INFLUENCE OF THERMOPLASTIC WASTES ON THE PROPERTIES OF BETEL NUT SHELL FIBER (*ARECA CATECHU* L.) PARTICLEBOARDS

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Abstract

This study aimed to prepared particleboards using bio-waste Betel Nut Shell Fiber (BNF) and resinous materials recycled thermoplastics polyethylene (RPE), polypropylene (RPP) and reused polystyrene (RPS) obtained from plastic wastes. The particleboards were prepared by mixing the fibers and plastics followed by hydraulic hot press molding method. The fibers and plastics (1:1) by weight ratio were pressed under 2200 psi with pressing temperature 170 ºC for 15 min. The properties of prepared particleboards were measured according to BS -1811, IS-3087 and ASTM D – 412 and ASTM D- 256 standard methods. The results obtained were compared with FAO (2013) and JSA (2003) standard values. The surface morphological characters of prepared particleboards were recorded by Digital Microscope. It was found that the properties of particleboards were in agreement with the standard values. The obtained properties convincingly indicate high bonding ability of the recycled and reused plastics. The reused polystyrene was the most suitable for particleboard production among two recycled and one reused plastics due to the particleboard made with reused polystyrene possess the highest bending strength 232.70 kg/cm^2, the lowest water absorption (9.31%) and swelling thickness (11.47%) even though it had the lowest thickness value of 0.35 cm.

Keywords: Betel nut shell fiber, recycled and reused plastics, hydraulic hot press molding method, particleboards, bonding ability

Introduction

Today, the construction industry is rapidly growing at an enormous pace due to the increasing population around the world. Presently, particleboard is one of the most popular construction materials commonly used for interior and exterior applications such as walls, ceiling panels office dividers, bulletin boards, cabinets, furniture, countertops and desktops (Guru *et al*., 2008).The most common type of particleboard is made from wood chips which came from timber waste, shavings and mill waste (Odozi *et al*., 1986).The increase in the demand for wood products led to the depletion of timber resources. Thus, the depletion of wood resources promotes the use of alternative raw materials for wood products. Agricultural residues comprise an alternative source for wood which would otherwise be used. Many types of natural fibers have been investigated for use in plastics including straw, wood fiber, rice husks, grass reeds, coir, banana fiber, pineapple leaf fiber, etc. Natural fibers have the advantage that they are renewable resources and have commercial and marketing appeal (Baccay, 2017). In this study, the potential of thermoplastics resins RPE, RPP and RPS as substitute for urea or formaldehyde-based resins that are known to emit carcinogenic gases. The recycling presents advantages such as reduction of environmental problems and saving both material and energy (Francis, 2016).

Thermoplastics are made up of linear molecular chains and this polymer softens on heating and hardens when cooled (Amin and Amin, 2011). The crystalline thermoplastics (RPE, RPP) have more mechanical impact resistance. The melting points and densities of RPE and RPP are 120 - 130 ℃, 160 - 171 ℃ and 0.93 - 0.97 g cm^{-3}, 0.89 - 0.92 g cm^{-3} (Van de Velde and Kiekens, 2001). The amorphous thermoplastic (RPS) has melting point 210 - 249℃ but they begin to flow at their

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glass transition point 100 °C and density of 0.96 - 1.05 g cm^{-3}. The density is a very important parameter because its purpose is to produce a composite that is as light as possible.

The betel nut palm is believed to have originated in the Philippines which grown in much of the tropical pacific, Asia and parts of East Africa (Heatubun *et al.*, 2012). The betel nut palms have been cultivated as gardens and hedges in Thaninthayi Region, Bago Region, Mon State, Kayan State and Rakhine State in Myanmar. They have been grown for its commercially important seed crop. The betel nut shell fiber is composed of cellulose (53.20 %) with varying proportions of hemicelluloses (32.98 %), lignin (7.2 %) and other materials (Ramachandra and Ashok, 2011). The betel nut shell fiber appears to be a promising material because of low cost, less weight, extremely strong, abundantly available and also biodegradable. It is also used as reinforcement in polymer composite particleboard (Hodzic *et al*., 2006).

