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MECHANICAL PROPERTIES OF CEMENT-BONDED COMPOSITE BOARD PRODUCED FROM ASEPTIC CARTON WASTE

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ABSTRACT
The mechanical and physical properties of cement-bonded boards (CBBs) made from aseptic carton waste were investigated. The aseptic carton waste cement boards (ACWCB) were produced at density of 800, 1,000 and 1,200 kg/m^3 and at four cement-to-fibres ratios, i.e. 80:20, 70:30 and 60:40 by weight. The mechanical and physical properties evaluated were modulus of rupture (MOR), modulus of elasticity (MOE), water absorption (WA), and thickness swelling (TS). MOR and MOE of the ACWCB increased with the increase of board density. On the other hand, WA and TS decreased with the increase of board density and cement content. The physical and mechanical of the optimum cement-to-fibres ratio with density of 1,000-1,200 kg/m3 of ACWCB demonstrated their good characteristics when comparing with the commercial Para wood cement board.

Keywords. Aseptic carton waste, cement-bonded boards, modulus of rupture, modulus of elasticity, thickness swelling

1. INTRODUCTION

Aseptic cartons are made primarily of paperboard (75 %) with thin layers of plastic (20 %) and aluminum (5 %), allowing liquid food to be safely stored at room temperature without preservatives. Figure 1 shows the dominating structure of an aseptic carton package. In 2007, more than 137 billion aseptic carton packages were delivered to every corner of the world (Tetra Pack, 2009). As a result, the amount of aseptic carton waste (ACW) is continuously increasing in municipal solid wastes. Thus, recycling of the ACW to the value-added products such as shopping bags, cores for paper reel, sheets of cardboard, disposable kitchen towels, printing paper, plaster board lining, and corrugated board is important from economic and environmental viewpoint (A., Korkmaz et. al., 2009). However, only 313,000 tons of ACW were recycled within a total capacity of 12 billion tons recyclable material that represents the recycling rate of 30% in Europe (Anonymous, 2007). Furthermore, the recycle of ACW is not popular in developing country due to the complicated and high technology in manufacturing process.

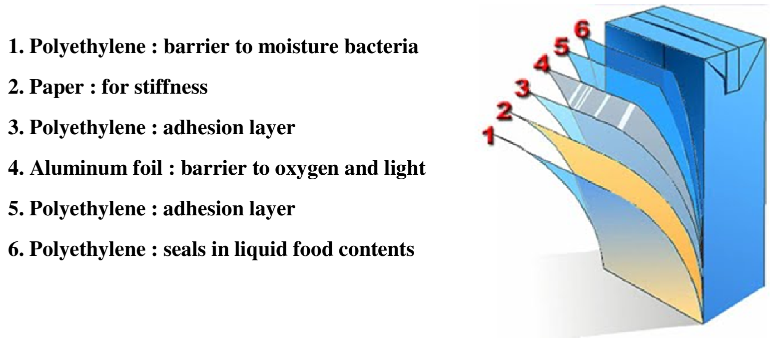


Figure 1. The dominating structure of aseptic beverage cartons (Buelens M., et. al., 2001)

Over the last two decades, the application of fibres in cement based composites has been gaining momentum and been applied to enhance the properties of various construction materials. One of the most important cement composites is Fibre Cement Board (FCB) used in flat or corrugated shape. They can be used as a material for roofing, internal/external wall, and facade. The most important ingredients to produce FCB are fibres, cement, and water (M., Khorami and E., Ganjian., 2011). Much effort has been devoted to wood fibres because they possess many advantages such as availability, lower cost, simple production processes for making cementitious composites of various shapes, renewability and recyclability, non-hazardous nature, and biodegradability (Bentur A, Midness S., 1990).

In Thailand, the parawood cement board (PWCB) has widely used as construction materials for more than four decades. This type of board was developed by Cellocrete Thai co. Ltd.. Cellocrete Sheet is manufactured by mixing cement with Parawood wool and compressing tightly by machinery. It is used as a substitute for wood in building walls, roofs, ceilings, concrete slab formworks, etc. (www.cellocretethai.com). Figure 2 shows the sample of PWCB sheet. Unfortunately, the lack of Parawood was the main problem adversely affecting the cost and manufacturing of PWCB. Recently, J. Kawklum et. al. (2010) applied aseptic carton waste fibres as fibre reinforcement in concrete. Interestingly aseptic carton waste fibres, which are broadly accessible in most developing countries, can be used as alternative materials for brittle cement matrix reinforcement.

