water entrapment. Untreated wood should not be on or near ground, because soil is a source of water and actively growing decay fungi. Design and construction details should direct rain water or condensation away from the structure. If wood must serve in soil or water contact, it should be pressure-treated with a preservative. These simple precautions may spare the building owner considerable repair costs.

Wood decay in structures results in serious loss in strength. Research has shown that most wood strength is lost in stages of decay so early that they can only be detected in the microscope—and long before the decay is visible to the naked eye. Strength properties, which involve resistance to shock or suddenly applied loads, are particularly sensitive to decay, providing special problems for structures in areas subject to earthquakes. Ability to detect decay in its early stages is therefore important, but more important is avoiding those situations that provide moisture needed for growth of decay fungi.

Research has shown that microscopical examination can be relied upon to estimate, roughly, the degree of decay present in a particular sample based on the number, size and occurrence of fungal hyphae, bore holes, cracks within cell walls or separations between cells, the thickness of cell walls, or the size of cells. Such data, however, are not available specifically for California species and current research is directed at providing this information in sufficient detail so that the stage of decay may be estimated with considerable accuracy.

Speculating that electrochemical reactions might explain unexpectedly large amounts of wear on wood-cutting tools, Forest Products Laboratory researcher Barney Klamecki (not shown) reduced wear 20 percent by insulating the cutter from the lathe in wood-turning experiments. Subsequent studies, in which electrical potentials were applied to cutters and the cutting forces were measured, showed essentially no change in force with applied voltage. Klamecki believes the difference in wear caused by electrical interaction is the result of changed corrosion behavior rather than abrasion.

W. Wayne Wilcox is Professor, Forestry, and Forest Products Pathologist, U.C. Forest Products Laboratory, Richmond.

Nonconventional bonding

Fred E. Dickinson

In California and in the United States as a whole, the single, largest use of forest products, excluding pulp and paper products, is for constructing single family dwellings. Solid wood and reconstituted forest products, with few exceptions, are the only products from a renewable resource economically suitable for building. In addition to this advantage, wood is produced with much less energy than are other competitive materials, such as aluminum, steel, or concrete. Ever-increasing costs for energy, capital, and labor to obtain nonrenewable materials from distant and inaccessible regions in the world also encourage substituting renewable wood for nonrenewable materials.

Complicating wood's advantages are the increasing demands to use our forests for such purposes as recreation and a trend towards using younger-growth timber for manufacturing. The latter leads to production of smaller-sized timber of decreased quality and consequent manufacturing losses. Reconstituted wood products, however, allow a more effective use of our raw material. Utilized are such processing residues as log and board ends, the slabs left in converting round logs to squares, sawdust, and other small, damaged, or otherwise unusable pieces. There is also a tremendous potential for the vast quantities of residues left in our forests after logging.

Particleboard is an excellent example of a reconstituted product that has shown remarkable growth over the last two decades; its compounded annual rate of growth between 1963 and 1973 was 22 percent. Most increased production has been in exterior grade particleboard for use in housing. This product can retain strength and dimensional stability at an acceptable level after extensive exposure to wetting and weathering.

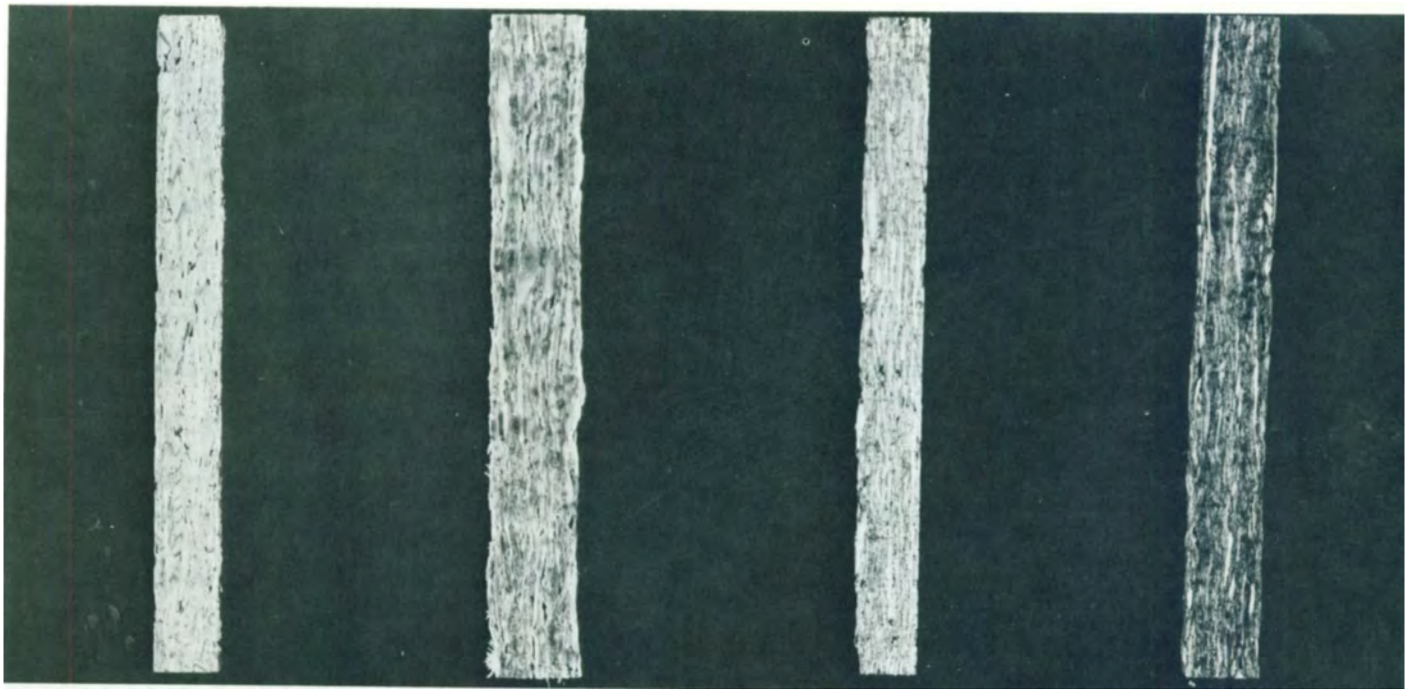
In recognition of the tremendous potential for improved waste and residue utilization and its importance to housing, the University of California Forest Products Laboratory has undertaken major research, largely concentrating on developing a bonding method known as "nonconventional bonding." This method differs significantly from existing methods in that it does not utilize conventional petrochemically-based synthetic resins, such as phenolformaldehyde, thereby reducing our present dependency on them.