Materials and Methods

Sample Preparation

The recycled plastics polyethylene, polypropylene and reused polystyrene were obtained from Polymer Department in Department of Research and Innovation (DRI), Ministry of Education, Yangon, Myanmar. The recycled and reused plastics were made into powder by Refiner Machine before blending with fibers. The three types of recycled and reused plastics are shown in Figure 1 (a-c). The betel nut shell fibers (*Areca catechu* L.) were gathered from betel nut plantation in Myeik Township, Thaninthayi Region.

Betel nut shell fibers (BNF) were soaked in water at ambient temperature for 2 days to loosen fibers. The fibers were washed with water 3 - times to remove impurities. The fibers were dried in air at ambient temperature for 3 days. The dried fibers were soaked in a 3 % NaOH solution at ambient temperature for 1 h to modify the fiber strength.

The fibers were then soaked in very dilute acetic acid for 1 h to neutralize the excess NaOH. The fibers were washed with water 2 times and dried in air at ambient temperature for 7 days. The modified dry fibers with 9.27 % moisture content were ground in Hensel Mixer for 7 min and screened into 1 mm particle size and dried again at 100 °C in air oven for 30 min to reduce moisture content. The modified betel nut shell fiber particles are shown in Figure 1(d).

(a) (b) (c) (d)

Figure 1 (a) Recycled polyethylene (b) polypropylene (c) reused polystyrene and (d) betel nut shell fiber particles

The modified dry betel nut shell fiber particles were blended with RPE, RPP and RPS separately in the weight ratio of (1:1) in Hensel Mixer for 5 min. Three different samples of particleboards were manufactured as indicated in Table 1. The target size of the particleboard was 15 cm × 15 cm with a thickness of 0.5 cm. After blending, the mats of the particles were formed manually by placing the blend in a mould and lightly press for 5 min at ambient temperature. Oil was used as a releasing agent on mould surface to achieve easy particleboard removal from the mould after formation. After being lightly pressed, the mats of particles were pressed under hydraulic hot press machine (LJT- 815566, APEX CONSTRUCTION) with

2200 psi at 170 °C for 15 min. The pressed particleboard was transferred to cool press and pressed the boards for 5 min to cure sides and surface of boards. The produced particleboards were subjected to physical and mechanical tests with their respective methods after successful curing.

Table 1 Composition of the Particleboards

Particleboards	Compositions (w/w)
RPEPB	50 %BNF + 50 % RPE
RPPPB	50 %BNF + 50 % RPP
RPSPB	50 % BNF + 50 % RPS

All tests were carried out in accordance with ASTM, IS and BS standard methods. At least three specimens were selected for each type of panel for testing the physical and mechanical properties. Density of boards (BS: 1811-1961), water absorption (IS: 3087 – 1965), swelling thickness (IS : 3087 -1965), moisture content (MOC - 63U), modulus of rupture (ASTM D- 412), impact strength (ASTM D - 256) and hardness (ASTM D - 2240) were determined by their respective methods. To obtain water absorption and swelling thickness, samples were fully immersed in water at ambient temperature for 24 h.

Results and Discussion

Effect of Thermoplastic Types on the Physical and Mechanical Properties of Particleboards

The three type of particleboards (RPEPB, RPPPB, RPSPP) were produced by using betel nut shell fibers and (RPE, RPP, RPS) in the ratio of (1:1) by weight. The physical and mechanical properties of prepared particleboards are shown in Table 2.