The objective of this study is to evaluate important physical and mechanical properties of cement-bonded boards made from aseptic carton waste. The aseptic carton waste cement board (ACWCB) were produced at density of 800, 1000 and 1,200 kg/m^3 and at four cement-to-fibers ratios, i.e. 60:40, 70:30 and 80:20, by weight. The mechanical and physical properties evaluated included modulus of rupture (MOR), modulus of elasticity (MOE), water absorption (WA) and thickness swelling (TS). The comparative study with Para wood cement board (PWCB) was also conducted.

Figure 2. Parawood cement board (PWCB, Cellocrete$^{(R)}$)

2. MATERIALS AND METHOD

2.1 Materials

ASTM C150 type I Ordinary Portland Cement (OPC) was used as binding material. The water to cement ratio was kept constant at 0.6. Stretched and cleaned aseptic carton waste was supported from Vongpanit Co. Ltd. The aseptic carton waste was manufactured into 4 x 100-150 mm^2 fibres by using paper shredder.

2.2 Mix Design and Specimen Preparation

The aseptic carton cement boards (ACCBs) were produced at density of 800, 1000, and 1,200 kg/m^3 and at three cement : fibres ratios, i.e. 60:40, 70:30 and 80:20, by weight, respectively. The mix containing ACW fibres, cement, and water was uniformly spread in a steel mould of 300 x 300 mm^2 in size. The mix was pressed hydraulically by controlling the approximate target density of specimen, so that the 20 ± 1 mm thick specimen was obtained. The whole assembly of the mould and plunger was kept in the pressed position for the specified time of 12 hours (L.K. Akkarwal et.al., 2008). A 20 tonne capacity of hydraulic pressure was used for making the boards into different density as shown in Figure 3. After demolding, all specimens were air cured at room temperature of 25±2^{o}C as shown in Figure 4.

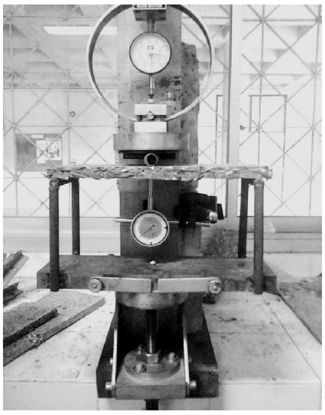
Figure 3. Molding system set with 20 tonne hydraulic pressure

Top **Edge**

Figure 4. ACWCB after demolding

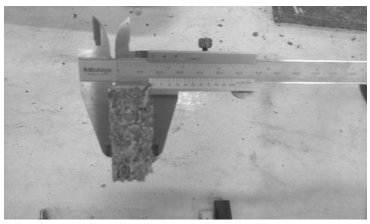
2.3 Cement Board Test

Physical and mechanical properties were carried out on the specimens split up from the 30 x 30 cm^2 panels as illustrated in Figure 3. Air dry density, water absorption (WA), thickness swelling (TS), modulus of rupture (MOR), and modulus of elasticity were investigated in accordance with Thai Industrial Standard (TIS 966-2547). The Parawood fibres cement board (Cellocrete$^{(R)}$ sheet) was also tested for comparison. The ACWCB after demolding was illustrated in Figure 5.



MOR and MOE test set up

Absorption test



Thickness swelling test

Figure 5. Physical and mechanical test set up

3. RESULTS AND DISCUSSION

The average values of testing results were summarized and showed in Table 1. The influence of fibres content and observed density on physical and mechanical properties was discussed separately.

3.1 Physical Properties

Air-dry density values of ACWCB specimens ranged from 825 to 1190 kg/m^3 which 0.6-6% differed from target density. Influence of fibres content with different density on water absorption (WA) and thickness swelling (TS) were illustrated in Figure 6 and Figure 7, respectively. The WA of ACWCB ranged from 10.9 to 27.3 %. The TS of ACWCB ranged from 0.84-2.12 %. While the WA and TS of PWCB was found to be 44.5 % and 2.18 %, respectively. Based on the results, the increase in cement content and density of ACWCB was significantly decreased with WA and TS. The WA and TS values of all series of ACWCB are much less than those of the PWCB.

