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Mechanical properties and dimensional stability of cement bonded particleboard from rice husk and sawdust

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Abstract

This study was conducted to evaluate the properties of cement bonded particleboard made from rice husk and sawdust. Sawdust and rice husk fine boards were made using two ratios of cement and particles of 70:30 and 80:20, but rice husk coarse was made with a ratio of cement and particle of 80:20. The density of sawdust and rice husk fine boards in a ratio of cement and particles of 70:30 was 960 and 880 kg/m^3 respectively. If the cement ratio was increased to the ratio of 80:20, the density increased to 1140 and 1200 kg/m^3 respectively. The density of rice husk coarse boards was 980 kg/m^3. The MOR of boards made from saw dust and rice husk fine in a ratio of 70:30 was 5.36 and 2.48 N/mm^2 respectively. It was 5.30 and 4.63 N/mm^2 in a ratio of 80:20. The MOE of saw dust and rice husk fine boards in a ratio of 70:30 was 3302.96 and 1684.52 N/mm^2, and in a ratio of 80:20 it was 3569.28 and 3139.27 N/mm^2 respectively. The MOR and MOE for rice husk coarse boards were 6.08 and 3041.71 N/mm^2 respectively. Rice husk fine and rice husk coarse board showed excellent properties in a ratio of cement and particles of 80:20. Therefore, rice husk can be an alternative source of raw material for manufacturing of cement bonded particleboard.

Keywords: Cement bonded particleboard, Rice husk, Modulus of rupture (MOR) and Modulus of elasticity (MOE).

Introduction

Recently, considerable changes in the housing and building construction industries have been taking place. Particularly, wood-based materials, and composite panel products bonded with either organic or inorganic binders are gaining importance. One of the composite materials that have attracted interest worldwide is the inorganic bonded panel products. Wood particles bonded together with an inorganic material such as ordinary portland cement (OPC) are referred to as cement-bonded particleboard (CPB). 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 gaining momentum. Important aspects that CPBs seem to demonstrate sensitive ecological climate such as its attraction in extending the use of wood waste and agricultural residues. These wastes have been considered as environmental problems and in addition avoid the risks of formaldehyde emission during production and usage.

The most widely used inorganic-bonded composites are those bonded with portland cement. Portland cement, when combined with water, immediately reacts in a process called hydration to eventually solidify into a solid stone-like mass. Successfully marketed portland-cement bonded composites consist of both low-density products made with excelsior and high-density products made with particles or fibers.

The low-density products may be used as interior ceiling and wall panels in commercial buildings. Low density composites bonded with portland cement offers sound control and can be quite decorative. In some parts of the world, these panels function as complete wall and roof decking systems. The exterior and interior of the panels is plastered. High-density panels can be used as flooring, roof sheathing, fire doors, load bearing walls, and cement forms. Fairly complex molded shapes can be molded or extruded, such as decorative roofing tiles or non-pressure pipes (Anon., 1987).

Because of the increasing scarcity of wood raw materials, the effort to find wood substitute is always encouraged. Non-wood lignocellulosic materials have been considered to produce various building materials. One of the main potential utilizations of these materials is conversion into composite panels. Considerable research studies have been conducted on sorghum, sunflower, cotton and corn stalks (Chow, 1974; Pablo *et al.,* 1996; Kimura *et al.*, 1996). Recently, the bast

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family of plants including kenaf, hemp, jute and flax has aroused a great interest. These bast fiber crops are noted for the strength of their fiber bundles. The studies showed that these crops are promising to manufacture high-performance composite boards (Rowell, 1997; Ohnishi *et al.,* 2000). With the largest yield in the non-wood lignocellulosics, cereal straw is probably the second most common agricultural materials for panel production (Youngquist, *et al.,* 1996).