Objectives

Although the bonding system is widely applicable to any form of glued wood product, research has been concentrated on its adaptation to particleboard. Objectives are:

1. To develop an exterior grade, medium-density particleboard with dry properties equal to—and wet mechanical and physical properties superior to—those presently obtained in commercially manufactured phenolformaldehyde boards.
2. To assess carefully, to the extent practical, the total impact of the system on the environment.
3. To explore the fundamental chemical and physicochemical transformations that take place in this process, with the philosophy that such knowledge should lead to development of particleboard with vastly superior properties applicable to many other glued wood products.

To expedite this program a University of California interdisciplinary research team has been formed, managed by Donald G. Arganbright, wood technologist, with David L. Brink and



PHENOLFORMALDEHYDE CONTROLS — NONCONVENTIONALLY BONDED

BEFORE — AFTER — BEFORE — AFTER

Cross-section view of 0.65 gm/cc density particleboard demonstrating the degree of thickness swelling after two hours of boiling with water. Note that the nonconventionally bonded wood is a more stable product as the amount of swelling is less than for the phenolformaldehyde bonded board.

Eugene Zavarin, forest products chemists, as principal investigators, and several assistants. Their research is supported, in part, by grants from five private forest products industry firms.

The bonding system

The general systems being investigated consist of treating chips or flakes with an oxidizing agent, such as nitric acid or hydrogen peroxide, to activate chemically the wood surface. A cross-linking agent or gap-filler comprised of a lignosulfonate, together with furfuryl alcohol and maleic acid, is then sprayed on the flakes. After a mat of flakes has formed, it is bonded into a sheet of particleboard with a hot press, using pressures, temperatures, and times roughly equivalent to those used by industry to press particleboard and/or plywood with conventional resins such as phenolformaldehyde.

Different properties for laboratory-produced, nonconventionally bonded boards made using Douglas-fir and white fir flakes are compared with the properties of similarly produced boards using phenolformaldehyde in the table. These results should be viewed in light of the fact that the resin content of the phenolformaldehyde controls was 7 percent, rather than the 5 percent commonly used in industry. Board properties increase significantly as resin content increases. The dry and wet modules of rupture values of the nonconventionally bonded boards are lower than those for the phenolformaldehyde controls, but the modulus of elasticities are reasonably similar. Neither system shows a consistent superiority for internal bond and thickness swelling after two hours of boiling in hot water. The 24-hour cold water swelling values, on the other hand, are in both cases lower for the nonconventionally bonded boards which is highly desirable. This result can be seen readily in the accompanying photo.

Test results to date indicate it is possible to produce particleboard, using nonconventional bonding, that meets the U.S. Department of Commerce Standard CS236-66 for mat-formed wood particleboard. With further research, even better overall mechanical properties and wet mechanical and physical properties may be obtained. Estimates of costs, based upon raw materials alone, indicate that the cost of nonconventionally bonded boards will be approximately equivalent to, if not lower than, comparable phenolformaldehyde-based boards.

When completed, this research, it is hoped, will provide a production method not dependent upon petrochemicals for industries supplying materials for residential construction.

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TABLE 1. Comparison of Properties for Nonconventionally Bonded Particleboard Using Nitric Acid and Phenolformaldehyde Boards (with density of 0.65 gm/cc)

Type of board	Species	Dry modulus of rupture	Wet modulus of rupture	Dry modulus of elasticity	Internal bond	Thickness Swelling: After 2 hrs. of boiling	Thickness Swelling: After 24 hrs. cold-water soak
		(lbs/in²)	(lbs/in²)	(lbs/in²)	(lbs/in²)	(%)	(%)
Nonconventionally bonded boards	Douglas-fir	2247	636	558,108	74.6	33.4	18.9
	White fir	2760	882	605,091	70.2	22.5	14.8
Phenolformaldehyde control	Douglas-fir	4748	1937	618,931	105	25.8	20.8
boards	White fir	4304	1639	561,896	52	41.9	35.0