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PREPARATION AND CHARACTERIZATION OF SAWDUST-CEMENT PARTICLEBOARDS

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Abstract

This work is mainly concerned with the preparation of particleboards from sawdust (SD). Cement (C) as used as binder. The physicochemical properties and characterization of sawdust and cement were also conducted. Six types of particleboards were prepared by mixing various proportions of sawdust (50 %, 40 %, 33.33 %, 28.57 %, 25 %, 22.22 %) and various proportions of cement (50 %, 60 %, 66.66 %, 71.43 %, 75 %, 77.78 %) and a chemical additive $CaCl_2$. The additive was based on 2 % by weight of cement used. Particleboards were prepared by cold compressing molding method. The prepared particleboards (SDC) were characterized according to physicochemical and physicomechanical parameters such as modulus of rupture, thickness, density, water absorption, swelling thickness and hardness. From the results, it was found that particleboard namely SDC 5 containing (25 % of sawdust, 75 % of cement and 1.5 % of $CaCl_2$) was a quality grade particleboard. It has 2058.34 psi modulus of rupture, 0.65 cm thickness, 1.2320 g cm^{-3} density, 13.05 % water absorption, 17.14 % swelling thickness and 98 D hardness. The SDC 5 particleboard, based on water absorption, modulus of rupture and hardness values, indicates that it was the best among all particleboards studied. The surface morphology of SDC 5 was studied by SEM and the thermal stability of particleboard was studied by TG-DTA.

Keywords: Particleboard, sawdust, cement, chemical additive, $CaCl_2$

Introduction

Wood as a raw material contributes significantly in improving a nation's economic base, industrialization and comfort of its teeming population. Globally the demand for wood and wood-based panel products has been on the increase (Youngs, 2002). Particleboard has become one of the most popular wood-based composite materials for integrating decoration because of its low density, good thermal insulation, sound absorption, and wonderful machining properties. The primary lignocellulosic material used in the particleboard industry is wood. The increased demands of raw materials in wood panel, pulp and paper manufacturing have led to worldwide shortages of forest resources (Fuwape, 1995).

The increasing population and growing concern about the environment have led to changes in forest management practices, resulting in a significant reduction in wood harvesting from national forests despite growing demands. In the meantime, a constantly increasing population has resulted in an escalating demand for wood in the forest products (Blankenhor, 1994). Cement-bonded particleboard (CBP) is one of the most important mineral bonded wood composites, a molded panel comprised of 10-70 wt % wood particles and 30-90 wt % Portland cement binder (Sorfa,1984). Unlike resin-bonded particleboards, CBP boasts excellent sound insulation, high resistance to water, termites and fungi, and excellent long-term weather durability in outdoor conditions. These advantages suggest its potential application as a replacement for traditional building materials and conventional wood composites in roofing, wall and flooring parts and noise absorbing partitions (Lee, 1984). CBP panel production provides attractive possibilities for using wood wastes and agricultural residues, which are otherwise environmentally problematic. In addition they have a low production cost (Karade, 2003).

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Aim

The aim of this research is to prepare the quality grade particleboard from renewable natural resource from sawdust, using cement as binder.

Materials and Methods

All necessary research facilities were provided by the Polymer Department, Department of Research and Innovation, (DRI). The apparatus consists of conventional Lab ware, glassware and modern equipment. Some of the instruments used in the experiments are E-Mettler balance (210 ± 0.1 mg) (LA – 310 S), Muffle furnace (Range 100-1100 ºC Gallenkamp, England), TG-DTA (Hi-TGA 2950, DTG-60 H Thermo gravimetric analyser), Mixer machine (Henschel Mischer, Germany), Hydraulic hot press (Apex Construction Ltd., Gravesend England), Electro-hydraulic tensile tester (Thwing-Albert Instrument Company Philadelphia, USA), Hardness tester (H.W Wallace and Co. Ltd., England), Vernier caliper (or) screw gauge, Specific gravity balance (Wallace Test Equipment), Sieves (US Series Equivalent, The Tyler Std. Screen Scale), Scanning Electron Microscope (No. JSM-5610, JEOL Ltd., Japan) and Thermal control status oven (H 053, 240 V, England).