Table 1 Average values of physical and mechanical properties of ACWCB and PWCB

Target Density	Fibres/Cement ratio	Air-Dry Density Kg/m^3	MOR MPa	MOE MPa	WA %	TS %
800 kg/m^3	40:60	825±29.7	2.30±0.70	1,265±103.4	27.29±3.75	1.84±0.34
	30:70	795±32.0	2.27±0.87	1,378±183.4	24.05±0.22	1.75±0.18
	20:80	787±16.5	2.00±0.53	1,310±105.0	21.84±3.78	1.81±0.08
1,000 kg/m^3	40:60	1,052±21.1	2.52±1.01	1,389±215.6	27.34±7.52	2.12±0.45
	30:70	1,032±28.2	3.08±0.72	1,933±182.0	20.12±4.65	1.87±0.28
	20:80	955±17.5	2.40±0.24	1,270±70.5	18.29±2.18	1.00±0.03
1,200 kg/m^3	40:60	1,190±8.78	3.57±0.67	1,852±202.2	18.83±5.88	1.96±0.51
	30:70	1,117±17.1	3.67±1.03	2,020±282.8	17.58±0.35	0.97±0.13
	20:80	1,187±18.4	2.95±0.46	1,778±113.4	10.87±3.23	0.84±0.07
PWCB		755±22.45	2.99±0.33	1,874±121.5	46.55±6.66	2.08±0.07

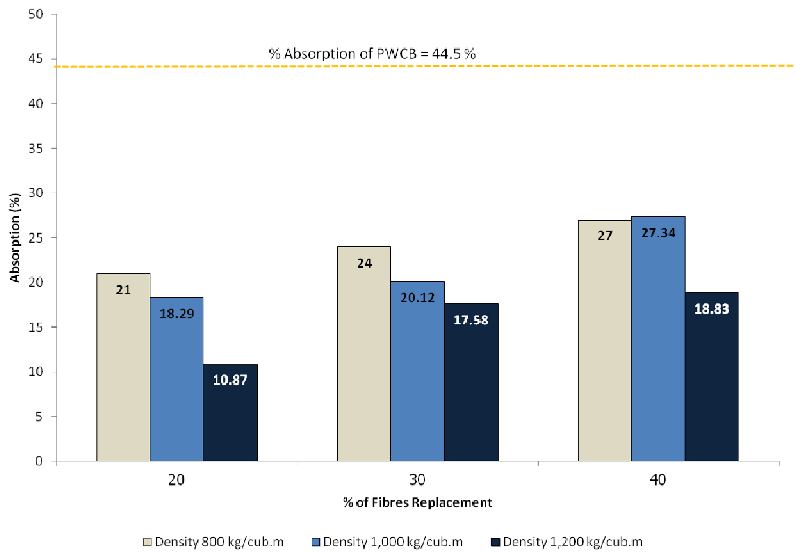


Figure 6. Influence of fibres content with different density on average water absorption

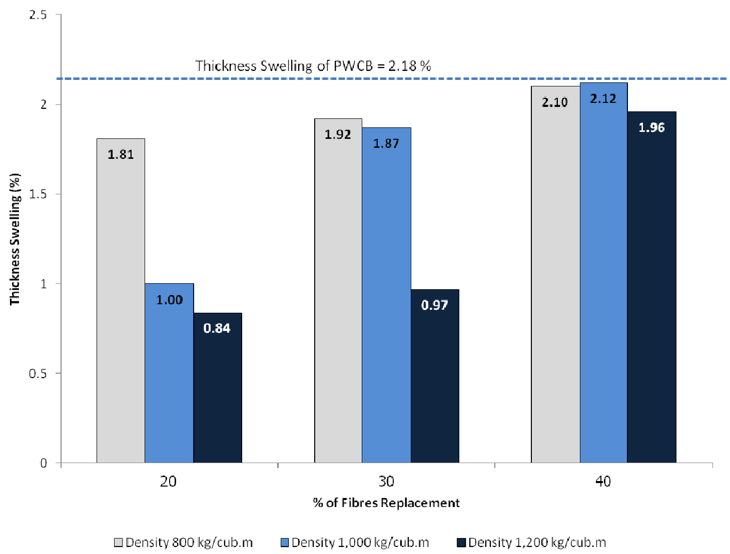


Figure 7. Influence of fibres content with different density on average thickness swelling