Table 2 Physical and Mechanical Properties of Prepared Particleboards

Properties	RPEPB	RPPPB	RPSPB	Reference** (Reported)
Thickness(cm)	0.40	0.50	0.35	-
Density (g/cm^3)	0.90	0.83	0.94	0.4 – 0.9 (JSA,2003)
Water absorption*(%)	10.65	16.23	9.31	20 -75
Swelling thickness* (%)	12.63	14.06	11.47	5 – 15
Moisture content (%)	2.34	2.33	2.41	5- 13 (JSA,2003)
Modulus of rupture (kg/cm^2)	163.21	108.41	232.70	100-500
Impact strength (kJ/m^2)	128.73	171.27	42.60	-
Hardness (Shore A)	88.90	92.75	94.95	-

* = after soaking period 24 h
** = FAO (2013), JSA (2003)
FAO = Food and Agriculture Organization
JSA = Japanese Standard Association
Pressing Temperature = 170 ℃
Pressing Pressure = 2200 psi
Pressing Time = 15 min

Fiber type = Betel Nut Shell Fiber (BNF)
Resin type =Recycled plastics polyethylene (RPE), polypropylene RPP), reused polystyrene (RPS)
RPEPB = recycled polyethylene particleboard made by RPE and BNF (1:1) by weight
RPPPB = recycled polyethylene particleboard made by RPP and BNF (1:1) by weight
RPSPB = reused polyethylene particleboard made by RPS and BNF (1:1) by weight

Physical Properties of Produced Particleboards

Thickness and density

As shown in Table 2, thickness of three prepared particleboards, RPEPB, RPPPB, and RPSPB were 0.40, 0.50 and 0.35 cm, respectively. The particleboard (RPSPB) was found to have the lowest thickness value of 0.35 cm due to the usage of RPS which had the greatest adhesive property. Polystyrene (PS) is amorphous thermoplastic, usually transparent with the molecules arranged randomly (Francis, 2016). It was found that the resin type is one of the essential parameters for good binding capacity of fibers.

Density is the most important gauge of particleboards performance, which mostly affects all other properties and considerations (Abdutkareem and Adeniyl, 2017). The densities of the particleboards (RPEPB, RPPPB and RPSPB) made from betel nut shell fiber waste at 50 % each of RPE, RPP and RPS were 0.90, 0.83 and 0.94 g/cm^3, respectively. According to JISA 5908 – 2003 standard (JSA, 2003), the densities of prepared particleboards were in the range 0.40-0.90 g/cm^3. Hence, the densities of all the produced particleboards fulfilled to the universal standard for the particleboards. Several factors that influencing of board density were wood density, pressing pressure, particle quantity in mat, resin content and other additive (Kelley, 1997).

Water absorption and swelling thickness

According to Table 2, the water absorption (WA) capacity of prepared particleboards were found to be in the range of 9.31-16.23 % (Figure 2). The standard range of particleboards was 20-75 % (FAO, 2013). Hence WA values of prepared particleboards were less than that of standard particleboards. The resultant particleboard (RPSPB) from the usage of RPS resin as binder is excellent water repellent. The higher density board absorbed less water than a lower density board.

The swelling thickness (ST) values of particleboards, RPEPB, RPPPB and RPSPB were 12.63, 14.06 and11.47 %, respectively (Figure 2). According to standard, ST values of prepared particleboards were found to be in the range of 5-15 % (FAO, 2013). Hence the ST values of prepared particleboards met the requirement of the universal standard value for particleboard. The density and WA capacity have more effect on ST and linear expansion of particleboard (Abdulkareem and Adeniyl, 2017). Guler *et al.* (2008) reported that ST of wood panels were influenced by quantity and distribution of adhesive, moisture content of furnish, furnish compatibility, chemical composition of furnish etc.