Collection of Samples

In the experiments, sawdust was collected from Family Saw Mill, North Okkalapa Township and commercial cement from Chan Myae Aung Trading, Mingalar Taung Nyunt Township, Yangon Region, Myanmar.

Preparation of Sawdust

The collected sawdust was soaked in water for 24 h to reduce the amount of water-soluble sugars and tannins and then the cleaned sawdust was solar dried for five days. It was dried again at 115 °C for 1 h and cooled in desiccators. The dried samples were screened to pass through the sieve aperture of 25 mesh (0.5 mm). The sieved (25 mesh) material was then stored in an airtight plastic bag for further experiment.

Determination of Physicochemical Properties of Sawdust and Cement

The physicochemical properties (moisture content, ash content, solid content, bulk density and pH) of the samples were determined by conventional methods (Table 1).

Characterization of Sawdust and Cement

SEM analysis

The morphology of prepared sawdust and cement was studied by using Scanning Electron Microscope (JSM-5160, JEOL Ltd., Japan) for analysing micro and macro pores present on the surface of the samples. The scanning electron micrographs of sawdust and cement were obtained.

TG-DTA analysis

Thermal analysis of the samples was done by a DTA-60H (Hi-TGA 2950) thermal analyzer. The sample (*ca.* 5 mg) was required and measurements were made in the temperature range 0~600 ºC at 20.00 ºC/min and the nitrogen gas at 50.00 mL/min.

XRD analysis

The nature of the cement was determined by X-ray diffractometer.

Preparation of Sawdust-Cement Particleboards

In this research, all of the sawdust-cement particleboards were prepared by cold compressing molding method.

Effect of proportion of cement on the preparation of sawdust-cement particleboards

Each sawdust (50 %, 40 %, 33.33 %, 28.57 %, 25 %, 22.22 %) was dipped in 20 ^{o}C water (500 mL) for 3 h and mixed with (50 %, 60 %, 66.66 %, 71.43 %, 75 %, 77.78 %) of cement. The chemical additive $CaCl_2$ based on 2 % by weight of cement was then added by Henschel mixer for 10 min. The mixture was then laid in mold. Care must be taken to get uniform surface layer in cold press section. Later, this mat was carefully transferred to the hydraulic press machine. Excess water was squeezed out by compression at 2800 psi pressure for 24 h. The particleboards were kept at room temperature for 1-2 weeks and then the edges and both sides of the particleboards were trimmed and sanded (15.24 cm x 15.24 cm).

Determination of the Physicochemical and Physicomechanical Properties of Sawdust-Cement Particleboards

The physicochemical and physicomechanical properties (moisture content, modulus of rupture, thickness, water absorption, swelling thickness, density, and hardness) of the prepared sawdust-cement particleboards were determined by the conventional method and modern techniques.

Characterization of the Selected Particleboard (SDC 5)

SEM analysis

The morphology of prepared SDC 5 particleboard was studied by using Scanning Electron Microscope (JSM-5160, JEOL Ltd., Japan) for analysing micro and macro pores present on the surface of the samples. The scanning electron micrograph of SDC 5 particleboard was obtained.

TG-DTA analysis

Thermal analysis of the sample was determined by a DTA-60H (Hi-TGA 2950) thermal analyzer. The sample (*ca*. 5 mg) was required and measured in the temperature range 0~600 ºC at 20.00 ºC/min and nitrogen gas at 50.00 mL/min. The TG-DTA thermogram (Figure10) and the description data (Table 7) are given.

