The Effect of Binder Concentration on the Mechanical and Physical Properties of Particleboard Prepared by using Luffa Fiber(*Luffa cylindrica* L.) and Urea-formaldehyde

Myint Sandar Win#1, Ei Ei Phyone#2, Saw Win#3
Department of Engineering Chemistry, West Yangon Technological University,Myanmar
1myintsdwin@gmail.com
2maeieipyone@gmail.com
3sawwinsawwin140@gmail.com

Abstract— **This study aimed to find out the feasibility of Luffa fiber as a raw material for particleboard production. Considering binder concentration an attempt was taken to produce urea-formaldehyde (UF) resin bonded luffa fiber particleboard by hot press molding process. The mechanical and physical properties of the board were examined by British Standard (BS) andIndian Standard (IS) methods.The particleboard made from 25% UF resin showed the best performance in aspect of properties such as modulus of rupture (MOR), impact strength, hardness, water absorption (WA) and swelling thickness (ST) which were 554 kgcm^{-2}, 69.63 kjm^{-2}, 95.5 Shore D, 50.5% and 18.03% respectively. These results obtained from the research work fulfilled to FAO (2013) standards. The control of binder concentration is the one of the most important factors for the production of particleboard. Luffa fiber particleboard may be a sustainable, cheap and durable building and packing materials and timber substitute.**

***Keywords*: Luffa fiber, urea-formaldehyde, hot-press, particleboard, mechanical and physical properties**

I. INTRODUCTION

Particleboards were first made during the 1930. Trade name of particleboard (PB) is Eco-board. The particleboard (sheet materials) containing lingo-cellulose such as pieces, flakes and strands held together with an organic binder. The common use of PB is to make furniture tools and wall fastener (Palakpuja, 2015). If laminate or furniture foil is properly affixed to the board surface, PBs can also be used in the production of furniture that can be exposed to the action of higher humidity such as laundries, bathrooms and kitchens (Wazny, 1994). Medium density fiberboard (MDF)and particleboard can be produced from variety of natural fibers: but wood, because of its relative abundance and year-round availability, is still the most important raw material. However, increasing demand of forest resources for different uses has led to the shortage of wood supply. Therefore, there is a need to find alternative raw materials or complete use of wood resources including harvesting residues, annual plants, lumber and furniture plant residues, residues of pulp plants, and recycles paper etc (Alireza *etal.*,2009).

According to Manthey *etal.*,(2010), such natural fibers are inexpensive, easy to process, renewable and they are recyclable. Luffa fiber is a light-weight natural material that has the prospective to used as an alternative sustainable material for various engineering applications such as acoustic and vibration isolation, impact energy absorption, and packaging (Shen *etal.*, 2013) luffa fiber is composed of 60.63 % α -cellulose, 19.4-22% hemicellulose, 10.6-11.2 % lignin and others (Siqueira *etal.*, 201l0).Akaline treatment, also known as alkaline mercerization, is the most commonly used chemical treatment of natural fiber composites in the preparation of thermoset and thermoplastic reinforced natural fiber composite materials. In the alkaline treatment process, the network structure of the hydrogen bonding is altered due to reaction of sodium hydroxide. This process is important for increasing the surface roughness of the natural fibers. According to Demir *etal.*, (2006), the alkaline treatment of natural fiber improves adhesion and creates better mechanical properties of reinforced natural composite materials. Moreover, the alkaline treatment process can remove the wax, oils, and lignin at the cell wall surface of the natural fibers.

At the present time, the majority of particleboard manufacturer employs formaldehyde-based adhesive such as phenol-formaldehyde (PF), urea-formaldehyde (UF), and melamine-urea-formaldehyde (MUF) as the main adhesive (Bono etal., 2010).Urea-formaldehyde adhesive is mostly used to glue wood together because of its chemical properties. UF is also used when producing electrical appliances casing also desk lamps. It is widely chosen as an adhesive because of its high reactivity, wonderful performance and low price. It is also used in agricultural field as a source of nitrogen fertilizer (Clausen, etal., 2003).

Particleboards having the best physical properties such as water absorption and swelling thickness were made of ammonium sulphate hardener and small chips (Mohsen, 2011). The presence of hardener enhances the cross linking between the resin and hardener thus increases the tensile strength (Sulaiman *etal.*, 2008). The surface fractures of the composites were evaluated using digital microscope (China) to look into the morphology. This study focused on the evaluation of mechanical properties and physical properties of particleboards made from treated luffa fiber and urea-fromaldehyde.