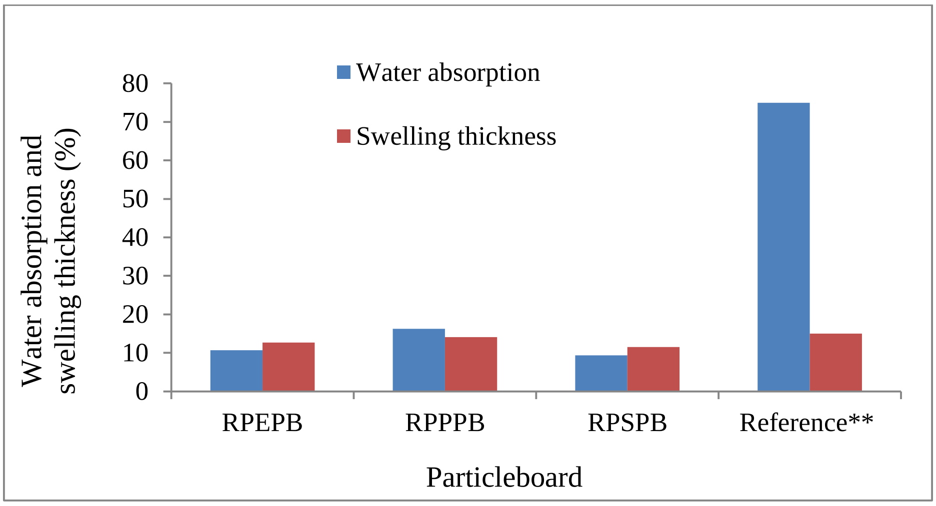


Figure 2 Water absorption and swelling thickness of particleboards

Moisture content

As shown in Table 2, the moisture content of prepared particleboards were found to be in the range of 2.33- 2.41 %. According to standard JISA 5908 - 2003, moisture content of prepared particleboards was in the range between 5 and 13 % (JSA, 2003). Maloney (1993) stated that initial moisture content of raw material is one of the important factors to determine of moisture content in particleboard produced. It was expected that possessing of low moisture content (ca 2 %) is due to the usage of hydrophobic plastics. It was expected that the fungi could not grow on the surface of board by using recycled and reused plastics.

Mechanical Properties of Prepared Particleboards

Modulus of rupture

The modulus of rupture (MOR) of prepared particleboards were in the range of 108.41 - 232.70 kg/cm^2 (Figure 3). Modulus of rupture is a measure of the ability of a sample to resist a transverse (bending) force perpendicular to its longitudinal axis. Table 2 also shows the modulus of rupture of particleboards with different resin type to betel nut shell fiber content. The result showed that particleboard with reused polystyrene (RPSPB) gave the highest value of MOR with 232.70 kg/cm^2. It is established that RPSPB with RPS content can withstand more force than the other samples before failure and therefore represents the optimum resin type. According to (FAO, 2013) standard, the MOR value of prepared particleboards were found to be in the range of 100 - 500 kg/ cm^2. It is noted that the MOR values obtained for the particleboards (RPEPB, RPSPB) were higher than the standard minimum value of 100 kg/cm^2. The MOR value of particleboard (RPPPB) with 108.41 kg/cm^2 also met the requirement of the standard value with 100-500 kg/cm^2.

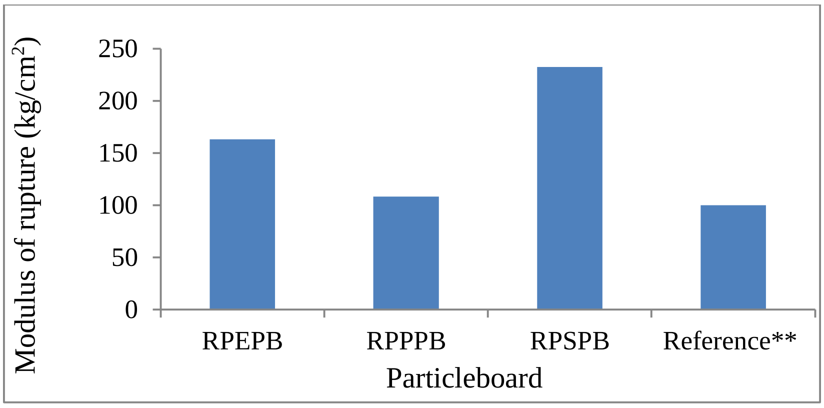


Figure 3 Modulus of rupture for particleboards

Impact strength

Impact Strength is the ability of a material to resist breaking under a shock loading or the ability to resist the fracture under stress applied at high speed. The impact strength of prepared particleboards were in the range of 42.60 - 171.27 kJ/m^2 as shown in Table 2. This indicates that the impact strength of particleboard (RPSPB) was the lowest value of 42.60 kJ/m^2 among them. It was expected that RPSPB had the lowest thickness 0.35 cm which is directly proportional to its lowest impact strength with 42.60 kJ/m^2.