Results and Discussion

Table 1 shows that the physicochemical properties (moisture content, ash content, bulk density, and pH) of the sawdust and cement determined by the conventional method. The pH values of samples were determined by pH meter. The moisture content of sawdust and cement were determined by oven drying method at 115-120 ºC to obtain constant weight. It can be observed that moisture content of the sawdust is 20.11 %, ash content is 11.25 %, solid content is 79.89 % bulk density is 23.10 g mL^{-1} and pH is 6.32 (Table 1). Cement was used as a binder for making particleboards. It can be observed that moisture content of the cement is 0.94 %, ash content is 18.25 %, solid content is 99.06 %, bulk density is 80.47 g mL^{-1} and pH is 7.86.

Table 1 Physicochemical Properties of Sawdust and Cement

No.	Physicochemical Properties	Sawdust	Cement
1.	Moisture content (%)	20.11	0.94
2.	Ash content (%)	11.25	18.25
3.	Solid content (%)	79.89	99.06
4.	Bulk density (g mL^{-1})	23.10	80.47
5.	pH	6.32	7.86

Characterization of Sawdust and Cement

SEM analysis

Surface morphology of sawdust and cement was examined by SEM (Figures 1 and 2). It is obviously seen that many non-uniform cavities and pores are on the surface of the sawdust. It can be observed that the diameter of cement has ~20 µm from SEM image. In this image, amorphous nature of cement is not similar in size.

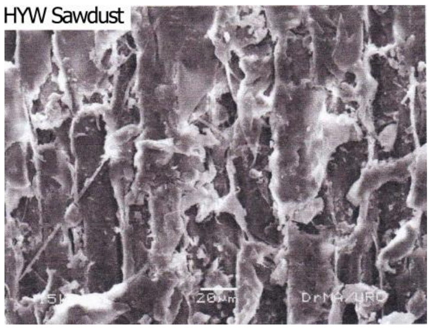

Figure 1 SEM photomicrograph of sawdust at 1.360 kx magnification

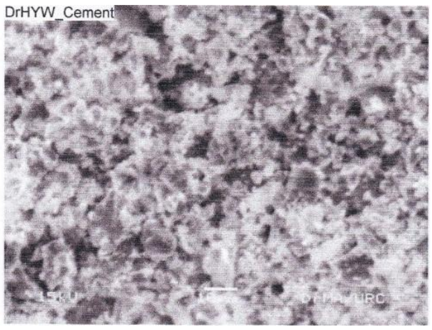

Figure 2 SEM photomicrograph of cement at 1.360 kx magnification

TG - DTA analysis

On the basis of the thermogram of sawdust (Figure 3), the initial region of the TG profile shows weight loss percent about 25 % at about 73.83 ºC. It may be dehydration process and at the temperature range of 39 ºC to 324 ºC. The major stage of the loss of about 50 % occurs from 324 ºC to 400 ºC. The exothermic peak was observed around 390 ºC. It may be attributed to decomposition of small segments from cellulose and lignin. The exothermic peak was found at 504 ºC with the weight loss percent about 20 %. It is due to the decomposition of cellulose backbones and formation on char and at the temperature range of 400 ºC to 600 ºC. Residual weight of sawdust was 0.146 mg (Table 2).

On the basis of the thermogram of cement (Figure 4) the weight loss % of about 9.44 % was found within the temperature range of 40 ºC to 140 ºC. This is due to the dehydration of moisture and absorbed water of cement, indicated by the endothermic peak at 122.04 ºC. The residual weight of cement was 19.023 mg (Table 3).