II. Materials and Methods

A. Materials

The luffa fibers were obtained from local sources in Maubin Township, Irrawaddy Region,Myanmar. Pellets of sodium hydroxide (NaOH), which are soluble in water, were used for chemical treatment of fibers. The used NaOH was produced from British Drug 4cm House (BDH). The urea-formaldehyde resin is the product of Watayar Glue factory, Shew Pyi Tha Township, Yangon, Myanmar. Ammonium sulphate was used as hardener which was produced from Chengdu kelong chemical Factory in China.

B. Methods

The luffa fiber can be extracted from the luffa cylindrical plant in two ways, by either naturally drying on the plant itself or drying under the sun after cutting it when it has matured. When luffa is dried, the hard top part of the luffa needs to be cut off to remove the seed inside the luffa pod. Striking the luffa pod against a hard wall removes the skin and the seed. And then, the luffa is soaked with water for two hours to remove the sap color. After drying for two days ,luffa fiber is chopped into smaller sizes (2cm to 4 cm) to use in specimen preparation.

Fig.1 Luffa pod with skin, Luffa sponge and Chopped luffa fiber

The luffa fiber was immersed in a 0.5% NaOH solution at ambient temperature (≈ 25ºC) for 30 minutes , followed by washed with very dilute acetate acid to neutralize excess NaOH. The luffa fiber was then cleaned with water three times and dried in air at ambient temperature for 7 days. The purpose of immersing the luffa fiber inside the alkaline solution was to remove impurities and to increase the surface roughness of the fiber. After sodium hydroxide treatment, most of the lignin and pectin had been removed, resulting in a rough surface with some fibrils (Sgriccia etal., 2008) .The air-dried luffa fiber was dried in an oven at 100ºC for 30 minutes and transferred to Hensen mixer. The luffa fiber was blended for 10 minutes to obtain certain particle sizes (1mm, 500mm, 250mm) and classified by horizontal screen shaker with definite size. Luffa particles (9.5 % MC) were blended with (15%,20%,25%,30% and 35%) UF resin with the solid content of 58% and 5ml of 0.4 % of hardener ammonium sulphate.

Five types of composite particleboards were made by using luffa fiber, UF and ammonium sulphate. Pre-weighed 100g luffa fiber with classified size was placed into a Henser mixer. The adhesive UF was throughly mixed with ammonium sulphate and then sprayed onto the fiber and blended for 5 min in the mixer to obtain a homogenized mixture. The mat configuration was single-layer. Boards measuring (6"x 6") were manually formed and pressed in a hydraulic hot press at 2200 psi at 120ºC for 15 min. Two composite panels were made for each type. After pressing, the boards were conditioned at ambient temperature about one week in vertical position. The finished boards were trimmed to avoid edge effects to a final size of 14.8cm x 14.8cm, and then cut into various sizes *for properly evaluation according to British Standa*rd (BS) and Indian Standard (IS) methods and their respective equipments and machines.

III. Results and discussion

A. Effect of Binder Concentration on the Mechanical and Physical Properties of Prepared Particleboards

Mechanical and physical properties of prepared particleboards are shown in Table 1.

TABLE I.

MECHANICAL AND PHYSICAL PROPERTIES OF PREPARED PARTICLEBOARDS

Properties	PB1	PB2	PB3	PB4	PB5	Reference** (Reported)
Modulus of rupture (kgcm^{-2})	354	399	554	399	383	100-500
Modulus of rupture(psi)	5063	5696	7911	5696	5468	-
Impact strength (kjm^{-2})	111.93	97.63	69.63	68.60	95.9	-
Tensile strength (lb)	7.00	7.00	6.46	6.16	6.83	-
Hardness (Shore D)	85.0	92.5	95.5	95	95	-
Thickness (cm)	0.47	0.42	0.30	0.40	0.45	-
Density (gcm^{-3})	1.05	1.18	1.39	1.05	1.12	0.4-0.8
Water absorption (%)*	90.5	72.5	50.5	68.0	43.5	20-75
Swelling thickness (%)*	68.7	21.5	18.03	2.5	2.5	5-15
Moisture content(%)	7.90	7.54	7.25	6.06	6.81	-

Press temperature = 120ºC
Press time = 15 min
Fiber type = Luffa
Adhesive type = Urea-formaldehyde
Hardener = Ammonium sulphate
* = after soaking period 24 hours
** = FAO (2013)
FAO = Food and Agriculture Organization
PB1 = particleboard prepared with 15% UF
PB2 = particleboard prepared with 20% UF
PB3 = particleboard prepared with 25% UF
PB4 = particleboard prepared with 30% UF
PB5 = particleboard prepared with 35% UF

B. Effect of Binder concentration on the mechanical properties

MOR values of composite particleboards prepared from luffa fiber and UF adhesive were 354-554 kgcm^{-2}.