The general physical and chemical characteristics and structures of non-wood lignocellulosic materials are different from wood. Most of these materials have very low density, which make them extremely bulky (Chow, 1974; Youngquist *et al.*, 1993). The high bulk density of non-wood materials restricts their utilization in composite panels. However, some agricultural residues were also used for board production. Sugarcane bagasse and rattan shavings were used both in the conventional and rapid curing methods in board production. Also, initial studies on the utilization of tobacco stalks, coco-coir fiber, cotton stalks and some bamboo species for cement bonded boards were found technically viable (Eusebio, 2000; Eusebio, 2002). Cement-bonded boards made from these materials possessed properties that are comparable with boards made from wood wool or excelsior provided the pretreatments are properly applied. The objective of this study was to evaluate the physical and mechanical properties of rice husk cement-bonded board with an aim to assess these raw materials in making value added products.

Materials and methods

Rice husk fine, rice husk coarse and sawdust were used to make cement-bonded particleboard. Rice husk fine, rice husk coarse and sawdust were collected respectively from a village in Koyra upazila, Batiaghata thana and Tutpara in Khulna District, Bangladesh. Ordinary portland cement (Holcim cement) collected from the market was used as the binder. The cement-bonded particleboards were made with cement: oven dry particle weight ratios of rice husk fine [70:30 and 80:20], rice husk coarse [80:20] and sawdust [70:30 and 80:20].

To obtain a uniform distribution of cement, particle and water, the mixing procedure was carried out systematically in a pan by spreading first the required amount of water into the particles followed by the addition of the cement. Mixing was continued until the particles were covered completely with cement. Each mixture was hand-formed into a square 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. Hand formed mats measuring 190mm × 190 mm were cold pressed. These were kept in pressing condition for 1 hour. After pressing, the mats were kept at room temperature for 2 to 3 weeks. Water was sprayed frequently for proper curing of the cement-bonded particleboards.

Specimens were cut from the boards after conditioning and tested according to ASTM in Universal Testing Machine in Khulna University of Engineering and Technology, Khulna. The specimen size for bending test was 180mm × 50 mm and the span was adjusted to 120 mm. The sample size for thickness swelling (TS) and water absorption (WA) test were 50mm × 50 mm. All the samples were sanded properly.

Modulus of Elasticity (MOE) was calculated from the following equation

$$MOE = \frac{P^{/} L^3}{4\Delta^{/} bd^3}$$ (Desch and Dinwoodie, 1996).

Where, MOE = is the modulus of elasticity in bending, in N/mm2, P´ = is the load, in N at the limit of proportionality, L = is the span, in mm, Δ´ = is the deflection, in mm at the limit of proportionality, b = is the width, in mm, d = is the depth, in mm.

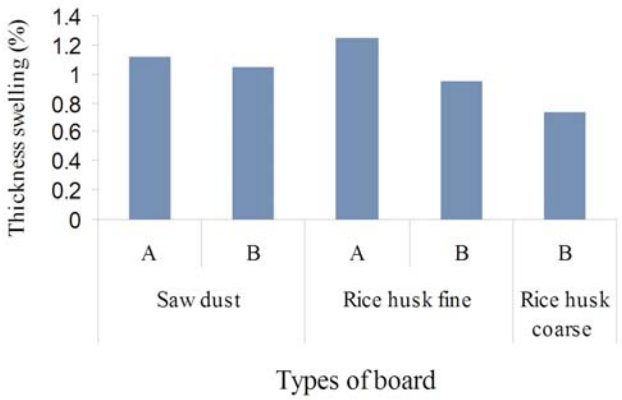
The modulus of Rupture (MOR) was calculated from the following equation:

$$MOR = \frac{3PL}{2bd^2}$$ (Desch and Dinwoodie, 1996).

Where, MOR = modulus of rupture, in N/mm^2, P= is the load, in N, L= is the span, in mm, b= is the width, in mm, d= is the depth, in mm.

