Khulna University
Life Science School
Forestry and Wood Technology Discipline

Author(s): Shahelia Kabir

Title: Effects of chemical additives on the physical and mechanical properties of cement bonded bagasse fiber board

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

Programme: Masters of Science in Forestry

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Shahelia Kabir
STUDENT ID : MS-150509

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COURSE TITLE: THESIS WORK

COURSE # FWT-MS 5112

[This thesis has been prepared and submitted in partial fulfillment of the requirement for the degree of Masters in Forestry from Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh]

Supervisor

31/12/17

Dr. Md. Iftekhar Shams

Professor

Forestry and Wood Technology Discipline

Khulna University

Khulna- 9208

Bangladesh

Submitted By

Shahelia Kabir
31.12.17

Shahelia Kabir

Student ID: MS-150509

Forestry and Wood Technology Discipline

Khulna University

Khulna- 9208

Bangladesh

DECLARATION

I, Shahelia Kabir, Student ID-MS-150509 declare that this thesis is the result of my own works and it has not been submitted or accepted for a degree in any university. I, hereby, give consent for my thesis, if accepted, to be available for photocopying and for inter-library loans, and the title and summary to be made available to outside organizations.

Candidate. Shahelia Kabir ....

Date. 31.12.2017 ....

DEDICATED TO

MY BELOVED PARENTS

ACKNOWLEDGEMENT

All praises to Allah, whose mercy keeps us alive and enables to pursue my education in Forestry and Wood Technology Discipline, Khulna University, Khulna and to complete my project thesis for the degree of Masters of Science (MS) in Forestry.

I would like to express my gratitude to all of my family members specially my mother. Without their continuous inspiration, the present achievement would not be possible.I gratefully acknowledge my deepest sense of gratitude and sincere appreciation to my respectable supervisor and honorable teacher, Dr. Md.Iftekhar Shams, Professor, Forestry and Wood Technology Discipline, Khulna University, Khulna for his constructive suggestion and continuous guidance at different stages of this thesis.

Finally, I wish to offer special compliments to all my friends specially Trisha and who gave memental and materialistic support during completing this project thesis.

ABSTRACT

The study was conducted to manufacture the cement- bonded fiber board from Bagasse (*Saccharum officinarum*) fiber and to evaluate the properties of cement- bonded board from Bagasse (*Saccharum officinarum*) fiber using different chemical additives, ($MgCl_2$ 7.5%, $CaCl_2$ 7.5%,$NaHCO_3$ 7.5%) and also ($MgCl_2$ 2%,5%,10%). The fibers used to make the board were isolated byhot water treatment. In this work the ratio of mixing was fiber: cement: water = 1: 2.2: 1.1. The laboratory tests for characterization of physical and mechanical properties were carried out for each type of board. In case of physical and mechanical properties the board treated with $MgCl_2$ 7.5% give better result than other chemical additives.When board treated with $MgCl_2$ in different concentration 2%,5%,10%,$MgCl_2$ 10% treated board shows greater mechanical and physical property than 2% and 5%.The addition of chemical additives in the production of cement bonded board increase the both physical and mechanical properties of cement bonded bagasse fiber board.BesidesIncreased concentration of $MgCl_2$ had higher physical and mechanical properties.

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CHAPTER ONE

INTRODUCTION

1.1General Introduction

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and numbers of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years.

A composite material is made by combining two or more materials to give a unique combination of properties, one of which is made up of stiff, long fibers and the other, a binder or 'matrix' which holds the fibers in place.Wood or non wood fiber bonded together with an inorganic material (cement) is called cement bonded fiber board. Its production and continuous research are becoming more prevalent in the number of countries around the world.Because there is an ever-increasing demand for construction materials having some or all of the following characteristics: relatively light weight, waterproof, nailable, odorless, insulative and relatively inexpensive.

Present world is very concerned about environmental pollution. All formaldehyde based resin binders are more or less toxic and injurious to health and both environment. Considering these aspects manufacture of cement bonded composites from saw dust and agricultural wastes are attempted. (Stillinger and Wentworth, 1977).Increased agricultural production and the development of agro-based industries have brought about the production of large quantities of agricultural wastes, most of which are not adequately man-aged and utilized. Agricultural wastes were generally used for fertilizer and fuel for energy production, but little work has beencarried out to develop utilization of these wastes in the production of building materials.

However, the use of cement composites based on agricultural residues opens up a vast field of study, production and application in civil engineering. The application of these elements is interesting as regards the recycling of the residues, since these are easily available and renewable low-cost raw materials.A large amount of agriculture wastes are generated every year in Bangladesh.

In recent years, several research groups have been evaluating the suitability of different lignocellulosic materials for the manufacture of WCB including cypress (Okino*et al.*2005), rubber wood (Okino *et al.*2004), eucalyptus (Okino *et al.*2004; Evans *et a*l. 2000; Del Menezzi *et al*, 2001), pines (Cabagon *et al.* 2002), acacia (Eusebio *et a*l.2002), agricultural residues (Almeida *et al.*2002) and fiber (Del Menezzi *et al.*2001).There are obstacles to the utilization of these materials for WCB. The main problems are the inhibitory effect caused by wood on the cure of cement and the high density of the final product. Wood component,mainly extractives and polysaccharides, affects reactions between wood and cement resulting in boardsof low quality. Jorge *et al.*(2004) argued that the nature of the extractives also has influence on this inhibitory effect.To solve inhibition problems, it is common to add inorganic chemicals, known as accelerators, to accelerate the cure of cement or use pretreatments such as aqueous extraction to remove inhibitory substances from wood. Cement chemicals accelerators usually improve the properties of WCB (Jorge *et al.*2004).

Fiber reinforcement of concrete remains an exciting and innovative technology because of its unique engineering properties. Presently, the major raw materials for cement bonded particle boards consist mainly of wood, cement and water with or without a catalyst.The scarcity of the economically preferred wood species and overexploitation of hardwood species inboth natural forests and plantations coupled with lack of effective utilization of wood resources.Finding alternative sources of raw materials for wood industries to manufacture panel products would meet the ever increasing demand of wood products for construction works in the world in general.Sugarcane is one of the main agricultural crops in Bangladesh. After crushing these are used only as fuel.In manufacture of cement bonded composites agricultural residues such as bagasse can be attempted.

1.2 Objectives of the Study

- To develop cement bonded board from bagasse fiber.
- To enhance properties of the board by addition of different chemical additives.
- Effect of different concentration of additives ($MgCl_2$) on board properties.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 General Information about Cement bonded Fiber Board

2.1.1 Definition of Cement bonded Board

Particles or fibers of lignocellulosic material bonded together with Portland cement matrix are produced in panel form is called Cement bonded particle board or Fiber board. Its production and continuous research are becoming more prevalent in the number of countries around the world. Discovering new methods of manufacturing technologies to replace the traditional ones, expanding base, and modifying the inorganic binders are some of the aspects that are increasing in momentum (Aoki, 1991).