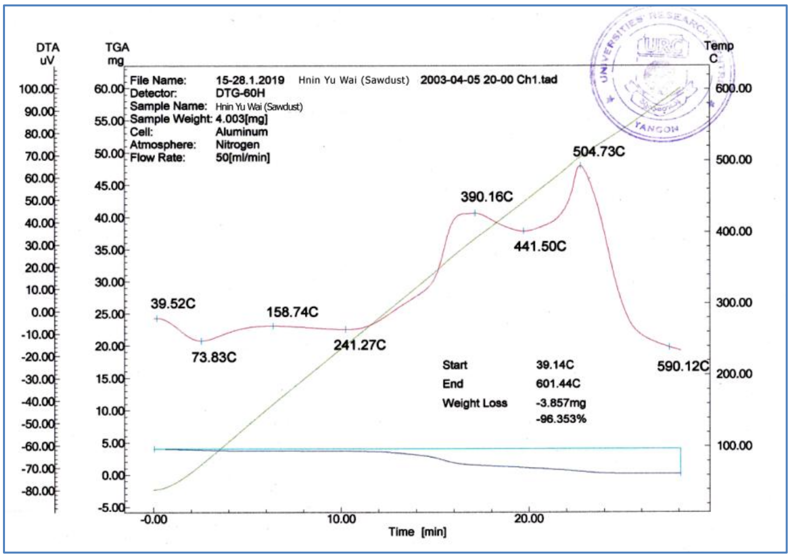

Figure 3 TG-DTA thermogram of sawdust

Table 2 Thermal Analysis Data of Sawdust

TG		DTA		
Break in Temperature (ºC)	**Weight loss (%)**	**Peak Temperature (ºC)**	**Nature of peak**	**Remarks**
39-324	25	73.83	endothermic	Dehydration due to surface water
324-400	50	390.16	exothermic	Decomposition of small segments from cellulose and lignin
400-600	20	504.73	exothermic	Decomposition of backbones of cellulose and burn into char, residual weight 0.146 mg

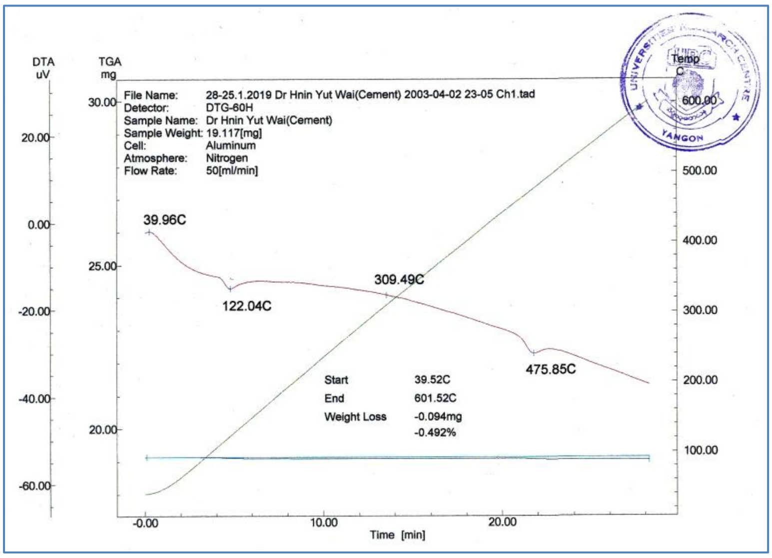

Figure 4 TG-DTA thermogram of cement

Table 3 Thermal Analysis Data of Cement

TG		DTA		Remarks
Break in Temperature (ºC)	**Weight loss (%)**	**Peak Temperature (ºC)**	**Nature of peak**	
40-140	0.48	122.04	endothermic	Dehydration due to moisture and absorbed water, residual weight of cement 19.023 mg

XRD analysis

In the X- ray diffraction profile of cement sample a big hump is observed at nearly 2 θ value of 30°. The simplest and most widely used method for estimating the average crystallite size is from the full width at half maximum (FWHM) of a diffraction peak using the Scherrer equation, $d = K\lambda / \beta \cos\theta$, where d is the crystallite size, λ is the diffraction wavelength, β is the corrected FWHM, θ is the diffraction angle and K is a constant close to unity. The crystallite size of cement was calculated by this method (Table 4).