3.2 Mechanical Properties

The influence of fibres content with different density on MOR and MOE was illustrated in Figures 8 and 9, respectively. The MOE of ACWCB ranged from 2 MPa to 3.67 MPa. The MOR of ACWCB ranged from 1,270 MPa to 2,020 MPa. While the MOR and MOE of PWCB was 2.99 MPa and 1,878 MPa, respectively. The specimens with cement-to-fibres ratio of 70:30 and the density of 1,200 kg/m^3 had the greatest values of MOR and MOE, i.e. 3.67 MPa and 2,020 MPa, respectively. As noted in Figure 8-9, the higher the density, the higher the MOR and MOE. Specimens with the fibres content of 30% and the density of 1,000-1,200 kg/m^3 had greater values of MOR and MOE in comparison to that of PWCB. It was found from the load deflection curves that the brittle phenomenon of cement boards was found when the percent of fibres was 20%, whereas the ductile phenomenon was found when the percent of fibres was greater than 30%. Based on the results obtained, it can be summarised that the optimum fibres content for producing ACWCB was 30%. This observation needs to be investigated for describing this phenomena including more samples and micro structural analysis using scanning electron microscopy techniques (SEM), which would help explanation.

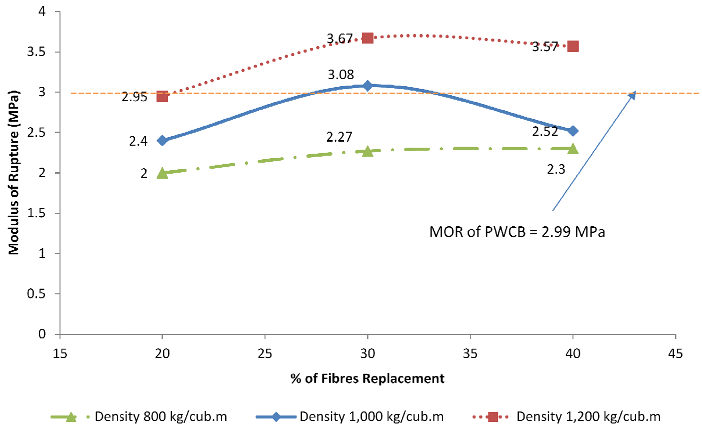


Figure 8. Influence of fibres content with different density on modulus of rupture

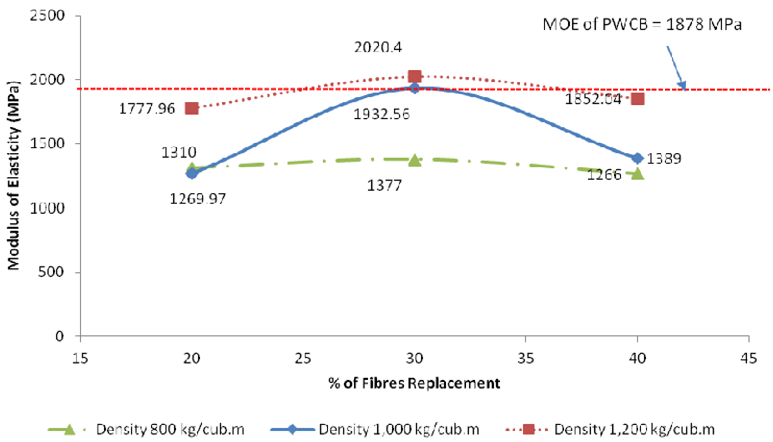


Figure 9. Influence of fibres content with different density on modulus of elasticity

4. CONCLUSIONS

- The increase of cement content and density of ACWCB significantly decreased WA and TS. The WA and TS values of all series of ACWCB are much less than that of PWCB.
- MOR and MOE of the ACWCB increased with increase of board density. The specimens with the cement-to-fibres ratio of 70:30 and the density of 1,200 kg/m^3 had the greatest values of MOR and MOE, which are 3.67 MPa and 2020 MPa, respectively. Thus, the optimum cement-to-fibres ratio for ACWCB production was 70:30 percent by weight.
- Comparison of the physical and mechanical of the optimum cement-to-fibres ratio with density of 1,000-1,200 kg/m3 of ACWCB to commercial board (PWCB) demonstrated their good characteristics.

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