Fiber cement board also called cement bonded fiber board has been used since the 1900s when first combined 90% cement and 10% asbestos fibers with water.The mixture was run through a cardboard machine to produce asbestos cement board.This board was used widely for residential constructional purposes until the 1970s discovery that asbestos cement board causes mesothelima (a rare form of lung cancer),at which time many countries strictly prohibited its uses. Cement bonded fiber board not only the oldest type of cement board but also the most widely used and produced.(Tachi *et al.*,1889;Moslemi et al.,1989;Van Elten,2013;Saunders and Davidson,2014).

Fiber cement boards consist of fiber,cement water. Wood fiber agricultural residue fiber reinforced cement bonded boards are manufactured from fiber (7- 8.5%), sand (60%), cement (30%), and Aluminum 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 proportions outlined above are combining the cement, sand, fibers and additives and diluted to form slurry with a solids content of 10% (Shakri, 2008).

2.1.2 Brief History about Cement bonded Board

Particle boards are not more than a few decades old production. Before particle board, modern plywood, as an alternative to natural wood, was invented in the 19thcentury, 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. 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. The new technologies 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. The first commercial piece was produced during World War II at a factory in Bremen, Germany. It was used waste material such as planer shavings, off cuts or sawdust, hammer-milled into chips, and bound together with a phenolic resin. In the early 1960s, a high density cement- bonded structural flake board was developed leading to expand applications (Deppe, 1974). Today, wood- cement panels have found acceptance in a number of countries as a result of certain desirable characteristics. The majority of research in this field has been carried out on particleboards and flake boards. An excellent review can be found elsewhere (Jorge *et al.* 2004).

Men developed composite wood products such as particle board, plywood, fiber board but they use mainly chemical resin as a binder. This chemical causes hazardous to human health. Even its load bearing capacity is not so good to use for building construction through it can be used for different types of furniture or decorative purposes. Considering that man is trying to find out the alternative which should not be harmful and bonding quality should be such that man can use it as building materials. All natural material is considered as environment friendly and cement is one of them. Environmental concern about the disposal of waste materials has focused renewed attention on low density cement bonded wood composites (CBWCs).In Indonesia the first mineral- bonded board made of saw dust was established in Palembang. This board used saw dust and shavings as raw materials. In 1970s there were six mineral bonded board mills in Indonesia and four of them used excelsior or wood- wool and rest used wood flakes in the mix. CBP established itself in Switzerland and central Europe in the mid 1970s and has been imported in UK since the late 1970s. The number of plants worldwide is over 40, with one in the UK (Desch, 1996). Currently, there are over 38 plants in operation throughout the world (Moslemi, 1989). An extensive development of CBP industry has taken place throughout the world during 1980- 90.

The industrial application of pressure to manufacture wood- cement panels did not occur until the about mid-1930s. With the gradual evaluation of resin- bonded particle board technology, much was leant that is also applicable to cement- bonded wood particle panels. Early industrial production of wood cement panels were produced in Japan in 1965(Moslemi, 1989).Interest in wood fiber-reinforced cement was sparked by the post-World War II shortage of asbestos fibers, which caused some private companies to consider cellulose fiber as a substitute for asbestos in fiber-reinforced cement. This interest faded as asbestos supplies recovered in the 1950s, but it regained strength by the mid- 1970s with growing concern over the health risks linked to asbestos. The controversy over asbestos led a number of companies in Australia,Europe, and Scandinavia to develop processes for fabricating fiber-reinforced cement boards using cellulose and other mineral fillers. Over the past 25 years, the American Concrete Institute has also sponsored research to develop high-performance fiber-reinforced cement composites that use discrete fibers, including steel, glass, synthetic polymers, and cellulose.

Today, cellulose fiber is used in a wide variety of fiber-reinforced cement products, many of which were originally developed using asbestos fiber. These materials use only 5 to 15 percent cellulose fiber by weight, have densities ranging from 1,100 to 1,800 kg/m^3, and have bending strengths ranging up to 30MPa. The primary function of fibers in these cement composites is to increase the energy of fracture. By bridging gaps, the fibers prevent stress concentrations at crack tips, thus retarding brittle fracture mechanisms and dissipating energy in the form of fiber pullout or rupture.

2.1.3. Present Status of cement bonded board

A description of status of cement bonded boards is found in Van Elten (2013).Europe has 38 producers,six of which are located in Germany,and three are in Denmark.Significantly a remarkable high number (15) are UK based.The America also has a large number (20) of cement board producers,most of which are located in North America,although Brazil and chili do both have one producer each. In contrast,Asia,the Middle East and Africa have 22 producers.The china has only five cement board companies which are very surprising because of its dominance in the cement industry.Though cement bonded board has been used since 1900s and more than 90 cement bonded boardproducer companies all over the world, there is no commercial production of cement bonded board in Bangladesh.The first particle board industry established in 1962 in our country named star particle board industry.It was also first particle board industry in Asia.It was jute based particle board industry.In Bangladesh wood based particle board industry started in 2006.After 2006 the demand of particle board increased day by day.Though particle board has many indoor uses it is not suitable for outdoor use.Cement bonded boards can overcome this problem Cement bonded board made from agricultural wastage can be good alternative of other boards which cause environmental hazards,because this cement board is environmentally friendly.

2.1.4. Inorganic Bonded Board

Inorganic binders fall into three main categories: gypsum, magnesia cement and Portland cement. Gypsum and magnesia cement are sensitive to moisture, and their use is generally restricted to interior applications. Composites bonded with Portland cement are more durable than those bonded with gypsum or magnesia cement and are used in both interior and exterior applications. Inorganic bonded composites are made by blending proportionate amounts of lignocellulosic fiber with inorganic materials in the presence of water and allowing the inorganic material to cure or "set up" to make a rigid composite. All inorganic bonded composites are very resistant to deterioration, particularly by insects, vermin and fiber.

2.1.5. Natural Pazzolans

Pazzolans are defined as silicious siliceous and aluminous materials that can react chemically with calcium hydroxide (lime) at normal temperatures in the presence of water to form cement compounds. Some common Pozzolonic materials include vocalic ash, fly ash, rice husk ash, and condensed silica fume. All these materials can react with lime at normal temperatures to make natural water resistant cement.Pozzolans increase the strength of the cement but slow the cure time and decrease the alkalinity of Portland cement.

