WOOD-PLASTIC COMPOSITES PRODUCED UNDER DIFFERENT CONDITIONS FROM SOME WOOD SPECIES, COTTON STALKS AND RECYCLED PLASTICS

A Thesis

Presented to the Graduate School

Faculty of Agriculture, Alexandria University

In Partial Fulfillment of the Requirements for the

Degree of

DOCTOR OF PHILOSOPHY

In

Forestry and Wood Technology

By

Ramadan Abd El-Sayed Abd El-Sayed Nasser

2002

ABSTRACT

Wood-plastic composite (WPC) panels were produced by melt-blending technique followed by compression molding. Panels were made of cotton stalks (as an agriculture residues), and two wood species, namely European redwood (Pinus sylvestris, as an imported wood), and casuarinas (Casuarinas pp., as locally tree) with low-density polyethylene (PELD).

Different conditions namely, pretreatment of wood (hot water or 4% NaOH extraction), chemical additives (stearic acid or phthalic anhydride at 1 or 3%), wood to polymer ratio (10/90, 20/80, 30/70, and 40/60 wt/wt), particle size of wood mill (-0.25/+0.125, -0.5/+0.25, -1/0.5, and -2/+1 mm screen sieve), and polymer quality (recycled or virgin PELD) were applied in three different experiments to determined the effect of these conditions on the mechanical and physical properties of WPC panels.

The studied properties included static bending properties (modulus of rupture "MOR" and modulus of elasticity "MOE"), ultimate tensile strength "UTS", tensile stress at proportionality limit "TSpl", and percentage of elongation at break "PEB", and Janka hardness number "JHN", as well as dimensional stability properties (water absorption "WA", thickness swelling "TS", and linear expansion "LE") after 2 and 24 hours water-soak.

The results of this study reveals significant difference between WPC panels made of each of the three mentioned materials. The data collected from different mechanical and physical investigations showed that the WPC made of causarina and PELD gave the highest MOR, UTS, TSpl, and JHN and physical WA, TS, and LE values after 2 and 24 hours water soak. Meanwhile, cotton stalks gave the lowest values. On the other hand, WPC

panels made of cotton stalks had the highest MOE and percentage of elongation at break. Accordingly, PELD-wood based formulations could be successfully compounded at die temperature of 180^{o}C for each of the three wood materials.

The results of this study indicated that for each wood species there was a certain treatment among the seven treatments (pretreatment and chemical additives) that produces WPC with the best performance.

Based on the data of this investigation, WPC could be produced from each of the three wood species used in this study after extraction by hot water or 4% NaOH. In addition, cotton stalks extracted by either hot water or 4% NaOH resulted in improvement in strand dolor (strand color changed from black to yellowish or brownish color), decrease in smoke and excessive odor during compounding process of the materials. However, extraction of cotton stalks by 4% NaOH sometimes decreased MOR, UTS, and TSpl values of its WPC panels.

The addition of 3% of stearic acid gave the highest MORT, UTS, TSpl, and JHN values. On the other hand, this addition produced WPC panels with high dimensional stability properties. As well the addition of phthalic anhydride (1 or 3% wt) to untreated wood-PELD mixtures improved most of the mechanical properties and dimensional stability parameters of WPC panels.

In general, the increase of the percentage of chemical additives (stearic acid or phthalic anhydride) may increase the properties of WPC within a range after which any farther increment leads to a decrease in the properties of WPC. This range varies according to wood species, the type of chemical additives, and the property under test.

Increasing wood to polymer ratio from 10 to 40% (by weight) decrease UTS, TSpl, PEB, and percentage of mold shrinkage. However, MOE, MC, JHN, and WA, TS, and LE behaved differently. It was found that WPC panels produced at 40/60 W/P had the highest MOE, JHN, as well as WA, TS, and LE after 2 and 24 hours water-soak, whereas the highest MOR and internal bond (IB) values were obtained at 20/80 W/P ratio. However, all composites produced from the three wood species under different W/P ratios satisfy the requirements of the dimensional stability standards.

The results showed that the size of polymer granules affected significantly most of the mechanical and dimensional properties of WPC. It was found that panels made of coarse recycled PELD gave the highest MOR, PEB, WA-2, and TS (after 2-and 24-hour), while the medium size of polymer granules gave the higher values with all the other studied properties. It can be recommended that although the coarse polymer size granules gave better values in some properties, the medium size granules are preferred in manufacturing of WPC.

The particle size of wood mill affected all the mechanical and physical properties of WPC made of the three wood species and different levels of polymer quality. It was found that MOE, MOR, UTS, TSpl, and IB of WPC panels increased with increasing particle size of wood mill up to -1/0.5 mm, at which point the above properties decreased. However, increasing particle size of wood mill increase PEB, and all dimensional stability properties (WA, TS, and LE) after 2-and 24-hour water-soak except LE after 24-hours water-soak.

With regard to the particle size of wood, it can be concluded generally that the particle size of wood should not be greater then 16 mesh

(1-mm) and smaller than 32-mesh (0.50-mm) to manufacture wood-plastic composites having highest MOE and MOR from the three wood species used in this study.

The quality of polymer (recycled or virgin) significantly affected the mechanical and dimensional stability properties of WPC panels. WPC panels made of virgin PELD and each of the three wood species had higher mechanical and physical properties as compared with recycled PELD except PMS, and WA and LE after 2-hour water-soak which were not affected by polymer quality.