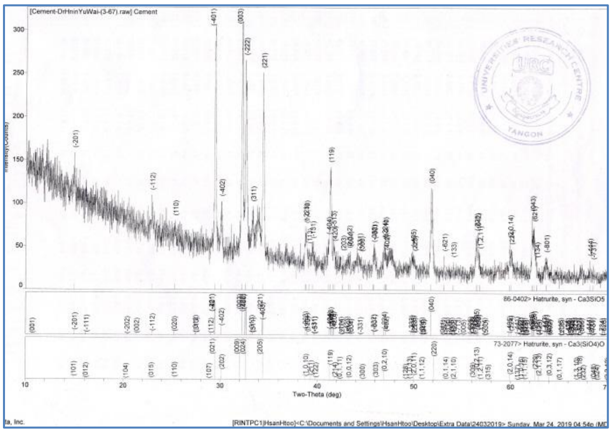

Figure 5 XRD diffractogram of cement

Table 4 XRD Data of Cement

No.	Miller Indice (h k l)	FWHM (degree)	2 Theta (degree)	Crystallite Size (nm)
1.	0 0 3	0.200	32.174	431.61
2.	2 2 1	0.209	34.344	415.36
3.	1 1 9	0.285	41.262	310.97
4.	0 4 3	0.276	62.185	350.96
Average Crystallite Size				377.225

On the Aspect of the Preparation of Sawdust-Cement Particleboards

For the preparation of particleboard, sawdust (SD) was mixed with cement (C) under the pressure 2800 psi. For all of the prepared particleboards, physicochemical and physicomechanical parameters such as thickness, swelling thickness, density, water absorption, modulus of rupture, and hardness were determined. Among these parameters, modulus of rupture is more specific than other for determining particleboards quality.

Effect of proportion of cement on the preparation of particleboards

SDC 1, SDC 2, SDC 3, SDC 4, SDC 5 and SDC 6 particleboards were prepared with various proportions of sawdust (50 %, 40 %, 33.33 %, 28.57 %, 25 %, 22.22 %), various proportions of cement (50 %, 60 %, 66.66 %, 71.43 %, 75 %, 77.78 %) and chemical additive $CaCl_2$ 2 % by weight based on the cement used. These particleboards were made at 2800 psi of pressure. The results of the physicochemical and physicomechanical properties including thickness, swelling thickness, water absorption hardness modulus of rupture (MOR) and density of SDC 1, SDC 2, SDC 3, SDC 4, SDC 5 and SDC 6 particleboards are presented in Table 6 and Figures 5, 6 and 7. It was found that the particleboard SDC 5 made with sawdust (25 %) and 75 % of cement has the highest modulus of rupture among them. Moreover, the water absorption tests of the particleboards are also found to be satisfactory. Water absorption test is a measure of the soaking characteristic of a test sample towards water when fully immersed in a quantity of water at room temperature for a certain time period (usually 24 h).The particleboards SDC 5 have the lowest water absorption percentage among them (Table 5). Therefore, particleboards SDC 5 was chosen to make the most suitable particleboard.

Table 5 Physicochemical and Physicomechanical Properties of Particleboards with Various Proportions of Cement (C)

Types of Particleboards	Cement (%)	Modulus of rupture (psi)	Thickness (cm)	Density (g cm^{-3})	*Water Absorption (%)	*Swelling Thickness (%)	Hardness Shore (D)
SDC1	50.00	820.25	0.60	0.5168	58.05	62.18	89
SDC 2	60.00	1030.01	0.63	0.7265	46.15	40.20	92
SDC3	66.66	1250.90	0.65	0.8060	35.42	38.19	94
SDC4	71.43	1648.48	0.65	0.9520	10.32	20.18	97
SDC5	75.00	2058.34	0.65	1.2320	13.05	17.14	98
SDC 6	77.78	1967.84	0.67	1.3460	18.70	30.28	96

*After 24h Applied pressure – 2800 psi Pressing time – 24 h

SDC1 = (50 %) sawdust with (50 %) Cement, SDC 4 = (28.57 %) sawdust with (66.66 %) Cement

SDC 2 = (40 %) sawdust with (60 %) Cement, SDC 5 = (25 %) sawdust with (75 %) Cement

SDC 3 = (33.33 %) sawdust with (140 g) Cement, SDC 6 = (22.22 %) sawdust with (77.78 %) Cement