2.1.6. Carbon dioxide treatment

In the manufacture of cement bonded lignocellulosic composites the cement hydration process normally requires from 8 to 24 hours to develop sufficient board strength and cohesiveness to permit the release of consolidation pressure. By exposing the cement to carbon dioxide the initial hardening stage can be reduced to less than 5 minutes. This phenomenon results from the chemical reaction of carbon dioxide with calcium hydroxide to form calcium carbonate and water. Research has demonstrated that composites treated with carbon dioxide can be twice as stiff and strong as untreated composites. Carbon dioxide treated composites do not experience efflorance (migration of calcium hydroxide to surface material), so the appearance of the surface of the final product is not change over time (Anon,1987).

Hot pressing method was not welcome move to manufactures, as it will entail additional investment for the equipment. One of the recent developments that would improve the manufacturing method is by storing the logs or billets prior to processing. It revealed that cold water extraction to remove the inhibitory effect on cement is not necessary. This would eliminate the use of too much water for soaking and saves on drying of the excelsior (Cabangon *et al.*,2000).

2.1.7Use of chemical additives

Recently additive treatment has done in many countries to improve the mechanical properties of cement bonded particle boards by reducing the inhibitory index and increase the compatibility. The cement bonded particleboard from bamboo and cement bonded fiberboards from oil palm frond were successfully manufactured by using the conventional cold pressing method with the different additives. The mechanical and the dimensional properties of the boards were tested in accordance with the Japan Industrial Standard, IS A 5908.In order to obtain adequate mechanical strength 10-15% Mgcl2 or Cacl2 and 7.55-10% of Mgcl2 were needed for bamboo cement particle board and oil palm cement fiberboard respectively (Ma et al.2000).

In recent years few methods of rapid curing systems for cement bonded particleboards by using together with stream injection pressing or hot platen pressing for the initial setting of cement ,followed by autoclaving or heating treatment for the subsequent curing ,were also developed (Yasuda *et al.*,1986;Nagadomi *et al.*,1996;Ma *et al.*,2000).

2.1.8. Application of Cement bonded Board

Successful new applications in Western Europe, different from that of 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. 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 A2boards.

2.1.9. Advantages of Cement bonded boards

There are different types of cement bonded board and have several advantages over using other boards. Cement bonded boards are strong, stiff and resistance to moisture, fungi and insect. Fire resistance is being higher than any other boards. In panel form, they are being utilized for structural and nonstructural application in both exterior and interior purpose. It reduces thermal conductivity and increase sound insulation. An added advantage over massive concrete panels is their ability to withstand larger deformation before failure. Present world is very much concern about environmental pollution. All formaldehyde based resin binders are more or less toxic to the environment; it is free from formaldehyde, isocyanides, wood preservatives, fungicides. It can be produced by either labor- incentive or machine incentive operations, which is most economically feasible. It can be used as erection of free standing solid partition, various sound damming partition construction. It is easy to cut to size service fabrication prior to site. It is easy to fix. It is frost resistance. It can be paned, sanded, drilled, routed screwed and primed. It is biologically safe. It can be disposed of on a landfill site.It can be decorated with different finishes which is helpful to diversify its uses. It is moisture proof and for this it can be used in damp condition.(Atchison *et al*, 1985; Hofstrand *et al,* 1984; Kimura *et al*, 1996; Eusebio and Kawai, 1999; Rowell, 1997; Rowell, 1998; Topf, 1989;Youngquist *et al*, 1996; Zhang *et al,* 1997).

2.2 General Information about Bagasse *(Saccharum officinarum)*:

2.2.1 General description of Sugarcane:

Sugarcane, or sugar cane, is one of the several species of tall perennial true grasses of the genus *Saccharum*, tribe Andropogoneae, native to the warm temperate to tropical regions of South Asia and Melanesia, and used for sugar production. It has stout jointed fibrous stalks that are rich in the sugar sucrose, which accumulates in the stalk internodes. The plant is two to six meters (6 to 19 feet) tall. All sugar cane species interbreed and the major commercial cultivars are complex hybrids. Sugarcane belongs to the grass family Poaceae, an economically important seed plant family that includes maize, wheat, rice, and sorghum and many forage crops. (https://en.Wikipedia.org/wiki/sugarcane).Sugarcane is a tropical, perennial grass that forms lateral shoots at the base to produce multiple stems, typically three to four meters high and about five cm in diameter. The stems grow into cane stalk, which when mature constitutes approximately 75% of the entire plant. A mature stalk is typically composed of 11–16% fiber, 12–16% soluble sugars, 2–3% non-sugars, and 63–73% water. A sugarcane crop is sensitive to the climate, soil type, irrigation, fertilizers, insects, disease control, varieties, and the harvest period. The average yield of cane stalk is 60–70 tonsper hectare per year. However, this figure can vary between 30 and 180 tons per hectare depending on knowledge and crop management approach used in sugarcane cultivation. Sugarcane is a cash crop, but it is also used as livestock fodder.

2.2.2 Sugarcane Production in the World

Sugarcanes grow to the best advantage on a rich, moist soil under sunny skies in a tropical climate. Clay-loam soil with some proportion of sand and silt, mixed with humus is among the best soils for sugarcane cultivation. Uniform high temperatures, strong sunlight, and frequent showers during the growing season are desirable. Irrigation is not necessary if the annual rainfall is 1250-1500 mm. A soil pH between 6 and 7.5 has been found suitable for plant growth. High humidity during the growing period and dry weather at maturation lead to satisfactory production. Sugarcane is a tropical crop grows best in hot and sunny areas. It grows both in tropical and sub tropical region. Optimum temperature for sprouting is 28 – 30^0C and absolute lowest temperature is around 12^0C. Optimum rainfall for obtaining high yield is 2000 – 2500 mm is ideal. During growth phage rainfall encourages rapid cane formation. But during ripening stage rainfall is undesirable because it leads to poor juice quality.At present, sugarcane is cultivated in about 100 countries. Sugarcane is considered to have originated in INDIA.Nowthe principal sugarcane growing countries are India, Argentina, Australia, Brazil, Barbados, China, Cuba, Mexico, Egypt, Jamaica, Peru, South Africa, and Hawaii, Florida, and Louisiana of the United States of America. In Bangladesh sugarcane is grown in about 0.38 million acres of land. The annual production of cane is about 5.5 million m tons. In BANGLADESH it is grown all over the country; however, the major sugarcane growing district are Rajshahi, Kustia, Jessore, Dinajpur, Rangpur, Faridpur, Mymensingh, Tangail, Jamalpur, and Dhaka.

