Mechanical And Physical Properties of Gypsum-Paper Sludge Board

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Abstract

This research was carried out in order to determine the mechanical and physical properties of Gypsum-Paper sludge Board. The sample was manufactured by mixing gypsum cement with paper sludge, with different proportion 90:10, 80:20, and 70:30 respectively. Bending strength, internal bonding strength, water absorption and moisture content was carried out based on Japanese Industrial Standard; JIS A 5908:2003 Particleboard (2003) and JIS A 6901:2005 Gypsum Boards (2005). From the result, it shows that 80:20 mixing ratio, the modulus of rupture (MOR), Modulus of Elasticity (MOE) and internal bond strength shows the better performance compared to 90:10 and 70:30 mixing ratio. By increasing addition of sludge, the strength was slightly decreased. The water absorption was increased parallel to each other on the increasing of sludge addition. In conclusion, paper sludge can be used as a substituted filer in gypsum board manufacturing for furniture application.

Keyword: *gypsum board, gypsum cement, paper sludge*

INTRODUCTION

Paper sludge has been known as the waste from pulp and paper industry. It produced during paper wood pulping in papermaking process (Asghar, 2006). The disposal cost of paper sludge is approximately half of the cost of wastewater treatment (Anon, 1986). Many of the pulp and paper industry manufacturers are very interested in reducing the paper sludge disposal cost through recycling and reuse. Paper sludge was considered as industry waste that did not being fully utilize as the source of new lignocellulosic material, which contain about 60% dry matter mainly composed of cellulose fibers, kaolinite, and calcite (Jean and Achène, 1998). Compare to the waste from other mill such as sawdust, wood end cut, furniture manufacturing, there are fully utilize by doing many value added product that can give many benefit to human and environment.

Paper sludge generated by the paper industry is generally composed of organic fibers (cellulose, hemicelluloses and/or lignin), inorganic fillers and coating materials such as kaolinite ($Al_2Si_2O_5(OH)_4$), limestone ($CaCO_3$) and starch (Hojamberdiev, 2008). Normally, paper sludge is usually disposed of in open dumps or in landfills, recycles as compost or incinerated for energy recovery in the manufacturing process. The use of industrial residues to replace wood as raw materials for wood base products has received considerable attention in recent years.

Through various studies, paper sludge has been demonstrated capable of serving as new reinforcing filler in the manufacturing of thermoplastic polymer composite (Son, 2004; Eom et al., 2000). From the research, it shows that the density and

tensile properties of the composite increased as the concentration of the paper sludge increased. A few research efforts have been conducted on using paper sludge in wood-based panels, such as particleboard (Taramian, 2006). Fernandez et al. (2001) showed that successful utilization of paper sludge as filler in cement board. He indicated that the cement board containing paper sludge had comparable mechanical and physical properties compared to conventional cement boards. The production of medium density fiberboard (MDF) using paper sludge was also had been carried out and it reported that all panels met quality requirements for MDF used for interior applications (Migneault et al., 2010). Paper sludge was also used as sorption materials of solid waste in water treatment (Hojamberdiev, 2007). Besides, a study also carried out by Ismail et al., (2005) where they used paper sludge as filler materials in maleated natural rubber as a coupling agent.

Gypsum board is extremely light, with a density of approximately 1g/cm^3 and has several useful properties, including fire resistance, heat and sound insulation. Gypsum board has an established market around the world since it can be used for partition wall, attachment shuttering, wall and ceiling paneling, suspended ceiling and dry floor cover decorating (Kim et al., 2007). This construction materials consists of natural gypsum and residual or recycled wood particles (Kim et al., 2007). The strength-enhancing advantages of mixing wood with an inorganic binder were foreseen as early as 1980 when a German patent was issued that described a light weight, gypsum bonded , wood wool board (Kim, 2008).

This study was conducted to evaluate the mechanical and physical study of the gypsum-paper sludge board. It will indicate the development of the gypsum-paper sludge in order to recycle the paper sludge by using inorganic binder.

MATERIALS AND METHODS

Paper sludge was supplied by Pascorp Paper Mill Sdn. Bhd., Bentong Pahang. The functional groups existing in paper sludge particle was evaluated using Fourier transform infrared (FT-IR) spectroscopy. Pellets were prepared by mixing approximately 5 mg of powder of each sample type with 95 mg of finely ground potassium bromide (KBr) and pressed into pellets of about 1mm in thickness. The FT-IR spectrum of sample was then analyzed using the Nicolet infrared spectrophotometer (Avatar 360 FT-IR E.S.P) between wave numbers of 4000cm_1 and 500cm_1 with a resolution of 4 cm_1 to detect the functional groups of the compounds of each material.