Results and Discussion

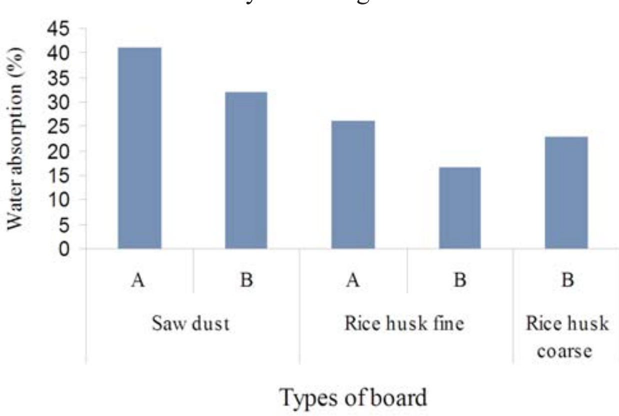
The density of saw dust and rice husk fine boards bonded with cement was 960 and 880 kg/m^3 respectively in a ratio of cement particle 70:30 (Fig. 1). The density of sawdust and rice husk fine boards increased when the ratio of cement to particles was increased from 70:30 to 80:20. The density of saw dust and rice husk fine board was 1140 and 1200 kg/m^3 at a ratio of 80:20 (Fig. 1). In case of rice husk coarse board at a ratio of 80:20, the density was 980 kg/m^3 (Fig. 1). The density of cement bonded particleboard from pine (*Pinus pinaster* Ait) was 1630 kg/m^3 in a ratio of cement to wood of 85:15 and 1460 kg/m^3 in a ratio of cement to wood of 80:20 and from blue gum (*Eucalyptus globules* Labil.) was 1600 kg/m^3 in a ratio of 85:15 and 1520 kg/m^3 in a ratio of 80:20 (Anon., 1996). The density obtained in this study (cement bonded board from rice husk and saw dust) was much lower.



A= Cement: Particle 70:30 B= Cement: Particle 80:20

Fig. 1: Density of cement bonded particleboard

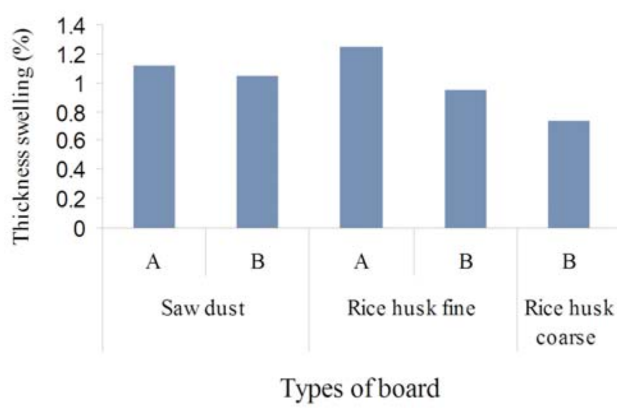
The absorption of water reduced significantly with the increase of percentage of cement both in cement-sawdust board and cement-rice husk board. It was found that after 24 hours the absorption of water by sawdust board and rice husk fine board were 40.95 and 25.96% respectively in a ratio of cement to particle of 70:30 (Fig. 2). The water absorption was 31.91, 16.67 and 22.97% in sawdust, rice husk fine and rice husk coarse board respectively in a cement particle ratio of 80:20 (Fig. 2). The absorption of water in the rice husk board was significantly lower than sawdust board in both 70:30 boards and 80:20 boards. The water absorption of cement bonded sawdust board varied from 31.91% in a density of 1140 kg/m^3 to 40.95% in a density of 960 kg/m^3. In cement bonded rice husk fine board water absorption varied from 16.67% in a density of 880 kg/m^3 to 25.96% in a density of 1200 kg/m^3. It is reported that water absorption decreased with increasing board density (Sulastiningsih *et al.,* 1996). According to physical and mechanical properties of bamboo-cement board in a density range of 600 to 1000 kg/m^3 the water absorption was 48.19 to 34.21% with mineralizer $CaCl_2$ and 54.30 to 36.58% with mineralizer $Ca(OH)_2$ (Sulastiningsih *et al.,* 1996). Water absorption obtained in this study (cement bonded board from rice husk and saw dust in a ratio of 70:30 and cement-bonded board from rice husk coarse in a ratio of 80:20) without mineralizer was lower.