Hardness property

Hardness property means a resistance to penetration, wear or a measure of low stress and resistance to cutting and scratching (Westbrook and Conrad, 1973). The hardness value of prepared particleboards RPEPB, RPPPB and RPSPB were 88.90, 92.75 and 94.95 Shore A, respectively.

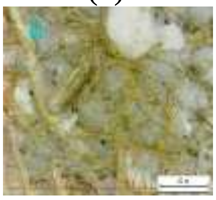
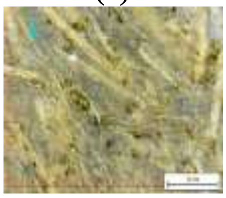
Shore A is unit of Hardness value. The particleboard RPSPB had the highest hardness value of 94.95 Shore A which was the best particleboard in this study. This is because hardness is a function of the relative fiber content and modulus of rupture.

Surface Morphological Study of Prepared Particleboards

The surface micrographs of over view and side view of prepared particleboards are shown in Figure 4.



(a) (b) (c)

(d) (e) (f)

Figure 4 Surface micrographs of prepared particleboards
(a) side view of RPSPB (b) side view of RPPPB (c) side view of RPEPB
(d) over view of RPSPB (e) over view of RPPPB (f) over view of RPEPB

The surface morphologies of the prepared particleboards were studied by Digital Microscope (50 x-500 x). The micrographs were recorded at (300 x) magnification to ensure clear images. The surfaces of board (RPSPB) were the smoothest in all of three boards i.e. the fibers and plastics were not pulled out from the surfaces. In other word, the surfaces of the boards had less micropores and microcracks on it. This tends to increases MOR value and decreases WA and ST values of the boards. The surfaces from over and side views of RPEPB was more uniform than that of RPPPB but not than RPSPB. The properties of RPEPB were better than that of RPPPB. The surfaces of RPPPB were the roughest in all of them which tend to decrease the properties. It can be seen clearly that RPP resin was not completely soft and melt. The distribution of resinous plastics between the fibers was not enough to form uniform board. So, the surface structure of particleboards is related to the properties of particleboards.

Conclusion

Based on the results of the present work conducted, the density test results recorded the extreme value of 0.83, 0.90 and 0.94 g/cm^3 for the RPPPB, RPEPB and RPSPB respectively. The particleboard RPSPB recorded the least water absorption value of 9.31% while exhibiting the least swelling thickness value of 11.47 %. The moisture content range of all particleboards was (2.33 – 2.41 %). This very low moisture content value of prepared board is due to usage of plastics resin having hydrophobic property.

In the bending strength test, two types of particleboard RPSPB and RPEPB exhibited the large modulus of rupture (bending strength) values 232.70 kg/cm^2 and 163.21 kg/cm^2. The particleboard RPPPB had modulus of rupture value (108.41 kg/cm^2). The impact strength of particleboard RPSPB showed the lowest value of 42.60 kJ/m^2 with the lowest thickness value of 0.35 cm. The hardness value of particleboard RPSPB had the largest value of 94.95 Shore A. The surfaces from over view and side view of particleboard RPSPB were the most uniform. It was found that the particleboards prepared using betel nut shell fibers and RPS was the best particleboard due to the highest MOR, lowest WA and ST values. This research work will encourage in waste materials being efficiently utilized as a sustainable resource for the industrial manufacture of particleboards thus reducing the amount of wastes and eliminating the environmental pollution occasioned by the burning of such residues.

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