

Thermosetting Composites from Wood/Bark and Waste Powder Coating Powder

Rizwan Paracha, Jyoti Verma, Sumit Lal and Allan J. Easteal

Department of Chemistry and Centre for Advanced Composite Materials, The University of Auckland,
Auckland, New Zealand

Introduction

Composites based on renewable sources such as cellulose are gaining popularity as they have low cost and are biocompatible.

Wood is a renewable resource that is utilised primarily as a structural material, and as a source of cellulosic fibre for paper. The major component of wood, ie cellulose, is infusible and insoluble in common organic solvents, so that processing cellulose is relatively difficult. Cellulose and wood can be plasticized to a certain extent, and moulded wood products can be made by roll forming plasticized wood.

The timber industry produces very large quantities of bark and sawdust as waste products. These materials represent a major raw material resource. Cellulosic fibre is used to make composite products such as MDF [1], which utilises synthetic resins as binders. The motivation of the present study was to utilise bark and sawdust, with minimal raw material processing, together with other waste products, to produce useful materials.

In the manufacture and application of powder coatings an estimated 60,000 tones per annum of waste powder (WPCP) is produced. This waste is currently heated so as to fuse the powder to form a solid mass and sent to landfills. Disposal of the powder coating is thus a cost to the producers, and can be viewed as loss of a potential raw material resource.

Recent work at the University of Auckland led to the development of compression moulded composite sheets incorporating sawdust, and WPCP as a binder [2]. In the present study we have used wood flour and bark flour, together with WPCP and other additives, in a variation of the previous work. The WPCP used in this research comprised mainly unsaturated polyester and hydroxyl alkyl amide with a trace amount of additives.

Experimental

Reaction between untreated wood/bark flour mixture and WPCP occurred after free radical initiation by methyl ethyl ketone peroxide. Cobalt naphthenate was used in the reaction mixture as catalyst to lower the reaction temperature to 65°C. Addition of butyric acid gave enhancement of some material properties. The mixtures of wood flour,

bark flour, WPCP and butyric acid were compression moulded at a range of temperatures and pressures to obtain composite sheets 2-2.5 mm in thickness.

Materials

Wood flour, bark flour were supplied from local wood industry while WPCP was supplied by Orica powder Coating Limited. Butyric acid was supplied by Fonterra Ltd, and methyl ethyl ketone peroxide (MEKP) (98%v/v) and cobalt naphthenate were purchased from Sigma Aldrich Chemicals, USA.

Preparation of composites

Three types of formulations were prepared (Table 1). Wood flour or wood flour and bark flour (and butyric acid, in one formulation) were thoroughly hand mixed with WPCP. Sufficient MEKP solution to give 1.5 gm of MEKP was sprayed on the mixture, which was then further mixed using a simple household mixer at low rpm. Cobalt naphthenate (1.5 g) was then added by spraying solution on the mixture.

Table 1 Composite formulations.

| Formulation # | Wood (g) | Bark (g) | WPCP (g) | MEKP(g) | Catalyst (gm) | BA(g) |
|---------------|----------|----------|----------|---------|---------------|-------|
| 1 | 25 | | 35 | 1.5 | 1.5 | |
| 2 | 12.5 | 12.5 | 35 | 1.5 | 1.5 | |
| 3 | 12.5 | 12.5 | 35 | 1.5 | 1.5 | 15 |

BA=butyric acid

Apparatus and procedures

Three point bending was carried out as per the ASTM D790-90 test method using an Instron Universal Tester (Model 5567). Scanning electron microscopy (SEM; Philips XL30 FEG) was carried out on samples attached to stainless steel stubs, at 15 kV accelerating voltage. FTIR spectra were obtained with a Nicolet 6700 (Thermo Electron Corporation) spectrometer.

Results and Discussion

Flexural properties and water swell

In sample 1 with no bark the flexural strength had the smallest value, possibly due to inhomogeneity of WPCP and excess of wood fiber.

The presence of butyric acid in sample 3 enhanced the strength of the composite, suggesting that butyric acid acted as a compatibilizer. In addition, this composite had higher gloss than samples 1 and 2.

