Straw-wood composites bonded with various adhesive systems

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Abstract In order to study the feasibility of utilizing wheat straw as an alternative raw material for panels, experimental one-layer particleboards were produced by mixing straw with industrial wood particles in various proportions (100:0, 75:25, 50:50, 25:75, 0:100). Three different adhesive systems were used for blending the raw materials: a UF resin (E2 grade), a PMDI resin and various UF:PMDI combinations (10:0, 8:2, 7:3, 6:4, 5:5). The evaluation of the mechanical and hygroscopic properties of panels showed the following results: Partial replacement of wood particles from straw in panels bonded with pure UF resin resulted in deterioration of all properties except linear swelling. Partial or whole substitution of wood by straw in PMDI bonded panels, improved the bending strength and all hygroscopic properties of the panels but reduced the internal bond (dry and wet) and screw holding strength, although to a much smaller degree compared to UF bonded panels. The properties of panels bonded with various UF:PMDI combinations and comprising 50% wood and 50% straw were considerably improved by increasing the PMDI content. In terms of the properties, pure straw panels or panels made of certain wood/straw mixtures, if bonded with PMDI resin or the appropriate UF:PMDI combination, can be used for specific applications where high quality panels are required according to the specifications of the related standards.

Introduction

Worldwide, economic growth and development have generated unprecedented needs for converted forest products such as pulp and paper, composite boards, plywood and lumber. Furthermore, the diminished supply of larger dimension timbers have created high pricing. Through these changes the industry is forced to identify alternative lignocellulosic sources and make improvements in traditional production methods.

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Lignocellulosics from field crop residues like cereal straw, flax straw, stalks from corn, cotton and sorghum, bagasse and grass represent a potentially valuable source of fibre which could be used either as a supplement to, or as a direct substitute for wood in the manufacture of forest products, e.g. particleboard, fiberboard or pulp for paper-based products. Approximately 2.5 billion mt of these agricultural residues are annually produced worldwide. Factors that consistently hamper increased use of agro-based residues in pulps and composites are economics and problems and costs associated with the seasonability, the collection, the transportation and storage of the raw material.

However, in those countries where there are little or no wood resources left, or where due to regulations the use of wood is restricted, alternate sources like agricultural residues are needed if there is to be a natural fiber industry in those countries (Youngquist et al. 1993; Rowell et al. 1997).

Cereal straw as an annually-renewable fiber is one of the most important agricultural residue because it is available in abundant volumes in many regions of the world; the worldwide production of cereal straw is estimated at 1.5 billion mt annually (Rowell et al. 1997). In EC about 140 million tons of cereal straw per year are produced of which just a small part (2–3%) is processed in the industry. Because of environmental restrictions, straw may not be burned anymore in many EC-countries. Therefore, new applications have to be found besides the traditional forage and bedding for animals (Dam et al. 1994).

In the search for alternative fibers replacing natural wood, the use of straw as potential fiber for composites and particularly for particleboards has been gaining increasing research interest during the last twenty years (Rexen 1975; Hesch 1979; Heller 1980; White and Ansell 1983; Tröger and Pinke 1988; Thole and Weiss 1992; Zucaro and Reen 1995; Möller and Böttcher 1995; Sauter 1996; Dalen and Sharma 1996; Russell 1996; Hague 1997). In terms of process, straw fiber offers advantages such as the ability to be processed with less costly chipping and drying equipment. On the other hand, greater press capacity may be needed to accommodate the longer press times required for adequate steam dissipation (Hesch 1979; Spelter 1996). The waxy coating on the epidermis of straw stem causes problems in bonding this material with conventional urea formaldehyde (UF) binders. As derived from previous works, the polymeric isocyanate binder (PMDI) is the most effective binder in the manufacture of straw composites (Heller 1980; Tröger and Pinke 1988; Zucaro and Reen 1995; Dalen and Shorma 1996; Sauter 1996; Hague 1997). Rexen (1975) achieved acceptable bond quality in straw boards by using a modified UF resin. Apart from UF and PMDI, other binders like polyester (White and Ansell 1983) and gypsum (Thole and Weiss 1992) have been used for various types of straw composites. A natural light composite product consisting of a core made from straw stems, parallelly glued with glutin foam and wooden faces from veneer, has been developed by Möller and Böttcher (1995) as alternative to synthetic and aluminium products. In spite of the fact that straw has always been inexpensive, at present there is only one plant in the USA which produces particleboard from straw (Dalen and Shorma 1996) and another is under construction in Canada (Porter 1997). This is attributed to the fact that the appropriate PMDI binder for straw is expensive and has created a big price gap with wood particleboard which uses the less expensive UF resin; now as the cost of wood is continually increasing, the gap tends to close. It is also important to note that straw composite plants could offer new employment opportunities in agricultural areas.