Moisture content of the sludge will be determined prior to addition of the water requirement during mixture. The gypsum was obtained from hardware shop at Jengka, Pahang. Three different of mixing ratios of gypsum to paper sludge (90:10, 80:20, and 70:30) will be used.

To manufacture the gypsum-sludge boards, the sludge were put in a mixer, water will be added followed by the weighed of the gypsums. Sludge will be added as reinforce materials at the level of 10, 20 and 30% weight of gypsum. Boards of 450 mm x 450 mm x 10 mm will be produced using lab scale mould. The target density of the sample was 1.2g/cm^3. The board was pressed at 3MPa at room temperature, for 30 minutes using commercial hydraulic pressure. The moisture content of the gypsum-sludge board mats was reduced to about 2-3% in the conditioning chamber set at 45°C. After being removed from the dryer, the mats were conditioned at room temperature for a week.

The physical and mechanical properties of the panels will be tested according to Japanese Industrial Standard; JIS A 5908:2003 Particleboard (2003) and JIS A 6901:2005 Gypsum Boards (2005). Three point bending strength and internal bond strength of the sample will be carried out using a Universal Instron Machine. Water absorption test will also be conducted.

RESULTS AND DISCUSSIONS

Evaluation of Functional Group

Fourier transform infrared (FT-IR) spectroscopy was employed to observe any functional group of paper sludge. The peak at 3695.8 and 3619.8 cm^{-1} corresponds to intermolecular hydrogen bonding and O-H stretching. The peak at 3375.0 cm^{-1} was detected which assigned to the amines group. The peak at 875.8 and 712.0 cm^{-1} corresponds to aromatic compound with p-subtituted and Ar-H stretching respectively.

Moisture Content and Density

Table 1 show the moisture content and density of gypsum-sludge board with three different ratios. From the result, it showed that, the moisture content for all the samples were in average.

Table 1: Moisture content and density of Gypsum-paper sludge board

Ratio	Moisture Content (%)	Density (g/cm^3)
90:10	4.33 (0.26)	1.06 (0.12)
80:20	4.19 (0.08)	0.99 (0.07)
70:30	4.78 (0.12)	0.85 (0.05)

*Result in parenthesis indicate the standard deviation

Based on the data obtained, the density of gypsum-paper sludge board with 90:10 was higher compared with sample manufactured using 80:20 and 70:30. This might due to the percentage of the gypsum cement was higher in 90:10. Gypsum cement was very fine structure that makes it very flexible to fill up the void part in the panel. This will affect the weight and porosity of the panel.

Water Absorption

Table 2 below showed the percentage of water absorption of gypsum-paper sludge board for different ratio. The water absorption rate was determined for every hour until it was constant.

Table 2: Water absorption of Gypsum-paper sludge board

RATIO	1 Hour	2 Hour	3 Hour	4 Hour	5 Hour	10 Hour	12 Hour	24 Hour
90:10	45.31 (1.18)	47.01 (1.17)	47.18 (1.69)	47.6 (1.11)	47.66 (1.27)	47.79 (1.48)	47.85 (1.50)	47.89 (1.48)
80:20	50.27 (2.16)	50.55 (2.56)	51.78 (1.99)	51.83 (3.00)	52.55 (1.71)	53.26 (2.20)	53.57 (1.96)	53.78 (4.02)
70:30	59.09 (10.19)	59.14 (12.29)	62.33 (10.85)	61.50 (10.82)	61.56 (9.93)	63.33 (9.29)	63.92 (9.22)	118.05 (23.89)

* Result in parenthesis indicate the standard deviation

From Table 2 it showed that the percentage of water absorption was higher in panel manufactured using 70:30 ratio compared with panel manufactured using 90:10 and 80:20. The percentage of water absorption was lowest at panel manufactured using 90:10. Generally, paper sludge properties are very fine fiber which tends to absorb lots of water. As we know, papers are made from wood fibers which have a hygroscopic property. Fiber will tend to absorb and pick up water all the time, when they are open to air or water. In this study, it shows that board with 70:30 ratio contain more paper sludge compare others two. By increasing of paper sludge contain, the higher rate of water absorption rate occurred.

Bending Strength

Table 3 below showed the result obtained from the bending strength testing that carried out in this study.

