

Growing markets for engineered products spurs research

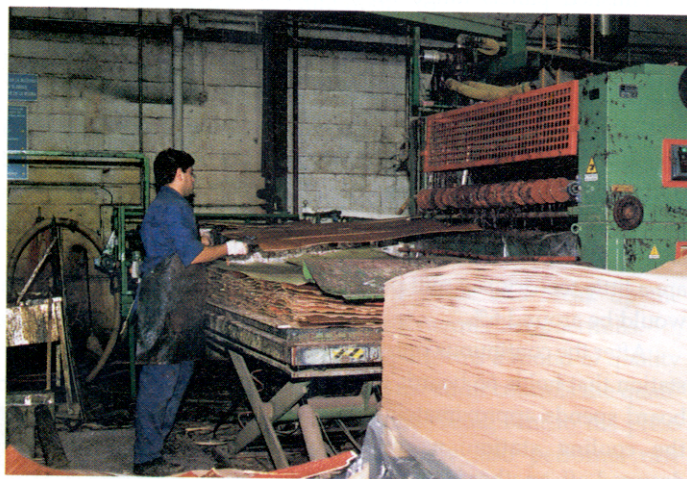
North America is a major producer and consumer of glued-wood products. Here is an overview of adhesives types and applications

by TERRY SELLERS

An expanded array of glued-wood products has increased demand for a variety of wood-adhesive resins and fostered adhesive systems with enhanced properties. North America consumption of adhesive resin solids required to bond glued-wood and related solids was estimated at 1.78 million metric tons in 1998, or 1,780 kilotons (kt).

In this year, about 35% of these products consisted of plywood and laminated veneer lumber. Oriented strand products accounted for 29%, followed by particleboard at 19%, medium-density fiberboard at 6% and a variety of other products at 11%. Estimated resin consumption by country was 1,370 kt in the United States, 374 kt in Canada and 36 kt in Mexico.

Amino resins bonded most particleboard, fiberboard and decorative/hardwood plywood. Consumption of these resins, mainly urea-formaldehyde (UF) based, came to 1,060 kt in 1998. Wood composite industries in the three countries consumed 568 kt of phenolic resin solids. These are primary binders for oriented strand products (OSB and OSL), construction plywood and laminated veneer lumber. Phenol-formaldehyde (PF) resins are used in some MDF and high-density fiberboard and hardboard. Other engineered lumber products are bonded with phenol-resorcinol-formaldehyde (PRF) resins.



Over the past 15 years, polymeric diphenyl methylene diisocyanate (PMDI) has gained a footing in North America. PMDI consumption is estimated at 90 kt, with 90% of this used in OSB and OSL. About 18% of the binder requirements for OSB is PMDI; liquid and powder PF resins make up the balance. PMDI resins are the preferred binder for agrifiber boards such as wheat straw, unless the fiber has been modified by mild chemical and steam pretreatment and refining.

Vinyl compounds (50 kt) are used in North America mostly for assembly glues, but some are used for hardwood plywood and hardwood lumber flooring products (for flatbed trailers and railway cars, e.g.).

This paper will review some of the excellent data available on many wood-based composites in Canada and the US. Substantial research and development on wood adhesives continues, focusing on amine, phenolic, polyurethane, vinyl, soy and accelerator modifications.

In 1998, industry used 1,780 kt of adhesive resin solids to manufacture 58 million cubic meters of primary glued-wood and related products. This does not include adhesives used in furniture and other secondary wood products. Nearly 60% of consumption was amino resins (UF, etc.); about 32% was PF and RF; the remaining 9% consisted of several products, including PMDI.

Increasing oil prices are boosting resin prices. Adhesives are a vital part of glued-wood composites; their share of manufacturing costs ranges from quite small to 32%. As capacity of these products increases and new products are developed, demand for wood-adhesive resins has grown and fostered research into adhesive systems with enhanced properties.

Since 1981, North American mills have used lignin-modified PF resins to bond fiberboards, strand boards and structural plywoods. Industry uses small quantities of lignin to replace as much as 35% of the phenol in modified PF resins. Researchers continue to seek natural alternatives that can effectively replace synthetic resin adhesives as wood binders.

Tannin adhesives are rarely used in North America, though interest continues elsewhere. In Germany, Bakelite AG developed tannin-based adhesives for marine grade OSB. Tannin extracts

Opposite page: A worker operates a glue-applying system for veneer sheets.

used were pecan nut, radiata pine bark, mimosa and quebracho. Tannin from radiata bark has been used in Chile to bind particleboard, MDF and OSB. CanFibre Group is looking into using high pressure and temperature to make barkboard; only bark's inherent phenolic compounds would bind the particles.

Caseins, perhaps the first structural adhesives, are still used. Volume is small (under 5 kt/year) and most is modified with soy flour.

Soy products have a history as soybean glues and soy-modified casein adhesives, but there is renewed interest in soy flour and soy protein isolates in binders for wood-based and agrifiber composites. Research continues on soy products for fingerjointing adhesives, as replacements for animal blood in plywood production, for PF and PMDI resin blends in OSB, wheat/soy blends as plywood glue extenders and other uses.

In North America, soluble animal blood is now rare as an adhesive, but it is indispensable in PF foam adhesives for industrial and construction plywoods. Eleven mills in North America and one in Europe were using foam glues in 1999.

Transformation of wood to a liquid with phenol to a pyrolysis oil yields a wide mixture of compounds that have shown promise as a raw material for modified-PF resins. Up to 50% of the primary binder has been replaced by liquefied wood components.