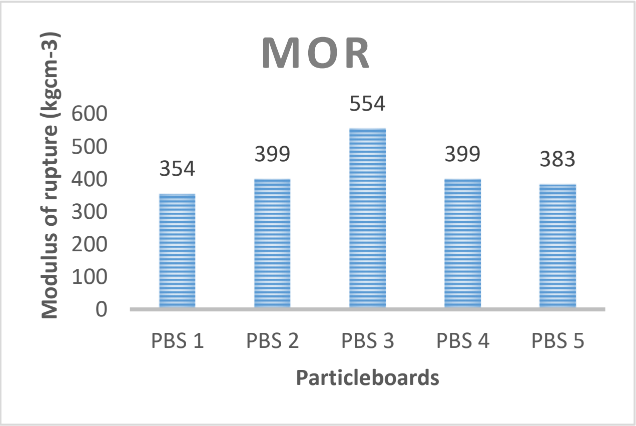

Fig.2 Modulus of rupture of particleboards

Generally, the increasing of resin content will be able to increase of MOR value for the particleboards. Maloney (1993) stated that resin content is the one of the important factors affecting on the board properties. In this research, MOR values of all prepared composites fulfilled to FAO (2013) Standard. Especially, MOR value (554kgcm^{-2}) of (PB3) was above the maximum value of 500 kgcm^{-2} for FAO (2013) Standard. PB3 having the greatest density had the highest MOR value.The composite board density plays as an important role on bending strength, as expected. MOR values of PB increased up to 25% UF content but it was found that MOR values of PB4 (30% UF) and PB5 (35% UF) content decreased. PB3 which was made by (25.2%) content had the highest MOR value of 554 kgcm^{-2}. It is expected the optimum resin content is required for obtaining the best quality of particleboard.

Impact strength values of prepared particleboards were 68.60-111.93 kjm^{-2}

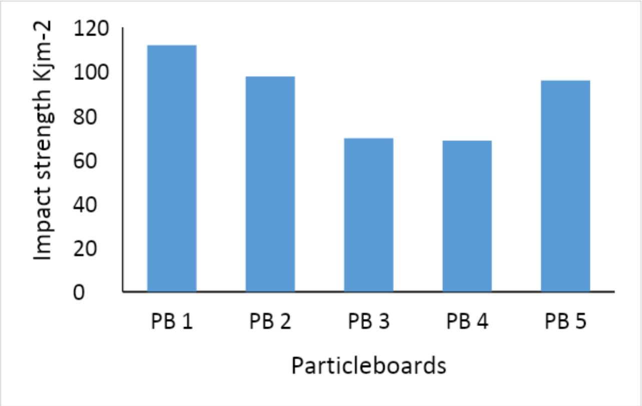

Fig.3 Impact strength of prepared particleboards

Impact strength of particleboards linearly decreased as the resin content increased, except PB5 (UF 35%). PB3 had the impact strength of 69.63 kjm^{-2}. The particleboards (PB1) made by (15% UF) content had the highest impact strength of 111.93 kgcm^{-2}. Impact strength is the energy required to fracture the sample.

Tensile strength of prepared particleboards also decreased as the resin content increased. Tensile strength is directly proportional to the impact strength of boards. Tensile strength range were from 6.16 lb to 7.00 lb. PB3 had the tensile strength of 6.46 lb.

Hardness of particleboards are the measurement of resistance to surface distortion (or) deformation. The particleboards having the highest hardness value have the best quality of boards, expected. In this research, the PB3 having highest MOR value had the highest hardness of 95.5 shore D. The PB3 made by 25% UF content had more compatibility which tends to increase MOR and hardness values.

The thickness range of prepared particleboard was from 0.30cm to 0.47cm. The more compatibility tends to decrease the thickness of board and increase the density of board formed. The particleboard PB3 had the lowest thickness value (0.30cm) and the highest density of 1.39 gcm^{-3}. All density values of prepared particleboards did not fulfill to (0.4-0.8) gcm^{-3} FAO (2013) Standard. The PB3 had the best quality even through the lowest thickness due to the highest MOR and hardness values.

Water absorption percentage range of prepared particleboards were (43.5-90.5) %. The WA values obtained for PBs fulfilled to (20-75) % FAO (2013) Standard. But, these WA values did not fulfill to the minimum WA value of 20% FAO (2013) Standard. The PB3 had 50.5% WA values which was made by 25% UF content.