2.2.3 General Description of Bagasse

Bagasse is a byproduct of making sugar. When sugarcane stalks are harvested, they're pressed to release their juices that get processed into sugar. Then, rather than burning or throwing the used sugarcane stalks away, the fibrous pulp is made into a paper-like substance called bagasse which is then formed into a wide.The composition of Bagasse depends on the variety and maturity of Sugarcane as well as harvesting methods applied and efficiency of the Sugar processing. Bagasse is usually combusted in furnaces to produce steam for power generation. Bagasse is also emerging as an attractive feedstock for bio ethanol production. It is also utilized as the raw material for production of paper and as feedstock for cattle. The value of Bagasse as a fuel depends largely on its calorific value, which in turn is affected by its composition, especially with respect to its water content and to the calorific value of the Sugarcane crop, which depends mainly on its sucrose content.

Moisture contents is the main determinant of calorific value i.e. the lower the moisture content, the higher the calorific value. A good milling process will result in low moisture of 45% whereas 52% moisture would indicate poor milling efficiency. Most mills produce Bagasse of 48% moisture content, and most boilers are designed to burn Bagasse at around 50% moisture. Bagasse also contains approximately equal proportion of fiber (cellulose), the components of which are carbon, hydrogen and oxygen, some sucrose (1-2 %), and ash originating from extraneous matter. Extraneous matter content is higher with mechanical harvesting and subsequently results in lower calorific value. Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a bio fuel and in the manufacture of pulp and building materials. The constituents of bagasse are moisture is 49%, fiber is 48.7% and soluble solid is 2.3%.

For each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse. Since bagasse is a by-product of the cane sugar industry, the quantity of production in each country is in line with the quantity of sugarcane produced. Bagasse contains bundles of fibers and the fibers are randomly dispersed. Bagasse fibers are consisting with pith fibers, rind fibers and dermax. Juices containing internal fibers are the pith fibers. Pith fibers are mainly parenchyma material. Outer tough fibrous materials are rind fibers. Higher hemicelluloses content and lower lignin content present in rind fibers. Fiber contains parenchyma cells and vascular bundles. Thin wax laden skin is called dermax. That is composed of epithelial cell. Waxy layer is hydrophobic and indirectly helps for bonding.

2.2.4 Chemical Composition Bagasse Fiber

Fibers in bagasse consist mainly of cellulose, hemicelluloses, and lignin. The cellulose is present in three types: α, β and γ. The cellulose is known as pure cellulose, whereas β and γ cellulose combined are called hemicelluloses. The hemicelluloses are chemically linked with cellulose molecules. The other main compound in sugar cane fiber bundles is lignin which is a high molecular weight substance. Because it is not possible to isolate lignin quantitatively from plant materials without chemical or mechanical degradation, its true molecular weight is not known. The amount of lignin that naturally occurs in sugar cane depends to a great extent on the variety and age of the cane. The amounts of sugar, lignin, and lignin-like compounds increase as the plant advances in age until the flowering time, when the plant is considered to be fully mature. Beyond the flowering time, the sugar cane plant tends to consume its stock of sucrose and lignin as a result of physiological changes due to flowering. The depletion of the organic compounds makes the rind and the fiber bundles softer and spongy.

Table 1: Percentage of chemical constituent of Bagasse

Chemical Constituents	Percentage (%)
Cellulose	45–55%
Hemicellulose	20–25%
Lignin	18–24%
Ash	1–4%
Waxes	<1%

(https://en. Wikipedia.org/wiki/Bagasse)

Table 2: Comparison of bagasse fiber with other vegetable fibers (G. Duraisamy&Karthic.T;)

Fiber	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Sugar cane	50	30	18
Kenaf	65.7	13.2	21.6
Ramie	68.6	13.1	0.6
Jute	64.4	12.1	18.8
Flax (un retted)	56.5	15.4	2.5
Flax (retted)	64.1	16.7	2.0

CHAPTER THREE

MATERIALS AND METHODS

3.1 Methods and Procedures

Collection of Raw Material

Bagasse pith was collected from Gollamari Bazar just beside Khulna University Campus. Ordinary Portland cement, Holcim was used as a binder, purchased from the local market.

Figure 1: Collection of raw material.

Preparation of Raw Material

After collection of raw material it was air dried for seven days. Then the pith part of bagasse was cut into 1-3 cm size by using conventional hand tool.

Figure 2: Bagasse fiber (pith)

Grinding

1-3 cm sized pith part was inserted into the laboratory grinding machine manually. After grinding pith fibers were separated. Then the grinded fibers were collected from the grinding machine manually.

Figure 3: Grinding process for making bagasse fiber.

Hot Water Treatment

After grinding the grinded fiber was boiled with water in a water bath of laboratory at 100^0C temperature for 2 hours. Then it was kept for cooling. After cooling the boiled fiber was washed for 20 minutes to remove remaining sugar from the fiber. Then it was air dried for 2 days. Then it was oven dried at 104^0C to 12-14% moisture content.

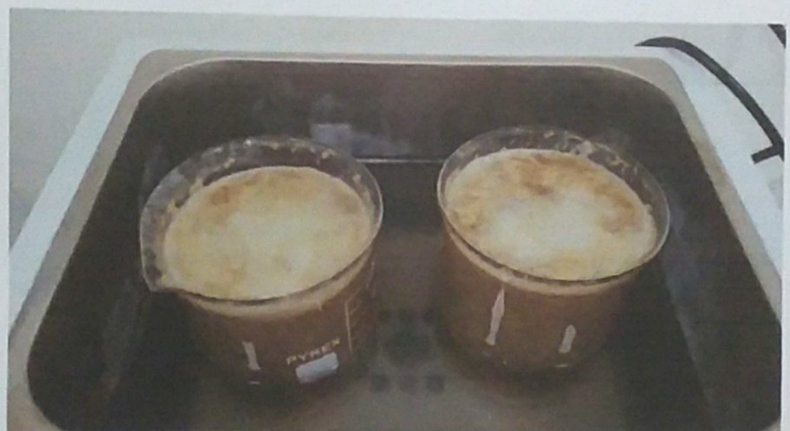

Figure 4: Hot Water Treatment

Mixing

Boiled fiber was used to manufacture cement bonded fiber boards. The weight ratio of fiber:cement:water was 1:2.2:1.1.This mixture condition was employed constantly through all of the following series of experiment. The additives ($CaCl_2$, $MgCl_2$,$NaHCO_3$) as a required percentage of the cement weight. Mixing was done in a pan. At first oven dried fiber was mixed with cement and then required amount of water was added into it. Mixing continued until the fiber was covered completely with cement. It was done to obtain uniform distribution of cement, fiber and water.

Mat Forming

Each mixture was hand formed 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.