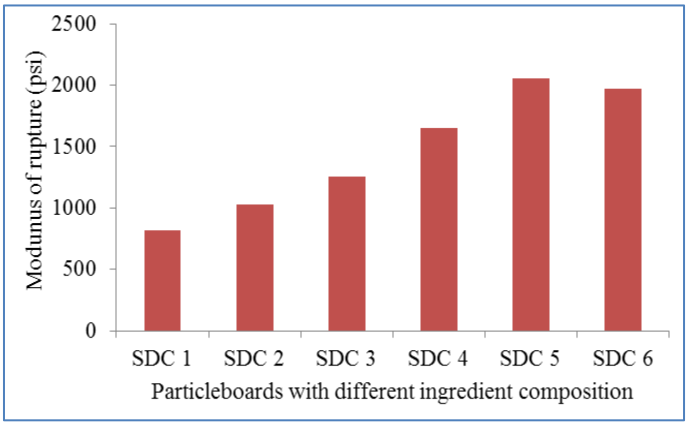

Figure 6 Modulus of rupture of SDC particleboards as a function of particleboards with different ingredient composition

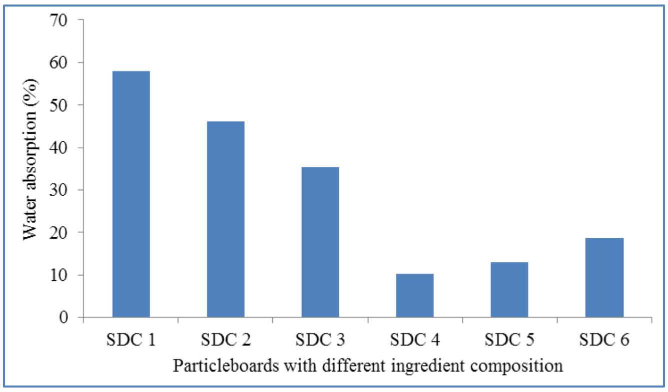

Figure 7 Water absorption of SDC particleboards as a function of particleboards with different ingredient composition

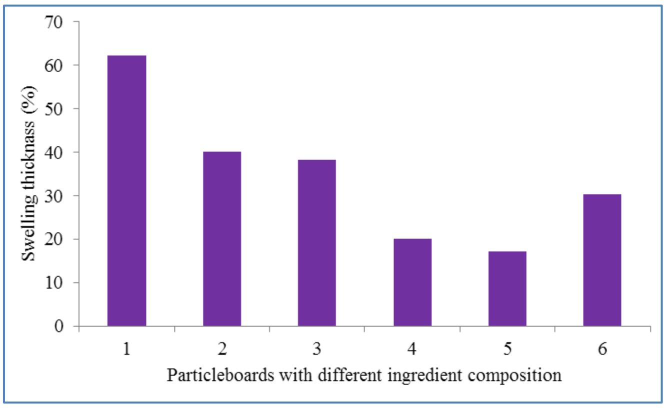

Figure 8 Swelling thickness of SDC particleboards as a function of particleboards with different ingredient composition

Characterization of SDC 5 Particleboard

SEM analysis

Scanning electron microscope (SEM) imaging technique has been used to identify the interfacial area between the wood particles and the cement matrix of the fracture surface of the selected particleboard (SDC 5). The SEM photomicrograph of SDC 5 particleboard shows that specimens containing calcium chloride exhibited cone-shaped, well-formed crystals in the cement (Figure 9).

Figure 9 SEM photomicrograph of SDC 5 particleboard

TG- DTA analysis

Thermal stability of particleboard (SDC 5), was investigated by TG-DTA analysis (Figure 10). On the basis of the thermogram of particleboard SDC 5, in first stage, the weight loss % about 7.73 % that was found within the temperature range of 38 ºC to 120 ºC. This is due to the dehydration of surface giving an endothermic peak at 107.35 ºC. In the second stage, the weight loss % about 37.25 % was found within the temperature range of 120 ºC to 400 ºC. This is due to the decomposition of small segments from cellulose and lignin giving an exothermic peak at 365.91 ºC. In the third stage, the weight loss % about 14.76 % that was found within the temperature range of 400 ºC to 600 ºC. This is due to the decomposition of backbones of cellulose and burning into char giving an exothermic peak at 487.77 ºC. The residual weight of SDC 5 particleboard was 16.73 mg (Table 6).