A= Cement: Particle 70:30 B= Cement: Particle 80:20

Fig. 2: Water absorption of cement bonded board

The thickness swelling was 1.11 and 1.24% in sawdust and rice husk fine boards, respectively in a cement particle ratio of 70:30 (Fig. 3). The thickness swelling was 1.05, 0.95 and 0.73% in sawdust, rice husk fine and rice husk coarse boards, respectively in a cement particle ratio of 80:20 (Fig. 3). Though thickness swelling of cement-sawdust board was lower than cement-rice husk fine board in 70:30, with the increase of percentage of cement that is with the increase of board density, thickness swelling reduced significantly in the rice husk fine boards. As a result the percentage of thickness swelling in rice husk fine board was lower than cement-sawdust board in a ratio of 80:20. In general, the thickness swelling after a long duration of water immersion have a tendency to increase with decreasing board density because of the greater spring back of compacted particle in boards of lower density incase of rice husk board (Hermawan, 2001). In case of bamboo-cement board in the density range of 600 to 1000 kg/m^3 the thickness swelling range was 4.02 to 1.66% with mineralizer $CaCl_2$ and 3.60 to 1.62% with mineralizer $Ca(OH)_2$ (Sulastiningsih *et al.,* 1996). The water absorption obtained in this study (cement bonded board from

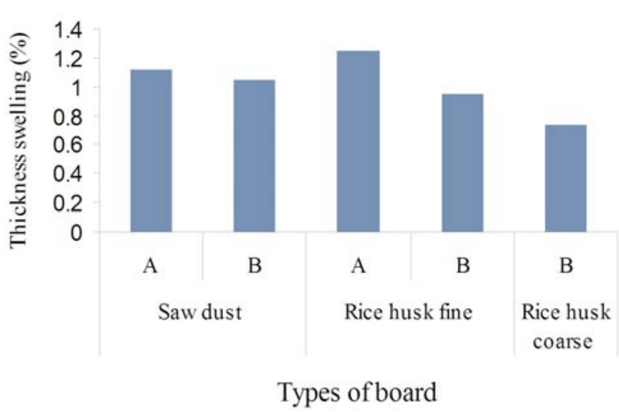


A= Cement: Particle 70:30 B= Cement: Particle 80:20

Fig. 3: Thickness swelling of cement bonded board.

rice husk and saw dust in a ratio of 70:30 and cement bonded board from rice husk coarse in a ratio of 80:20) without mineralizer was much lower.

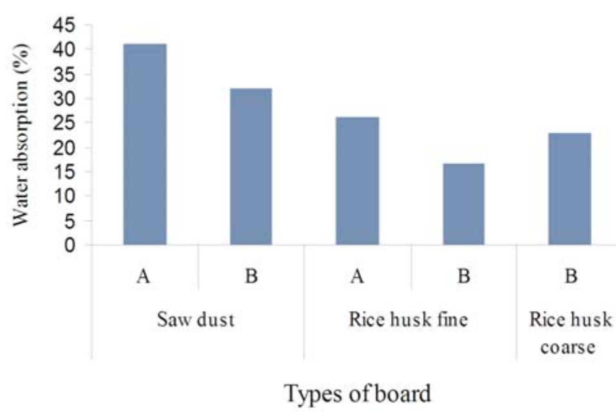
The modulus of rupture (MOR) of boards in a ratio of cement and particle of 70:30 made from saw dust and rice husk fines was 5.36 and 2.48 N/mm^2 respectively. However, in a ratio of cement and particle of 80:20 the MOR was 5.30, 4.63 and 6.08 N/mm^2 for sawdust, rice husk fine and rice husk coarse boards, respectively (Fig. 4). It is seen in Fig.1 that in a ratio of 70:30 the density between saw dust and rice husk fine boards was almost similar. However the MOR of the cement bonded saw dust board was more than double than that of rice husk fine board. When the ratio of cement particle was increased to 80:20, a remarkable increment of MOR was observed in case of rice husk fine board. The MOR of rice husk fine cement bonded board at 80:20 ratio was 4.63 N/mm^2. The most significant result was noticed in case of rice husk coarse board. It exceeded 6 N/mm^2. It is reported that the MOR value was 9-13 N/mm^2 in wood-cement particleboard at the target density of 1200 kg/m^3 (Harmawan, 2001). The MOR was 3.90 and 4.01 N/mm2 in cement bonded particleboard from pine (*Pinus pinaster* Ait) in a cement and wood ratio of 85:15 and 80:20 with a density of 1630 and 1460 kg/m^3 respectively (Pereira *et al.,* 2004). The MOR was 3.83 and 5.80 N/mm^2 in cement bonded blue gum (*Eucalyptus globules* Labil.) particleboard in a cement and wood ratio of 85:15 and 80:20 with a density of 1630 and 1460 kg/m^3 respectively. The MOR of bamboo-cement board with a density of 890 kg/m^3 was 8 N/mm^2 (Anon., 1996). Compared to bamboo-cement board, the MOR of cement-bonded rice husk board and saw dust board was comparatively lower.