The PBs possess the best quality when the PBs have the lowest WA percentage. Swelling thickness values of prepared particleboards were 2.5-68.7%. The ST value is directly proportional to the WA values. The ST and WA values decreased as increased in resin content due to the water resistance property of UF resin. The ST of PB4 and PB5 only fulfilled to (5-15) % FAO (2013) Standard. But, PB3 had the ST value of 18.03% which did nearly (approximately) fulfilled to maximum ST values of 15% FAO (2013). It was clearly found that increasing UF resin content tends to the decreasing WA value.

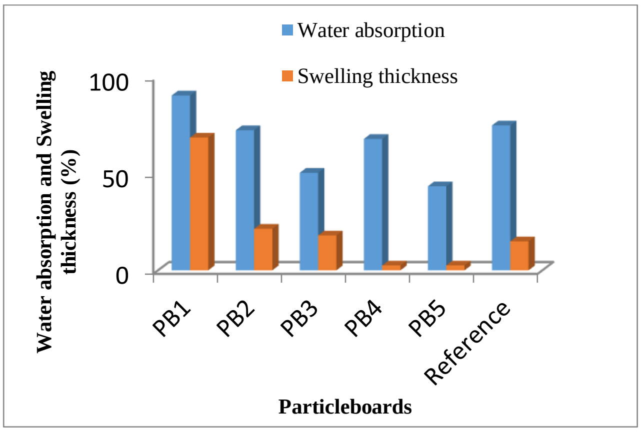

Fig.4 Water absorption and swelling thickness of particleboards

Moisture content (MC) percentages of prepared particleboards were (6.06-7.90%). According to Balakrishna et al. (2013), the chemical treatment removes the moisture and impurity of the fiber which increases strength. MC is the one of the most important factors for fungi growing on the board surface. MC of boards should be reduced as possible by using various treatments. The particleboard with high MC content (16%) tend to grow fungi on the surface of board and which can give problem to human health (Burmester, 1974).

C. Surface Morphology of selected prepared Particleboard

The morphological studies of the prepared composite boards were observed using Digital microscope (50x-500x), China. The surface of both PB2 and PB3 had net work structures. On the surface from overview and side view of

PB3is less micro pores and fibers did not come out from the surface due to the sufficient distribution resin. This lead to enhance mechanical and physical properties.

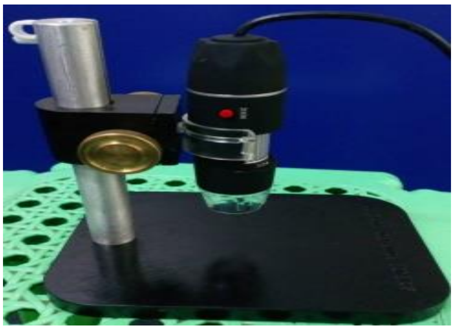

Fig. 5 Digital microscope

Overview of PB2 Sideview of PB2

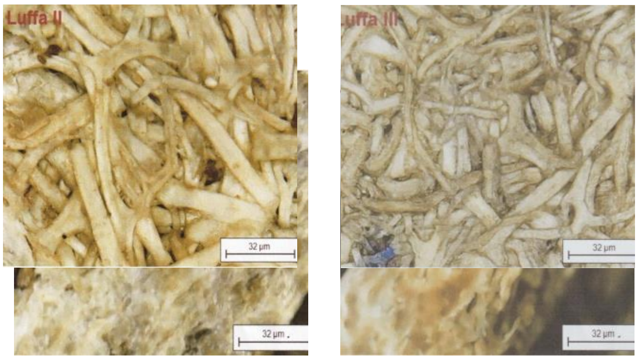

Fig.6 (a) Surface micrograph of PB2

Overview of PB3 Sideview of PB3

Fig.6(b) Surface micrographs of PB3

D. *Application of particleboards*

PBs are widely used as construction materials such as wall partition, celling board and floor-underlayment.

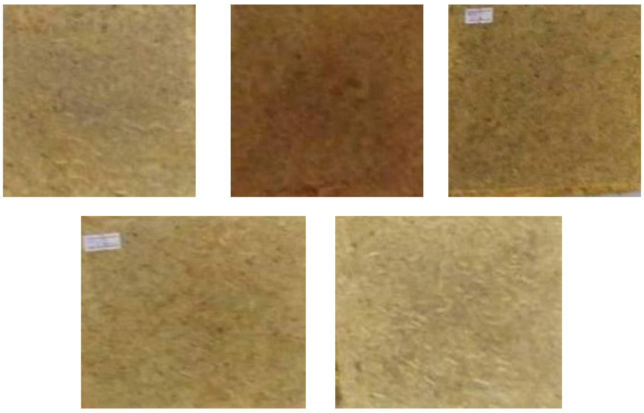

Fig.7 Construction materials (wall partition, celling board and floor-underlayment)

CONCLUSION

The results presented here suggest that it is completely feasible to manufacture acceptable or high quality particleboard using luffa fiber as an alternative lignocellusosic raw material. Since particleboards produced with 25% urea-formaldehyde had the most desirable quality which fulfilled to FAO(2013) Standard values. The binder concentration (25% UF) was also found to have a great effect on the properties of UF bonded luffa fiber particleboards. The use of renewable materials such as luffa fiber for manufacturing particleboards could help to alleviate the scarcity of raw material for the particleboard industry.