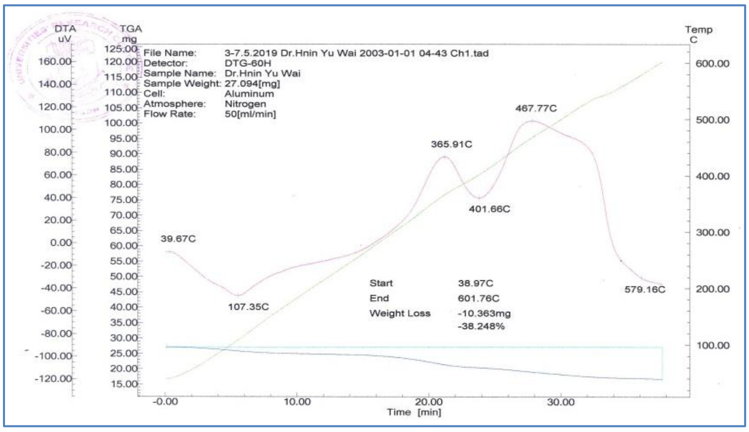

Figure 10 TG-DTA thermogram of SDC 5 particleboard

Table 6 Thermal Analysis Data of SDC 5 Particleboard

TG		DTA		
Break in Temperature (ºC)	**Weight loss (%)**	**Peak Temperature (ºC)**	**Nature of peak**	**Remarks**
38-120	7.73	107.35	endothermic	Dehydration due to surface water
120-400	37.25	365.91	exothermic	Decomposition of small segments from cellulose and lignin
400-600	14.76	487.77	exothermic	Decomposition of backbones of cellulose and burn into char, residual weight 16.73 mg

Some Possible Application of Prepared Particleboards

The sawdust-cement particleboard can be used in eaves, exterior wall, ceiling, partition wall, flooring and cladding. The photographs of SDC particleboards (15.24 cm x 15.24 cm) are presented in Figure 11.

Figure 11 Photographs of SDC particleboards

Conclusion

The sawdust (SD) was collected from the Family Saw Mill, North Okkalapa Township and waste cement (binder) from Chan Myae Aung Trading, Mingalar Taung Nyunt Township, Yangon Region. The collected sawdust was purified and sieved with 0.5 mm aperture size.

The particleboards were prepared by mixing different proportions of sawdust with different proportions of cement by cold pressing method. The physicochemical and physico-mechanical properties of the particleboards (SDC) were characterized. The optimum conditions of prepared particleboards were defined by the improvement of modulus of rupture (MOR) and least water absorption parameters. From the experimental results, (SDC 5) particleboard with 25 % of sawdust with 75 % of cement and 1.5 % of $CaCl_2$ was found to be a quality grade particleboard possessing 2058.34 psi of modulus of rupture, 0.65 cm of thickness, 1.2320 g cm^{-3} of density, 13.05 % of water absorption, 17.14 % of swelling thickness, and 98 Shore D of hardness, respectively. Sawdust particleboards prepared by simple hand lay-up process provide an opportunity of replacing materials with a higher strength, low cost alternative that is environmentally friendly. Particleboards are made of wastes by product from saw mill, which can change harm to benefit by developing the "green" particleboards from materials of natural degradation. Moreover, the use of sawdust-cement particleboard can reduce overall weight of the construction, since their density and weight are generally low. It is a very versatile material that can be used eaves, exterior wall, ceiling, partition wall, flooring, cladding even roofing provided that proper coating is applied and wire meshes imbedded to enhance the interlocking capacity especially for long life spans.

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