A= Cement: Particle 70:30 B= Cement: Particle 80:20

Fig. 4: MOR of cement bonded board

The modulus of elasticity (MOE) of saw dust and rice husk fine cement bonded boards in a ratio of cement and particles of 70:30 was 3302.96 and 1684.52 N/mm^2; but in a ratio of cement and particle 80:20, the MOE of saw dust, rice husk fine and rice husk coarse boards was 3569.28, 3139.27 and 3041.71 N/mm^2, respectively (Fig. 5). It was observed that with increasing of the ratio of cement, MOE increased significantly in cement bonded rice husk board. However, the value of MOE of cement bonded sawdust board was almost similar on various proportion of cement. The MOE was 6897 and 3719 N/mm^2 in cement bonded particleboard from pine (*Pinus pinaster* Ait) in a cement and wood ratio of 85:15 and 80:20 with a density of 1630 and 1460 kg/m^3 respectively (Pereira *et al.*, 2004). The MOE was 7008 and 4961 N/mm^2 in cement bonded blue gum (*Eucalyptus globules* Labil.) particleboard in a cement and wood ratio of 85:15 and 80:20 with a density of 1630 and 1460 kg/m^3 respectively (Pereira *et al.,* 2004).



A= Cement: Particle 70:30 B= Cement: Particle 80:20

Fig. 5: MOE of cement bonded board.

According to general properties of low-density cement-wood composites in a specific gravity range, 0.5 to 1.0, the modulus of rupture was 1.7 N/mm^2 to 5.5 N/mm^2 and the modulus of elasticity 621 N/mm^2 to 1241 N/mm^2 (Wang and Xu, 1994). The data of MOR and MOE obtained in this study satisfies the specified property in a ratio of 70:30 for cement bonded saw dust and rice husk fine particleboard and in a ratio of 80:20 for cement bonded rice husk coarse board. The results obtained for the MOR of the panels in this study were significantly lower than the European standard (>9 N/mm^2) when the density ranges from 1200 to 1300 kg/m^3 (Anon., 1996). Particle size plays an important role in mechanical properties of board. Length and thickness are important factors for board quality. It is expected that surface quality and internal bond strength are higher with small particles (Pereira *et al.*, 2004).

Conclusion

Effective utilization of forest resources and valuable uses of agricultural products may be possible by using sawdust and rice husk as an alternative raw material in cement bonded particleboard industry. It may help to reduce pressure on forest. Both thickness swelling and water absorption values of cement bonded rice husk board can be reduced greatly with increasing board density by increasing cement-particle ratio. The MOR value of cement bonded rice husk board can also be enhanced by increasing the cement-particle ratio. The MOE value of cement bonded rice husk fine board was almost double in a ratio of cement particle 80:20 compared to the ratio of 70:30. Both cement bonded saw dust and rice husk board at a density level of 1000 kg/m^3 satisfy the standard of the low density cement bonded board. Further study is necessary to improve the mechanical properties of cement bonded rice husk board.

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