Figure 5: Mat forming

Cold Pressing

Hand formed mats measuring $170\times130\times32$ mm was cold pressed at 5 Mpa pressure. It was kept in pressing condition for 24 hrs.

Figure 6: Cold pressing.

Curing

The cement bonded fiber boards were cured in the conventional process. After pressing the boards were kept at room temperature for 14 to 30 days. Water was sprayed frequently for proper curing of the CBF.

Trimming

After the boards of each type were produced separately, these were trimmed at edges with the fixed type circular saw.

3.1.2. Flow diagrams of Cement bonded Fiberboard Production

Raw material collection

Air Drying (7days)

Chipping (1-3 cm)

Grinding

Hot water treatment (2 hrs / 100 degree)

Mixing (cement: fiber: water= 2.2: 1.0: 1.1)

Mat forming (170×130×32)mm

Cold Pressing (24hrs)

Curing (14-30 days)

Conditioning

Trimming

Figure 7: Flow Diagrams of Cement bonded Fiber Board

3.1.3. Specifications of manufactured Cement bonded Fiber Boards

Target Dimensions (mm)	300 ×200
Target Density (g/cm^3)	1000-1200
Fiber Isolation Process	Hot water treatment
Ratios (Fiber: Cement: Water)	1:2.2:1.1
Pressing	Cold
Pressure	5 MPa
Total number of Board manufactured	10
Used of Chemical Additives	$MgCl_2$,$CaCl_2$,$NaHCO_3$

3.2 Preparation of samples for testing

Two replications of each type of boards were collected for testing physical and mechanical properties; three samples were collected from each board of each type. The dimension of samples for testing the physical properties was approximately (5 cm × 4 cm).

3.2.1 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 Akij particle board industry, Dhaka, Bangladesh.

3.2.2 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 is carried out in the laboratory of Forestry and Wood Technology Discipline, Khulna University, Bangladesh.

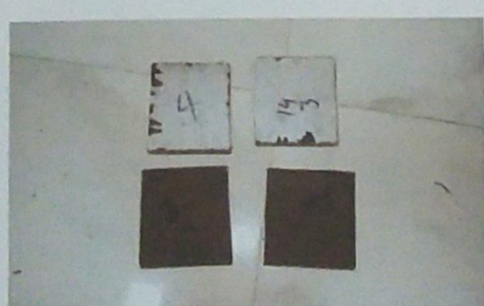

Figure 8: Sample of physical test.

At first all the specimens were weighted and green dimension are taken at room temperature. 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-

$$A_w = \frac{(m_2 - m_1)}{m_1} \times 100$$

Where,

A_w=Water absorption (%)

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

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

Thickness Swelling

Thickness swelling was calculated by the following formula-

$$G_t = \frac{(t_2 - t_1)}{t_1} \times 100$$

Where,

G_t=Thickness swelling (%)

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

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

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Effect of Chemical Additives on Board Properties

4.1.1 Mechanical Properties

4.1.1.1 Modulus of Rupture (MOR)

Figure 9 shows the effect of different chemical additives on the modulus of rupture of the board. The modulus of rupture for untreated board was 5.67 N/mm^2, when $MgCl_2$ (7.5%) added the MOR became 10.43 N/mm^2 after the addition of $CaCl_2$ the MOR became almost same to the $MgCl_2$ treated board and it was 10.31N/mm^2.But after the addition of $NaHCO_3$(7.5%) the MOR of the board drastically decrease to 2.78N/mm^2. Previous study shows that cement bounded board treated with combination of $MgCl_2$ and $NaHCO_3$ gives higher MOR Value (Mamun 2013). The hydration of Cement under water sock condition was accelerated by the addition of $NaHCO_3$ in combination with $MgCl_2$ (Ma *et al.*,1996). As we use $NaHCO_3$ separately it might be reduce the MOR value of the board. In previous study it is found that too high $NaHCO_3$ hinder the cement hydration as too much $CaCO_3$ is produced and it covers the cement clinker and reduce the strength of the cement (Nagadomi *et al.*,1996).

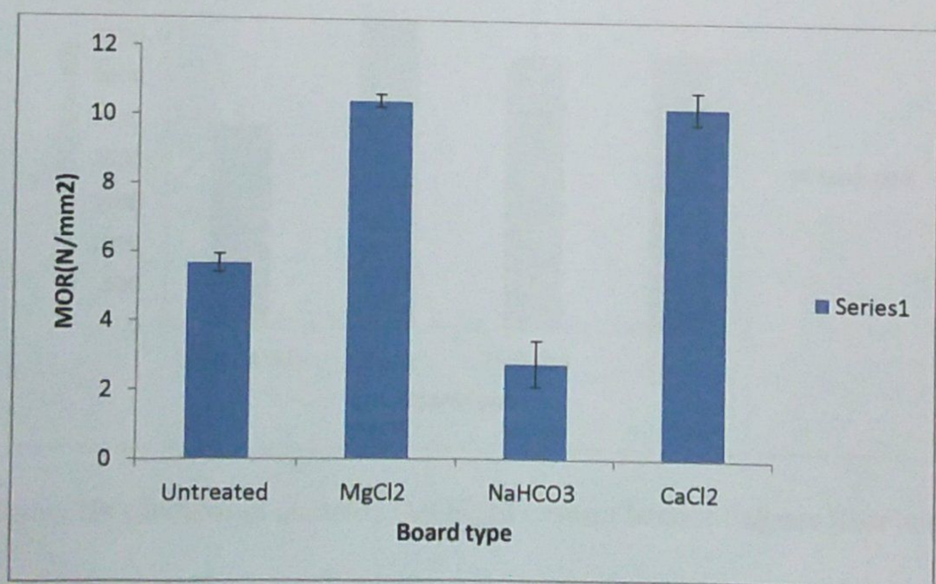

Figure 9: Modulus of rupture (MOR) of Cement bonded Bagasse fiber board

4.1.1.2 Modulus of Elasticity (MOE)

Figure 10 shows the effect of different chemical additives on the modulus of elasticity of the board. Modulus of elasticity was found for untreated 2453.615N/mm^2,when $MgCl_2$ (7.5%) added the MOE became 3783.11N/mm^2,after the addition of $CaCl_2$ the MOE became 3362.63N/mm^2,But after the addition of $NaHCO_3$ (7.5%) the MOR of the board decrease to 3352.75N/mm^2 .Study on Betel nut for cement bonded fiber board showed that the MOE ranges from 265.11 N/mm^2 to 319.59 N/mm^2 in fiber cement ratio of 1: 2 (Ghosh, 2013).It was also found that MOE of coconut coir cement bonded board was 2400-2500 N/mm^2(Aggarwal, 1992).Compare to above study cement bonded bagasse fiber board showed the higher MOE value when additives added. Conventional cement-setting accelerators such as calcium and magnesium chloride(~1.5 to 2.0 w/w cement) were very effective at improving the properties of wood-wool cement boards made from *Acacia mangium* to remove phenolic extractives.(Semple *et al*,2004).The higher MOE value of board treated with different accelerator than the untreated board, might be using accelerator is the fact that the possibility of the washing out of the aggressive extractive is minimized and therefore mechanical properties are increased as well.(Frybort *et al*.,2008).