Table 3: MOR and MOE of Gypsum-paper sludge board

Ratio	MOR (Mpa)	MOE (Mpa)
90:10	0.46 (0.10)	184.61 (36.34)
80:20	0.58 (0.06)	189.19 (5.97)
70:30	0.38 (0.02)	122.33 (22.46)

* Result in parenthesis indicate the standard deviation

From Table 3, MOR and MOE of board with ratio 80:20 showed the highest strength properties. The value of MOR and MOE of the board with the ratio 90:10 was the lowest because less amount of filler were being used in manufactured this board. Filler will contribute to increase the board stiffness. While, the board with ratio 70:30 gained the lowest MOR and MOE value because, paper sludge contain very fine fiber and the bonding between the fiber in not strength then virgin pulp, so it cannot stand by its own. The paper sludge must support with correct proportion of binder to make the board increase in strength. The board with ratio 80:20 obtained a higher MOE and MOR strength properties also due to the stable amount of gypsum and paper sludge to produce board. The correct combination of gypsum cement and paper sludge will get the better strength properties of the board.

Internal Bonding

Table 4 below showed the Internal bonding strength obtained from the testing that carried out during the study.

Table 4: The internal bonding strength of Gypsum-paper sludge board

RATIO	IB (Mpa)
90:10	0.10 (0.04)
80:20	0.13 (0.04)
70:30	0.11 (0.01)

* Result in parenthesis indicate the standard deviation

Based on the result obtained from the study, the board with ratio 80:20 gained the higher internal bonding strength properties compares other two board sample. This situation happens because the board contains a suitable amount of paper sludge that will enforce the bonding of board. So the particles stick very well with each other. Besides that, the amounts gypsum cement that used to manufactured the board

significantly suitable with the amount of paper sludge that been used. The correct combination of gypsum cements and paper sludge in board with ratio 80:20, make the board have higher internal bonding strength, were the bonding of this material are well mixture and bond together very well.

CONCLUSIONS

From the results of this study, it may be concluded that paper sludge is good reinforcement materials for the manufacture of the gypsum-paper sludge board with a suitable ratio proportion. In terms of water absorption rate, the gypsum-paper sludge board was still not meet the standard, however further study need to be carried out in order to increase the water resistance. MOR, MOE and internal bond strength of the gypsum-paper sludge boards experienced good rate at 80:20 proportion. However, MOR, MOE and internal bond strength exhibited the different trend when paper sludge adding contents increased. The applications of paper sludge as filler in gypsum board manufactured requires further investigations. The negative effect of paper sludge on the gypsum boards strengths may be due to the inorganic materials of the paper sludge. Therefore, in further studies, it is recommended that paper sludge need to treatment or neutralized with others organic materials.

References

Asghar Taramian, Kazem Doosthoseini, Sayyed Ahmad Mirshokraii, Mehdei Faezipour, 2006, Particleboard Manufacturing: An Innovative Way To Recycle Paper Sludge, Journal Of Waste Management 27 (2007) 1739-1746.

Anon, 1991.,NCASI Technical Bulletin,. Progress in Reducing Water Use and Wastewater Loads in the US Paper Industry, No.603

Anon, 1986., Springer, A.M, Industrial Environment Control – Pulp and Paper Industry. John Wiley and Sons, New York.

Son, J., 2004. Physico-mechanical properties of paper sludge-thermoplastic polymer composite. Journal of Thermoplastic Composite Material 17, 509-522.

Eom, Y.G., Son, J.I., Hyun, J.K., 2000. Studies on paper sludge –high density polyethylene composite. Forest and Humanity, Kookmin University 12, 95-108.

Son, J., Kim, H.J., Lee, P.W., 2001. Role of paper sludge particle size and extrusion temperature on performance of Paper sludge-thermoplastic polymer composites. Journal of applied science 82 (11), 2709-2718

Fernandez, E.C., Lamason, C.R., Delgado, T.S., 2001. Housing construction material from paper sludge . In: proceding of the 5th International Workshop on the use of paper Industry Sludge in Environmental Geotechnology and construction, 23-24 May, Philiphines.

Rosario García & Virginia Rubio & Iñigo Vegas & Moisés Frías 2008. Influence of thermally activated paper sludge on the behavior of blended cements subjected to saline and non-saline environments, Environ Sci Pollut Res (2009) 16:274–277.

Jean Pera A, and Achène Amrouz, A, 1998. Development of Highly Reactive Metakaolin from Paper Sludge, Advanced Cement Based Materials, Volume 7, Issue 2, (Pages 49-56).

Sumin Kim, Hyun-Joong Kim, and Jin Chul Park, 2009. Application of recycled paper sludge and biomass materials in manufacture of green composite pallet, Resources, Conservation and Recycling, Volume 53, Issue 12, October 2009, Pages 674-679.

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