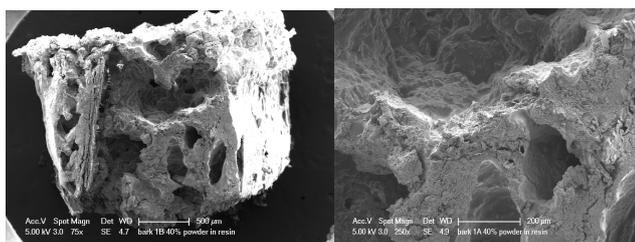
The water swell (swelling ratio, expressed as relative increase in thickness) decreased with increasing flexural strength. The reason is most likely that the highest strength sample was the most homogeneous and least porous (see Figs. 1 (a) and (c)).

Table 2 Flexural strength and swelling ratio data.

| Formulation # | Flexural Strength (MPa) | Swelling Ratio (%) |
|---------------|-------------------------|--------------------|
| 1 | 5.30 | 7.1 |
| 2 | 7.80 | 6.8 |
| 3 | 12.60 | 5.7 |

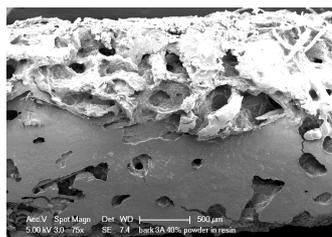
SEM analysis

SEM was used to analyse the microstructure of the composite sheets. The micrograph of sample 1 in Figs.1 (a) and (b) shows large pores formed by evolution of gas (eg. water) during compression moulding, or by gas evolved by the reaction between WPCP, bark and wood, or due to insufficient pressure applied during compression moulding to fill the voids in the mixture. The cross-section of sample 3 was clearly much less porous. That effect appears to be due to the presence of butyric acid in that composite.



(a)

(b)



(c)

Fig.1 SEM images of cryo-fractured cross-sections of samples 1 and 3. (a) sample 1, 75x; (b) sample 1, 250x; (c) sample 3, 75x.

Mechanistic analysis by FTIR

The FTIR spectra showed bands at 2900-2950 cm^{-1} corresponding to stretching of CH_2 bonds present in WPCP and MEK peroxide. The bands at 1700-1750 and 1200-1250 cm^{-1} are attributed to $\text{C}=\text{O}$ and $\text{C}-\text{O}$ stretching vibrations of the composites. A peak corresponding to $\text{C}-\text{O}-\text{C}$ stretching due to wood was observed at 1100 cm^{-1} . The most significant band that emerged when the spectrum of WPCP was compared with that of the composites was found at 1150-1160 cm^{-1} in all of the three composites. This band is attributed to the stretching vibration of $\text{C}-\text{O}-\text{C}$ bonds formed during composite formation, and to $\text{C}-\text{C}-\text{C}$ bending vibrations. The formation of new $\text{C}-\text{O}-\text{C}$ bonds validates the proposed mechanism in which cellulose is coupled to WPCP during composite formation.

Conclusions

The significant results of this study can be summarized as follows.

1. Incorporation of butyric acid in the composites increased the flexural strength and decreased water swell. The water swell was quite small, which suggests that these composites might be utilisable in applications where water may be present.
2. Bark acted as a filler and induced homogeneity of the composite, resulting in enhanced flexural strength and appearance.
3. Mixtures with suitable proportions of wood, bark, WPCP and additives can give composites with acceptable mechanical properties for non-structural applications. These composites have potential applications in the building industry.

References

- [1]Juson J, Kuo M, Myers D. Properties of medium density fibreboards made from renewable biomass. *Bioresource Technology* 2007; 98: 1077-1084.
- [2]Squire N, Abhayankar A, Watson K. Composite material manufactured from a binder system including waste powder coating powder. PCT/NZ2007/000217; AC Abyhankar, NR Edmonds and AJ Easteal, "Use of waste powder coatings as binders for the manufacture of composite materials", in *Ecosystems & Sustainable Development VI (ECOSUD 2007)* (Transactions on Ecology & the Environment, Vol.106), Eds. E Tiezzi, JC Marques, CA Brebbia and SE Jorgensen, WIT Press, Southampton (2007).