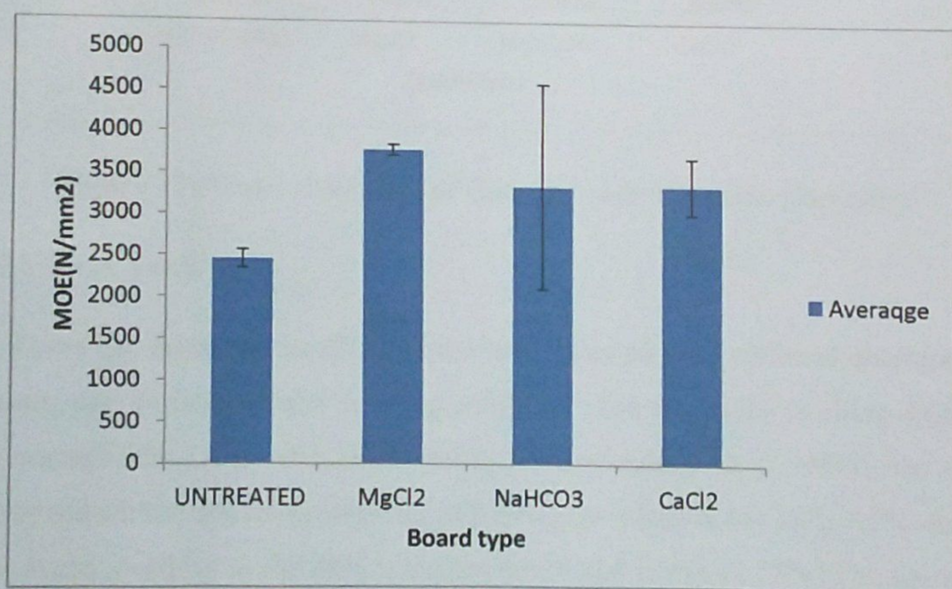

Figure 10: Modulus of elasticity (MOE) of Cement bonded Bagasse fiber board

4.1.2 Physical Properties

4.1.2.1 Water Absorption

Figure 11 shows the water absorption of the board treated with different chemical additives after 2 hours and 24 hours water soaking condition. The water absorption for untreated board

(25.96%),the $NaHCO_3$ 7.5% treated board shows almost similar water absorption as untreated board and it was (24.24%),addition of $CaCl_2$ 7.5% the water absorption reduce to (18.50%) and the addition of $MgCl_2$ 7.5% shows the lowest water absorption (15.24%) after 24hoursWater absorption was lower in $MgCl_2$ 7.5% treated board than untreated,$NaHCO_3$ 7.5% and $CaCl_2$ 7.5% treated board. The variation in water absorption among these type of fiber board might be due to the high internal bond strength of $MgCl_2$ treated board (Harmawan and Kawai,2000).For the same reason untreated board absorbed higher amount of water than $CaCl_2$ and $NaHCO_3$ treated board.

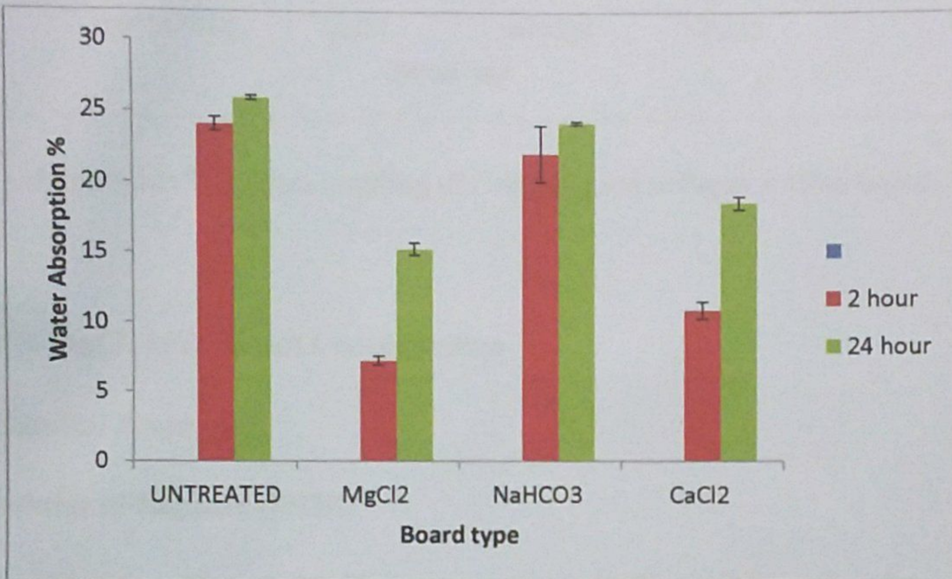

Figure 11: Water absorption of Cement bonded Bagasse fiber board

4.1.2.2 Thickness Swelling

Figure12 shows the thickness swelling of the board treated with different chemical additives after 2 hours and 24 hours water soaking condition. The thickness swelling was found for untreated board(5.28%),after addition$NaHCO_3$ 7.5% it reduce to (3.345%), the addition of $MgCl_2$ 7.5% reduce the thickness swelling to(2.29%),the addition of $CaCl_2$ 7.5% shows almost similar thickness swelling to the $MgCl_2$ treated board and it was (2.58%).The untreated board showed the highest thickness swelling value than the other treated board.The $MgCl_2$ treated board showed the lowest thickness swelling value than the treated board might be due to the high internal bond strength of $MgCl_2$ treated board (Harmawan and Kawai,2000).For lower internal bond strength untreated boards showed the highest value of thickness swelling.

