Composites: Part B 58 (2014) 10–15

Contents lists available at ScienceDirect

Composites: Part B

journal homepage: www.elsevier.com/locate/compositesb

Correlation between sound absorption coefficients with physical and mechanical properties of insulation boards made from sugar cane bagasse

Kazem Doost-hoseini [a], Hamid Reza Taghiyari [b,*], Abdollah Elyasi [a]

[a] Wood and Paper Sciences and Technologies Department, Faculty of Natural Resources, The University of Tehran, Iran
[b] Wood Science and Technology Department, The Faculty of Civil Engineering, Shahid Rajaee Teacher Training University, Iran

ARTICLE INFO

Article history:
Received 9 July 2012
Received in revised form 11 March 2013
Accepted 18 October 2013
Available online 29 October 2013

Keywords:
A. Fibers
D. Acoustic emission
D. Ultrasonics
D. Non-destructive testing
Bagasse

ABSTRACT

Physical and mechanical properties, as well as sound absorption coefficients, of insulating boards made of bagasse were studied here. Urea–formaldehyde (UF) and melamine–urea–formaldehyde (MUF) were used to produce homogeneous as well as three-layered insulating boards with three densities of 0.3, 0.4, and 0.5 g/cm^3. The obtained results indicated that resin-type had no significant effect on physical or mechanical properties; however it affected sound absorption coefficients. Physical and mechanical properties were significantly influenced by the density, while sound absorption coefficients were affected by the board-type. High correlation was found between the physical and mechanical properties; however, considering the low correlation between the physical and mechanical properties with the SAC values, it may be concluded that SAC could not be an authentic criterion to predict physical and mechanical properties in particleboards made of sugar cane bagasse.

1. Introduction

Sound insulation, otherwise known as sound reduction, is the prevention of sound being transmitted from one side of a wall or building to another. In a densely built living environment, particularly in terraced houses and blocks of flats, good sound insulation is a crucial part of living comfort; it must be possible to sleep, rest and work in a residence without disturbance from neighbors or other external noise. In this connection, composite-boards offer the advantages of a homogeneous porous material without restrictions as to the shape and size [6] as well as the possibility of a wide range of density. Limited sources of forests and wood necessitates the efficient use of agricultural residues such as bagasse is a desirable goal from both environmental and economic standpoints. Agro-based particleboards are manufactured from various lignincellulosic materials, usually wooden and mainly in the particle form, which are combined with an adhesive that consolidates under the action of temperature and pressure [19,23]. In fact, application of lignocellulosic sources for the production of particleboard depends primarily on the availability of the materials in the region; kenaf stem was used in many researches in the South–East Asian countries [1,2]). Different combinations of biofiber-composites were studied: PLA-flax, PLA-kenaf, PLLA-curaua, PLLA-hemp, and PHB-ramie [9]. The application of green composites in automobile body panels was reported to be feasible as far as green composites have comparable mechanical performance with the synthetic ones. Promising results were also reported in terms of mechanical performance and fire properties of kenaf-fiber-reinforced core by a thin halogen-free flame-retardant layer [4]. The main factors that influence the properties and quality of the composite-panels are the density of the panel, geometry, and moisture content of the particles, the pressing cycle, hot-press time and temperature; and the quantity and type of adhesive and many studied have been carried out to promote the quality of the resin and boards [3,8,12,21,24,26]. Low density of bagasse fibers make it suitable for the production of composite panels as to the fact that the compression ratio of the bagasse composite panels increases.

Use of agricultural fibers in building products represents a high-value application, in comparison to the common use as fuel or mulch. Bagasse fiber performs similarly to hardwood fiber in composite board products, and there has been considerable interest in developing such products [6]. This interest has run the gamut from cheaply produced products for local construction use [5] to more refined and dimensionally stable fiberboards [18] and particleboards [27,28]. Sugarcane, a very tall grass with big stems, is largely grown in countries like Brazil, Cuba, Australia, South Africa, Peru, Mexico, and India [17]. Bagasse, or sugarcane rind, is a fibrous

---

* Corresponding author. Address: Shahid Rajaee Teacher Training University, The Faculty of Civil Engineering, Wood Science and Technology Department, Lavizan, Shabanloo St.,Tehran, Iran. Tel.: +98 930 2005235; fax: +98 21 22970021.
E-mail addresses: htaghiyari@srttu.edu, htaghiyari@yahoo.com (H.R. Taghiyari).

1359-8368/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compositesb.2013.10.011

by-product of sugar extraction from sugarcane, *Saccharum officinarum* L. Another kind of bagasse, coconut bagasse, is also used in the industry [13,20]. Sugarcane bagasse consists of cellulose 43.8%, hemicellulose 28.6%, lignin 23.5%, ash 1.3%, and other components 2.8% [11]. The two former components are hydrophilic, and the latter is hydrophobic [22]. Bagasse fiber performs similarly to hardwood fiber in composite board products; thus, it could be very important for countries that lack of wood fiber [15]. However, only a very small portion of the bagasse is reused to produce high-valued product, such as paper and bio-based products [10]. In fact, sugarcane bagasse is considered either as a waste, affecting the environment, or as a resource when appropriate valorization technologies are implemented [14]. Sugarcane bagasse, in combination with coconut husk, has also had promising results in the production of thermal insulation boards [13].

