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SCIENCE DIRECT®
Bioresource Technology 96 (2005) 1003–1011
BIORESOURCE TECHNOLOGY

Mechanical properties and decay resistance of wood–polymer composites prepared from fast growing species in Turkey

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Received 29 September 2003; received in revised form 24 September 2004; accepted 24 September 2004
Available online 11 November 2004

Abstract

Some mechanical properties of wood–polymer composites from maritime pine (*Pinus pinaster* Ait.) and poplar (*Populus* x. *euramericana cv*. I-214) wood were investigated. Three different monomers; styrene (ST), methyl methacrylate (MMA) and styrene/methyl methacrylate (ST/MMA) mixture were used in preparation of wood–polymer composites (WPCs). Full-loading (FL), half-loading (HL) and quarter-loading (QL) were used as polymer content levels. Untreated pine and pine–polymer composite samples were tested in compression strength parallel to grain and static bending strength. WPCs mechanical properties increased compared to untreated wood. The polymer had greater effect on the strengths of the ST/MMA treated pine than on the ST and MMA treated pine samples. Increasing of the mechanical properties should improve the structural competitiveness of WPCs made from fast growing-low density woods. Weight losses due to fungal attack for pine and poplar–polymer composites were also determined. Although polymers at full and half loading levels helped decreasing weight losses due to both fungi for each wood species, weight losses were still found to be higher.

Keywords: Wood–polymer composites; Styrene; Methyl methacrylate; Maritime pine

1. Introduction

Over the years wood has been treated with a variety of chemicals to change its physical characteristics. From 1930 to 1960 a number of new wood treatments were introduced: acetylation of the hydroxyl groups, ethylene oxide addition to the hydroxyl groups, polyethylene glycol bulking of the cell-wall, the phenol formaldehyde treatments under the name of Impreg and Compreg, and wood–polymer composites (WPCs). WPCs are prepared by impregnating of wood with vinyl monomers followed by free radical bulk polymerization in the lumens and cell-walls. By adding bulk vinyl polymers to the void spaces in wood, compression strength, hardness, and abrasion resistance are greatly improved. The diffusion of the water in and out of the WPCs is restricted. WPCs have found commercial application where the specific physical property improvements can be used to advantage. Parquet flooring is a major commercial product. Other commercial items include archery bows, billiard cues, golf clubs, musical instruments, office equipment, and knife handles. With the finish integrated through the WPCs, maintenance problems are kept to a minimum. WPCs are produced in United States, Germany, England, Poland, Italy, Japan, Taiwan, New Zealand and other countries (Meyer, 1982). Several review articles on WPCs have

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doi:10.1016/j.biortech.2004.09.010

been published (Meyer, 1981; Rowell and Konkol, 1987; Schneider, 1994; Kumar, 1994; Lu et al., 2000).

From the viewpoint of the method of production of WPCs, the most decisive factor in choosing a suitable wood for raw material is its homogenous impregnability. Hardwoods (deciduous species) have mainly been used in making WPCs. Many woods, including tropical species, have been found useful to make WPCs, such as alder, yellow poplar, ash, maple, walnut, birch, basswood, red gum, beech, red and white pine (Rowell and Konkol, 1987). However, a few studies dealing with the suitability of fast growing wood species have been done (Kumar, 1994; Elvy et al., 1995).

The main objectives of this study were (i) to prepare WPCs from maritime pine and poplar as important fast growing wood species in Turkey, (ii) to evaluate the mechanical properties of this pine–polymer composite materials, (iii) to evaluate their decay resistance.

2. Methods

2.1. Wood materials

Ten 28-year-old maritime pine (*Pinus pinaster* Ait.) trees from the original plantation areas in Kerpe Burnu, Kocaeli where is western part of Turkey and ten 9-year-old poplar (*Populus* x. *euramericana cv*. I-214) trees from the original plantation areas in Meric, Ipsala where is western border of Turkey were cut down as wood material. were cut down as wood material. Two blocks (each 65 cm long) from the sapwood portion of each log were sawn for mechanical tests. These blocks were air-seasoned to equilibrium moisture content prior to preparing of samples. Test and control samples were prepared from these blocks for each mechanical property according to the relating standards. The prepared test and control samples were dried at 103 ± 2 °C to determine the oven-dried weights before polymerization (WBP). Test samples were then conditioned until they had 7% moisture content prior to monomer impregnation.

2.2. Monomer solutions

Three monomer solutions were used for wood–polymer composite production: styrene (ST), methyl methacrylate (MMA) and styrene/methyl methacrylate (ST/MMA, 65/28 (w/w) %) mixture containing 2% benzyl peroxide catalyst (polymerization initiator) and 5% divinyl benzene as cross-linker. Monomer solutions were used with the addition of benzene in order to adjust the three different polymer loading levels in WPCs; the full-load level (FL) consisted of 100% monomer solution, the half-load level (HL) 70% monomer solution, 30% benzene, and the quarter-load level (QL) 40% monomer solution, 60% benzene in weight bases.

2.3. Impregnation and polymerization procedure

Test samples were placed in a vacuum-chamber and, a full vacuum (<70 mmHg) was drawn on the wood for 30 min. The monomer solutions were introduced into the treatment chamber until the samples were completely covered. The samples were then soaked in monomer solution for 24 h in normal atmosphere and room temperature conditions. The impregnated samples were wrapped in aluminum foil and heated to 90 °C for 24 h to polymerize the monomer. After unwrapping, the samples were dried at 103 ± 2 °C to remove residual monomer and determine the oven-dried weights after polymerization (WAP). The polymer content (PC) in the test samples was calculated by the formula (Duran and Meyer, 1972):

$$\mathrm{PC}\% = \frac{\mathrm{WAP} - \mathrm{WBP}}{\mathrm{WBP}} \times 100,$$

where WAP, the oven-dried weights of wood sample after polymerization; WBP, the oven-dried weights of wood sample before polymerization; PC, The polymer content.

2.4. Mechanical tests

The following mechanical properties of WPCs and their controls were tested: (i) compression strength parallel to grain with the samples milled to 20 × 20 × 30 mm, (ii) static bending strength with the samples 20 × 20 × 300 mm. Compression and bending tests were performed in accordance with American Society for Testing and Materials 143 (1996).

2.5. Laboratory fungal decay resistance tests

Decay resistance was assessed using European Standard EN 113 (1994), with *Coniophora puteana* for 3 × 2 × 5 cm cut pine wood samples and *Coriolus versicolor* for 3 × 2 × 5 cm cut poplar wood samples as the test fungi. Four control and four test samples for each group were used. The wood samples and Kolle flasks were sterilized. Each Kolle flask containing malt extract agar was inoculated with an agar disc cut from the actual growing edge of the test fungus and Kolle flasks were incubated at 20 ± 2 °C and 65 ± 5% relative humidity until malt extract agar was covered by mycelium. Sterilized test blocks were then placed in the Kolle flask and incubated at 20 ± 2 °C and 65 ± 5% relative humidity for 16 weeks. One test wood polymer composite sample and one control were placed inside each Kolle flask. After the incubation period, test blocks were removed and conditioned at 25 ± 2 °C and 65 ± 5% relative