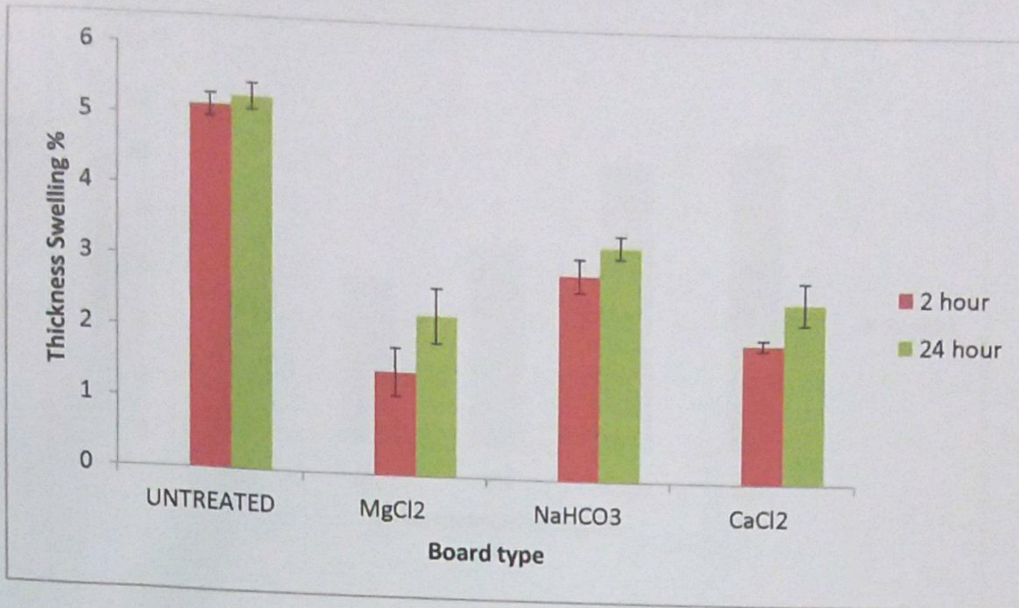

Figure 12: Thickness swelling of Cement bonded Bagasse fiber board

4.2 Effect of $MgCl_2$ in Different Concentration

4.2.1 Mechanical Properties

4.2.1.1 Modulus of Rupture (MOR)

Figure 13 shows the effect of $MgCl_2$ concentration on the modulus of rupture of cement bonded bagasse fiber board. Boards without and with 2% $MgCl_2$ showed property inferior to those of other boards. When 5% $MgCl_2$ added, the MOR was 7.29N/mm^2 and when 7.5% $MgCl_2$ added, MOR value drastically increased to 10.43N/mm^2. Above 7.5% when $MgCl_2$ added 10%, the MOR value changed very little (11.17 N/mm^2). It has been found that the modulus of rupture and elasticity increased with increasing amounts of $MgCl_2$.(Anon,2001).The improvement effect of $MgCl_2$ on the strength property of the cement bonded board might be due to the suitable alkalinity of $MgCl_2$.The alkalinity of $MgCl_2$ could not be expected to trigger dissolution of the inhibitory extractives but rather to enhance the hydration reaction of cement and substantial strength development of the board.(Anon,2001).It was found that the MOR Of cement boards made from unsoaked *Acacia mangium* wood-wool and treated with the chelating accelerators Sn or $FeCl_3$ of 0.1 M concentration were 10.8 and 10.9 MPa respectively.(Semple *et al 2004.*).

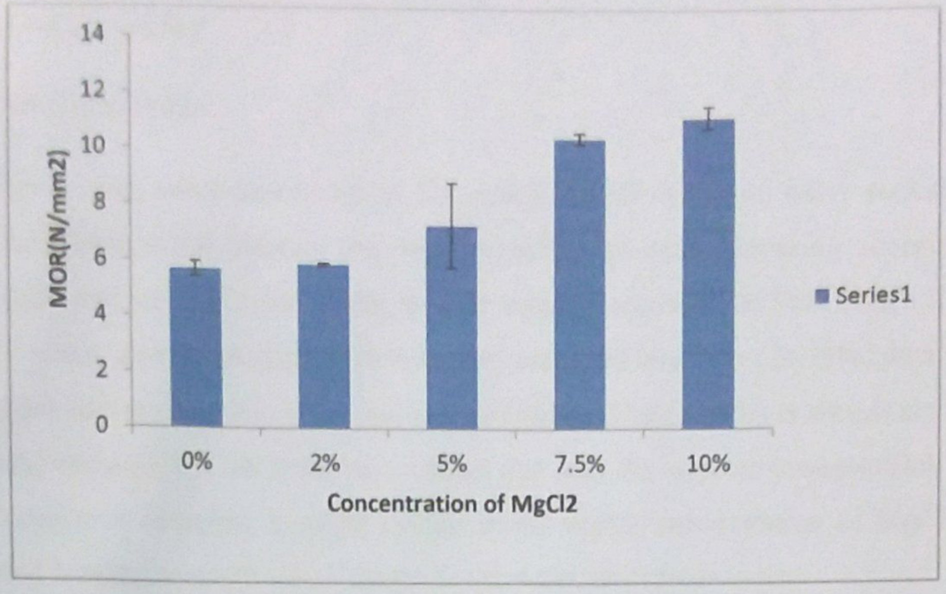

Figure 13: Modulus of rupture (MOR) of Cement bonded Bagasse fiber board in different concentration of $MgCl_2$.

4.2.1.2 Modulus of Elasticity (MOE)

Figure 14 shows the effect of $MgCl_2$ concentration on the modulus of elasticity of cement bonded bagasse fiber board. Board without and with 2% $MgCl_2$ showed MOE inferior to those of other boards. The MOE value drastically increased to 3783.11 N/mm^2 when $MgCl_2$ added 7.5%.Above 7.5% when $MgCl_2$ added 10%, the MOE value changed very little 3821.48 N/mm^2.The MOE value increased with the increased concentration of $MgCl_2$ as because of the same reason of value increased in MOR. It has been found that MOE of cement boards made from unsoaked *Acacia mangium* wood-wool and treated with the chelating accelerators Sn or $FeCl_3$ at 0.1 M concentration were and 2256 and 2178 MPa.(Semple *et al* 2004).

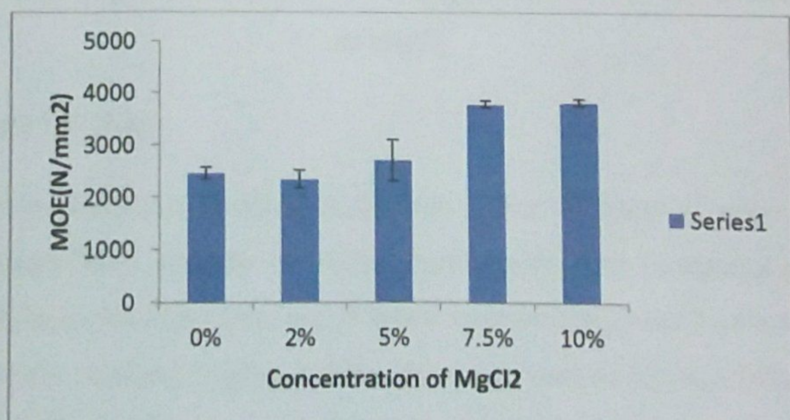

Figure 14: Modulus of elasticity (MOE) of Cement bonded Bagasse fiber board in different concentration of $MgCl_2$

4.2.2 Physical properties

4.2.2.1 Water Absorption

Figure 15shows the water absorption of the board after24 hours of water soaking. It was revealed that dimensional stability improved significantly with increasing concentration of $MgCl_2$ Boards without $MgCl_2$shows the highest water absorption (25.96%),when 2% $MgCl_2$ added then water absorption slightly reduce than untreated which is (23.39%),then when 5% added it again reduce (16.70%).Board treated with$MgCl_2$10%(14.25%) is almost similar to the board treated with$MgCl_2$ 7.5%.It has been shown that with the increase concentration of $MgCl_2$ water absorption is reducing, it might be due to the higher concentration of $MgCl_2$ provide high internal bonding strength which causes lower water absorption value.