ACKNOWLEDGEMENT

The authors are grateful to Rector and Department of Engineering Chemistry, West Yangon Technological University for their kind encouragement and valuable advice. My sincere thanks are also dedicated to Director and all the staff members of the Polymer Department, Department of Research and Innovation (DRI), Ministry of Education ,Myanmar for their helpful suggestions and supporting research feasibilities.

REFERENCES

Alireza, A., N. Amir and K. Abolfazl. (2009). Properties of Medium Density Fiberwood Based on Bagassc Fibers, Journal OfComposite Materials, 43(18), 1927-1934.
Balakrishna, A., D. N. Rao. and A.S. Rakesh. (2013). “Characteristization and modelling of process parameters on tensile strength of short and randomly oriented Borassus flabellifer (Asian palmyra) fibre reinforced composite,” compos.Part B: Engineering, 55, 479-485.
Bono,A., M.Nur., S.M. Anisuzzaman., S.Sualah., and H.K.Chiew. (2010). The performance of MUF resin with Palm kernel asfille Advanced Matreials Research,3,233-235.
Burmester, A. (1974). Simple methods of improving dimensional stability (2) Treatment of wood-based materials technology, economics, Holz und kunststoffverarbeitung **9**(9): 610-617 (in German)
Clausen, C.A., L.L. Haughton., and C. Murphy. (2003).Evaluating Wood-based Composites for Incipient Fungal Decay with the Immunodiagnostic Wood Decay Test. *Gen Tech. Rep*., FPL. GTR 142 Medison, WI: US. Department of Agriculture, Forest Service, Forest Products laboratory.
Demir, H., U. Atikler., D. Balkose and F. Tihminlio glue. (2006). “The effect of fiber luffa treatments on the tensile and water *comps.* absorption properties of polypropylene- luffa fiber composites”*Part A*:Applied Science and manufacturing **37**(3), 447-456.
FAO.(2013).Characteristic Mechanic of Polyester Composite Particleboard with Filler Particle of Areca Nut Fiber, http://www.fao.org/3/a-i4441 e.pdf (Accessed 8 June2013)
Maloney, T.M.(1993). Modern Particleboard and Dry-process Fiberboard Manufacturing (updated edition), Miller Freeman,San Francisco
Manthey, N., F. Cardona., T. Aravinthan., H. Wang., and T. Cooney. (2010). Incorporating Saustainable Practise in Mechanics and Structure of Materials, Sam Fragomeni., and S. Venkatesan. (eds.), CRC Press, Boca Raton, FL, pp 956.
Mohsen, S. (2011). Effect of Hardener Type and Particle Size on Formaldehyde Emission Pollution; *International Conference an Environment Science and Engineering* IPCBEE **8**, 242-244.
Palakpuja, P.(2015). *Properties and uses of urea-formaldehyde* formaldehyde-resin/Resin.(Accessed 8 June 2015)
Sgriccia, N., M.C. Hawley., and M. Misra. (2008). “Characterization of natural fiber surfaces and natural fiber composites”,*composites: Part A***39**,1632-1637.
Shen, J., Y.M. Xie., X. Huang., S. Zhou., and D. Ruan. (2013). “Behaviour of luffa sponge material under dynamicloading,” *International Journal of Impact Engineering* **57**,,17-26.
Siqueira.G., J. Bras., and A. Dufresne. (2010). “Luffa cylindrica as a Lignocellulosic source of fiber, microfibrillated cellulose, and cellulose nanocrystals”, *Bioresources*, **5**(2),pp. 727-740.
Sulaiman.S., R.Yunus; N.A. Ibrahim., and F.Rezaei. (2008). Effect of Hardener on Mechanical Properties of Carbon Fiber Reinforced Phenolic Resin Composites. *Journal of Engineering Science and Technology*, **3**,(1). 79-86.
Wazny, J. (1994). “The present classification of wood Degradation Factors”. Revised version, International Research Group on wood Preservation,document No.