There are numerous fields in the Southern provinces of Iran cultivating Sugar Cane for the production of sugar. However, bagasse as a side product was previously considered a residue. In recent years, however, there have been studies on establishment of factories for the manufacturing of particleboard from sugar cane bagasse because the abundance of this raw material made the project economically logical. In the meantime, petrochemical insulation boards are used in vast quantities as a construction materials; so that would be reasonable to study the production of insulation boards made from some other sources too. In this connection, the use of bagasse in the production of sound absorbing insulation boards with different densities as well as two different resins is studied here to evaluate the results of resin-type as well as density [7] in particleboards made from sugar cane bagasse. Furthermore, the correlations between the sound absorption coefficients at different frequencies with the physical and mechanical properties of the boards are also to be studied.

2. Materials and methods

The bagasse fibers were procured from Imam Khomeini Farms located in Shooshtar city in the Southern parts of Iran. They were dried with a rotary dryer for 90 min to the final moisture content of 2%. The temperature of the drier was about 70 °C. Once dried, they were put in plastic bags and sealed. For homogeneous boards, no separation was made in the fibers; however, for multi-layered boards, fibers were passed through laboratory sieves to be separated into two groups of small- and large-sized fibers.

Urea–formaldehyde (UF) and melamine–urea–formaldehyde (MUF) were procured from Siran-Chemistry Factory in Iran. Specifications of the resins used are summarized in Table 1. For all treatments and both resins, the resin-content was 12%, based on the dry-weight basis of the fibers. Chloride ammonium (1%) was used as catalyst.

Both homogeneous as well as multi-layered boards were produced with three densities of 0.3, 0.4, and 0.5 g/cm^3. Moisture content (MC) of the mat was 10%. A Burkle-LA 160 laboratory hot press was used to produce the boards. Specific pressure of the plates was 15 kg/cm^2; total nominal pressure of the plates was 100 kgf. Temperature of the hot-press plates were fixed at 170 °C. The press time of all treatments was fixed at 4 min. Thickness of all boards was controlled by stopper bars to be fixed at 12 mm ([16]). Totally, twelve treatments were produced; for each treatment, five replications were made. Boards were kept in the conditioning chamber (30 °C, and 40–45% relative humidity) for 21 days before the tests were carried out on them [25]. Physical and mechanical tests were carried out in accordance with the ISIRI 9044 PB Type P2 (compatible with ASTM D1037-99 2007) specifications. Specimens were tested using INSTRON 4486 test machine, with 5 KN capacity. Sound absorption coefficient (SAC) was carried out in accordance to DIN-68763; five different frequencies of 250, 500, 1000, 2000, and 4000 Hz were measured for each single specimen, using standing wave apparatus type 4002, sine random generator type 1024, and beat frequency oscillator type 1022.

Two-way analysis of variance (ANOVA) was performed, using SAS software program, version 9. (2008), to discern significance difference at 95% level of confidence. Regression and hierarchical cluster analysis, including dendrogram and using Ward methods with squared Euclidean distance intervals, were carried out by SPSS/18 (2010).

3. Results and discussion

The obtained results indicated that the highest modulus of rupture (MOR) was obtained in the homogeneous board with the highest density of 0.5 g/cm^3 using MUF resin (11.84 MPa); and the lowest MOR was found in the multi-layered board with the lowest density of 0.3 g/cm^3 using UF resin (2.99 MPa) (Fig. 1). A significant increasing trend was seen in the MOR values as the density increased; this increasing trend in the MOR values was seen in both types of the boards. This clearly showed the impact of compression of fibers in forming high integration among the chips and fibers, resulting in the improvement of the bonds in the board matrix.

No clear trend was observed between the two resins of UF and MUF. UF showed lower MOR in homogeneous board with 0.4 g/cm^3 of density; however, in the three-layered boards, MUF showed the lower value. Furthermore, MOR values did not show much difference when the resin was changed in each treatment, or even when the board type was changed (Fig. 1). It can therefore be concluded that the bending strength of the boards is more influenced by the density rather than the resin- or board-types.

The highest internal bond value was observed in the homogeneous board with 0.5 g/cm^3 in density using MUF resin (0.407 MPa); the same treatment as the highest MOR was also seen. IB values also showed a clear significant positive correlation with the density. Three-layered boards showed less values in comparison to their corresponding values in the homogeneous treatments (Fig. 2). As to the fact that the fibers in the middle layer of the mat were comprised of only large fibers in size, this lower IB values is quite reasonable, because the integration and surface to surface bonds between fibers of larger sizes are less than those having smaller sizes.

No significant difference was observed in the WA values between the two resins of UF and MUF in either of the board types (Fig. 3). Although not significantly different from their three-layered counterpart, the highest water absorption was observed in the homogeneous board with the lowest density of 0.3 g/cm^3. With due consideration to the more compression ratio in the surface layer of the multi-layered board treatments, this less water absorption in these treatments may be reasoned. In fact, the more integrity between the surface-layer-matrix may decrease its permeability towards the penetration of water.

Table 1
Specifications of the urea formaldehyde and melamine urea formaldehyde resins.

Resin type	Density (g/cm^3)	Solid (%)	pH	Viscosity (cP)	Gel time (s)
Urea formaldehyde (UF)	1.25	59	6.8–7.1	200–240	50–65
Melamine urea formaldehyde (MUF)	1.225	56	8–9	90–100	70–80