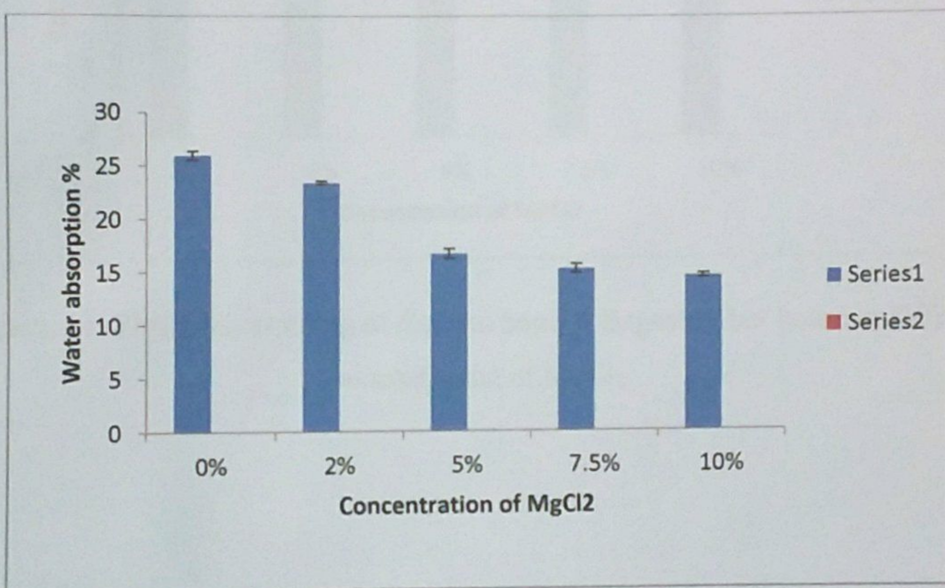

Figure 15: Water absorption of Cement bonded Bagasse fiber board in different concentration of $MgCl_2$.

4.2.2.2 Thickness Swelling

Figure 16shows the thickness swelling of the board after 24 hours of water soaking. It was revealed that dimensional stability improved significantly with increasing concentration of $MgCl_2$. After 24 hours thickness swelling of board without $MgCl_2$was 5.28%.When 2% $MgCl_2$ added, the thickness swelling slightly reduces than untreated which is 5.24%.Then when 5% added, it again reduces4.58%. Thickness swelling of the board treated with$MgCl_2$10%is 2.21% which is almost similar to the board treated with$MgCl_2$ 7.5%.The difference among different concentration of $MgCl_2$ might be as because higher concentration of $MgCl_2$ provides high internal bonding strength which causes lower water absorption value. Study on *Albizia* *falcataria* wood for cement bonded particle board shows that thickness swelling of the board was 2.87% after 24 hours submission into water.(Biswas *et al.*,1997). Previous study showed that thickness swelling for only pine (*pinus caribaea* M) saw dust, saw dust: coir ratio (2:1) and saw dust: coir ratio (2:2) for cement bonded particle board was thickness swelling of12.3%,4.6%,2.9%.(Aggarwal,1992).

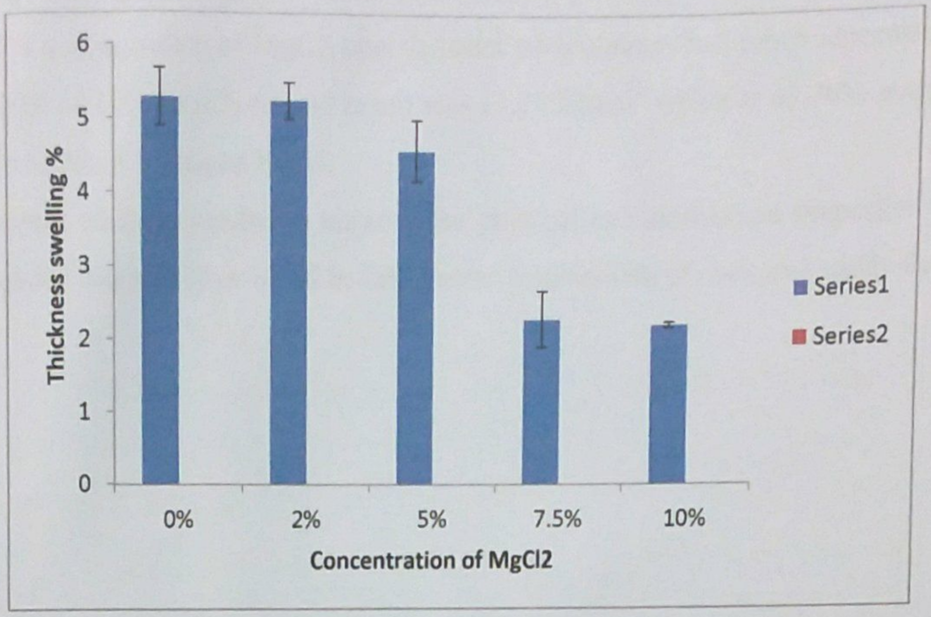

Figure 16: Thickness swelling of Cement bonded Bagasse fiber board in different concentration of $MgCl_2$.

CHAPTER FIVE

CONCLUSION

- Cement bonded fiber board has been successfully developed by Bagasse fiber.
- $MgCl_2$shows better performance than $CaCl_2$ and $NaHCO_3$ on board properties.
- 10% concentration of $MgCl_2$ attends better performance than other concentrations. The MOR of 10% $MgCl_2$ treated board was 11.17 N/mm^2 which is 49.76% increased than the MOR of untreated board.
- Further study is needed to improve the physical and mechanical properties of cement bonded Bagasse fiber board by using some combination of chemical additives.

CHAPTER SIX

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