North America's 103 softwood plywood plants and 21 LVL mills relied almost exclusively on PF resins to manufacture 18.7 billion cubic meters of these products in 1998. Glue costs range from \$14-16/cubic meter for plywood and \$24/cubic meter for LVL, according to a 1996 US Forest Products Laboratory survey.

OSB had nearly half of North America's industrial and structural panel market in 1998. Oriented strand board and lumber represent almost 30% of wood composite products and their market share is growing rapidly. In 1998, the 56 OSB mills and two OSL plants used PF resins in 82% of output and 18% PMDI. Use of isocyanate adhesives allows gluing strands at more than 6% moisture content at relatively fast speeds (4 seconds/mm of panel thickness) when combined with steam injection.

Adhesives meeting North American standards for exterior uses in I-joists, glulam beams and structural fingerjoints historically have been RF- and PRF-based. Recent formulations involving polyurethane/isocyanate resins have been marketed. For structural interior and external environments protected from the weather, MF-based (melamine-formaldehyde) adhesives have been used.

UF resins were mainly used to bind the 10.9 million cubic meters of particleboard and 3.4 million cubic meters of MDF manufactured in 104 North American mills in 1998. PB mills paid an average of \$32/cubic meter for US glue and wax in 1996. These two boards account for more than 25% of total wood composites

made in North America, and demand for them is growing.

PF or lignin-modified PF resins are mainly used to make **hard-board** (1.96 million cubic meters in 1998). A variety of binders is used in low-density insulation board (1.55 million cubic meters).

Production of decorative plywood and glued hardwood lumber involves primarily UF, MF and **UF/MF** blended resins, or polyvinyl acetate (**PVAc**) emulsion and **X-PVAc** emulsion adhesive systems. Vinyl acetate emulsion adhesives include various ingredients such as polyvinyl alcohol, cross-linked phenolic or isocyanate (as **thermosets**), wood flours, kaolin and other plastic additives.

Two factors in the hardwood plywood industry are affecting adhesives: thinner face veneers and higher-moisture content veneer (shipped at **18-19% MC**, reduced to **12-13% MC** during transportation and storage).

As concerns rise over allergies, parquet and laminate flooring markets have grown, replacing carpet. Wood floors are solid wood strips, solid and glued 3-ply parquet and "laminate" flooring strips. Laminate flooring (3% of the total 1999 flooring market) includes 3-ply and 5-ply hardwood veneer plywood that is cut into strips or blocks and a four-layer composite. The composite consists of a **transpar-**

ent, abrasion-resistant surface layer, a decorative subsurface, an impact-resistant/stability layer and a balancing back layer.

Resin research continues to identify mechanisms to bond **treat-**ed woods, particularly those containing fungicides, **copper-chromium-arsenic (CCA)** or borate compounds, fire retardants and composites of wood fiber and thermoplastic/thermosetting materials. Moderately low molecular weight RF resins are helpful in bonding CCA-treated wood. One-part polyurethanes containing 20% PMDI polymers are available to bond treated wood. These same adhesives offer opportunities to bond recycled treated wood, as well as high-extractive-content wood species, into useful products.

Agrifiber composites are sometimes described as being between MDF and PB in physical and mechanical characteristics. By 2001, 13 agrifiber PB plants are expected to be running in North America with an annual capacity of 1.56 million cubic meters. Wheat straw is the main fiber used currently, but soybean stalks, grass straw, bagasse, cotton stalks, rice straw, hemp and kenaf are among the fibers being considered. Some of these fibers' high silicon content acts as a bonding barrier and causes higher tool wear. Some agrifibers have wax on the surfaces that interfere with **resin-**

■
Increasing oil
prices are
boosting resin
prices.
■

adhesive bonding.

Without fiber modification-mild chemical and steam pretreatment and fiber bundle refining-to improve buffering capacity and surface functionality, PMDI resin (up to 6% resin solids or higher, dry fiber-weight basis) has been shown to be the preferred binder for most agrifiber boards. This makes adhesive costs for these **nonwood** boards up to three times higher for a given volume that for comparable wood-based panels.

However, with pretreatment and refining of agrifibers, conventional formaldehyde-based resins reportedly work well. It has been reported that some straws without pretreatment can replace up to 20% of the fiber weight in wood PB with acceptable board properties.

The key to success for adhesive companies in an increasingly global environment lies in designing strategies that gather and analyze adhesive information worldwide, then applying this knowledge to achieve interactive technologies and expand market shares that meet regional requirements. For the wood adhesive and wood composite industries to succeed long-term, progressive and appropriate long-term investment is necessary.

Life-cycle analysis is a major factor in this investment. Life-cycle analysis of resin adhesives includes energy costs, long-term durability, environmental and recycling factors as well as humanities and social-science functions. It is more than a question of raw materials, end products, markets and resin deliveries to mills.

In terms of durability in structural applications, the cured adhesive must equal or exceed the wood in strength. For all end uses, the cured adhesive and wood composite must be evaluated for four environmental degradation conditions: heat energy (pyrolysis) for thermal-chemical degradation; chemical energy (hydrolysis) for moisture content changes, atmospheric exposure, tool wear and compatibility with coatings and finishes; physical energy for responses to shrinking and swelling stresses; and biological energy for susceptibility to bacteria and fungi.

Structural adhesives should have known and comparable test properties for in-service performance. These test properties include tensile and bending strength, impact and fatigue propagation, environmental durability regimes (cyclical loads under elevated temperature and moisture) and biological responses under adverse conditions where applicable.

These areas offer future opportunities: cure on command; combination adhesive technologies with benefits from all; relatively inexpensive adhesive primers and surface treatments; environmentally benign adhesive systems (with proof); and life-cycle predictions with associated costs. ▣