Jute. In Jute Basics (ed) International Jute Study Group. Pp 35-55.

44. Sarkar S., and Adhikari B., 2001. "Jute felt composite from lignin modified phenolic resin". Polymer Composite. Volume: 22 (1) pp: 518-527.

45. Shen, K.C. 1986. Process for manufacturing composite products from lignocellulosic materials, Patent CA1211913A.

46. Shao, S. Jin, Z. Wen, G. and Iiyama, K. 2009. Thermo characteristics of steam-exploded bamboo (Phyllostachyspubescens) lignin. Wood Sci. Technol. 43(7–8). pp:643–652.

47. Salvado, J., Velasquez, J.A. and Ferrando F. 2003. Binderless fiberboard from steam exploded MiscanthusSinensis : optimization of pressing and pretreatment conditions, 37, pp. 279–286

48. Suzuki, S. Shintani, H. Park, S.-Y. Saito, K. Laemsak, N. Okuma, M. and Iiyama, K. 1998. Preparation of self-bonded boards from steam exploded pulps of oil palm (ElaeisguneensisJaxq.) fronds and structural characteristics of lignin and wall polysaccharides in steam exploded pulps to be discussed for self-bindings, Holzforschung-International Journal of the Biology, Chemistry, Physics and Technology of Wood, 52(4), pp. 417–426.

49. Stamm, B. 2006. Development of friction welding of wood – physical, mechanical and chemical studies, Doctoral dissertation no. 3396, Lausanne: Ecole Polytechnique Fédérale de Lausanne.

50. Tanahashi M., Goto T, Horii F., Hirai A, Higuchi T., 1989. Characterization of steam exploded wood III transformation of cellulose crystals and changes of crystallinity. MokuzaiGakkaishi 35. Pp: 654-662.

51. Van Dam JEG, Van Den Oever MJA, Keijsers ERP 2004. Production process for high density high performance binderless boards from whole coconut husk. Ind Crop Prod 20. pp:97–101

52. Widyorini, R. Xu, J. Watanabe, T. and Kawai, S. 2005. Chemical changes in steam-pressed kenaf core self-bonded particleboard, Journal of Wood Science, 51(1), pp. 26–32.

53. Xu, J. Widyorini, R. and Kawai, S. 2005. Properties of kenaf core self-bonded particleboard reinforced with kenafbast fiber-woven sheets, Journal of Wood Science, 51(4), pp. 415–420

54. Xu,J.R. Widyorini;Y. Hidefumi; S.Kawai.2006. Development of Binderless Fiberboard from Kenaf Core. J Wood Sci 52. pp: 236-243.

55. Youngquist, J.A., English, B. E., Spelter, H. and Chow, P. 1993. Agricultural fibers in composition panels. In: Proceeding, 27th International Particleboard/ Composite materials symposium, Washington State University, Washington, USA. pp.133- 152.

56. Zhang, D. Zhang, A. and Xue, L. 2015. A review of preparation of binderless fiberboards and its self-bonding mechanism, Wood Science and Technology 53. Pp: 369- 375.