SELECTIVITY OF BONDING FOR MODIFIED WOOD

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Introduction

Wood is an unusual substrate in that it is macro porous and micro porous, as well as being an ordered, structural nanocomposite. Wood undergoes volume expansion and contraction as its moisture level increases and decreases, leading to poor bond durability. One way to reduce shrinking and swelling is to modify wood by acetylation.

Acetylation with acetic anhydride is one of the most studied chemical modifications for wood. For every acetyl group attached to the wood, one hydroxyl group is blocked from hydrogen bonding with the adhesive. which can reduce adhesive interaction with the wood surface. If interfacial interaction is the controlling aspect of bond strength, then acetylation should reduce the percentage of wood failure during shear tests. Deep penetration of resin adhesives into the wood structure is very important to structural performance of bonded products under exterior exposure conditions (1).

Because adhesives work by surface attachment. the adherend's surface qualities are extremely important to satisfactory joint performance (2). Wood is resurfaced just before bonding to remove any raised grain areas and any extractives. This seems logical for unmodified wood, but what effect does surfacing of wood prior to bonding have on modified wood? The concern is that planning acetylated wood would provide a surface that is not fully acetylated.

Experimental

Yellow-poplar sapwood specimens (0.6 cm × 3.2 cm × 15.2 cm) were cut and dried at 105°C in a forced draft oven for 24 hours. Specimens were cooled for 1 hour in a desiccator, weighed, and then reacted in a glass reactor for 4 hours with acetic anhydride (3). After modification, specimens were air dried overnight under a fume hood, oven dried, and weighed. Weight percent gain was determined from original oven-dried weights. Percentage acetyl content was determined using anion exchange high performance liquid chromatography (HPLC) with a suppressed conductivity detector, using a previously described method (4).

Three types of commercial adhesives were bonded to unmodified and acetylated wood. The unmodified wood was planed according to standard practices; the acetylated wood was both planed and unplaned. The wood was bonded at room temperature under pressure.

Block shear specimens were cut from the joint assemblies and randomly assigned for wet or dry shear test. Dry and wet specimens were tested according to ASTM D 905 (5), and wood failure was estimated to the nearest 5% on the sheared area, according to ASTM D 5266 (6).

Results and Discussion

Data analysis indicated that for shear strength and wood failure in both wet and dry conditions, adhesives, planing, and their interaction were highly significant. This means that the various adhesives reacted differently to planing and/or acetylation, and therefore it is necessary to look at the effect of treatment by adhesive,. where treatment represents the interaction of planning and adhesive.

The figures depict results obtained for each adhesive. Data are presented in shear strength or wood failure versus treatment. Each treatment is identified by two letters: The first letter represents the characteristics of the surface materia1-C for control, P for acetylated surface that was planed before bonding, and U for acetylated wood that was not planed before bonding. The second letter represents the adhesive type. The absence of error bars for some of the wood failure for some treatments indicate that all the values were either 100% or 0% wood failure.

Resorcinol–Formaldehyde

Resorcinol–formaldehydeadhesive developed bonds that gave high substrate failure in all cases. Figures land 2 show the high shear strength and wood failure found in both dry and wet conditions on both unmodified and modified wood. Acetylated wood showed greater retention of shear strength when wet because of lower moisture pick up and less softening of the wood under water soak conditions.

Emulsion Polymerized Isocyanate (EPI)

The emulsion polymer–isocyanateperformed well in the dry condition in both shear strength and wood failure. In the wet condition, no significant decline was found in bonds for unmodified wood, but it was affected by acetylation regardless of surface preparation. Figures 3 and 4 show the dramatic decline between dry and wet conditions of both shear strength and wood failure for acetylated wood.

Epoxy

Epoxy bonds to wood are generally strong when tested in a dry condition, but they weaken drastically when subjected to water saturation and drying (7). Data in Figures 4 and 5 illustrate that epoxy gives desired strength and wood failure in the dry condition. Epoxy strength and wood failure decrease in the wet condition except in the case of un-

planed acetylated wood, where it has unusually high wood failure for an epoxy adhesive.

Discussion

Resurfacing modified wood before bonding may affect the stability of the modification and ultimately affect the way adhesive reacts with the surface. Previous studies (1.7) involved planing the wood after acetylation; thus, in some cases the results may have been different if the adhesive were applied to a fully modified surface.

Why is the epoxy bond more durable with unplaned acetylated wood than with untreated wood? The reduced polarity of acetylated wood is not likely the answer, because polar interactions generally favor stronger adhesion. The lower dimensional change of acetylated wood during wetting likely puts less force on the interphase compared with the control sample. The lower strain on the bondline seems to be sufficient not to cause fracture of the epoxy in the interphase region. Epoxy–wood bonds have been reported to fail in the epoxy interphase region (8).

Conclusions

This work shows that acetylation of wood surfaces can affect the way the adhesive interacts with the surface. Response to modification varies with type of adhesive. The tendency in previous work has been to lump the different adhesives together (7), but insight can be gained by separating out the results for each adhesive. The resorcinol–formaldehyde adhesive bond was insensitive to either wood type or wet conditions, although the wood was weaker under wet conditions. The emulsion-polymerized isocyanate was insensitive to wet conditions for unmndified wood but was sensitive for acetylated wood. The epoxy gave unexpectedly strong bonds 'to acetylated wood under wet conditions.

These data have led to a new conceptual model of the durability of wood bonding that emphasizes the importance of minimizing the swelling stress at the interphase regions. An extension of this model places emphasis on the adhesive for stabilizing the wood surface as opposed to strong interfacial attraction for good bond durability.

Acknowledgements

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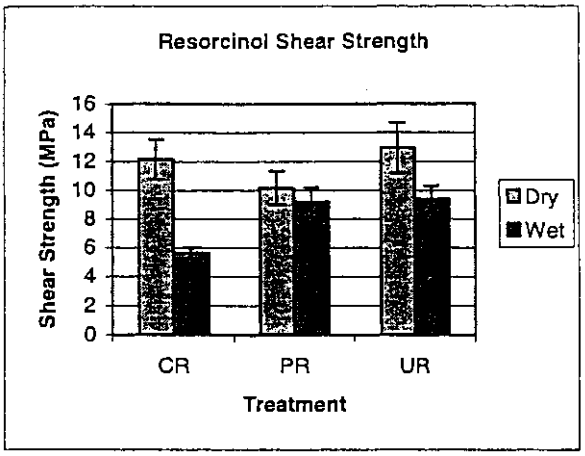

Figure 1. Shear Strength Values For Resorcinol.

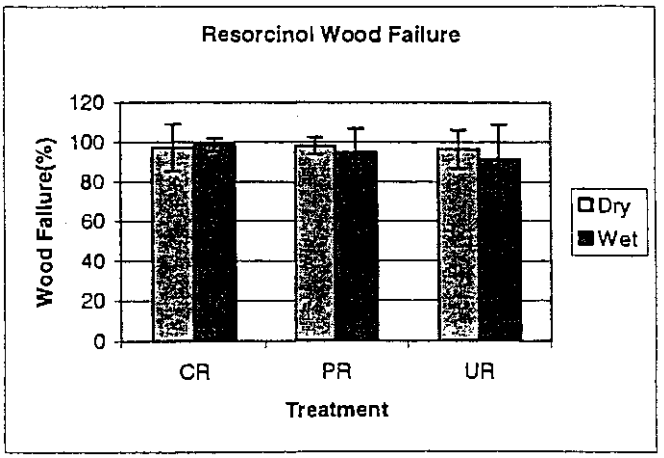

Figure 2. Wood Failure Values for Resorcinol

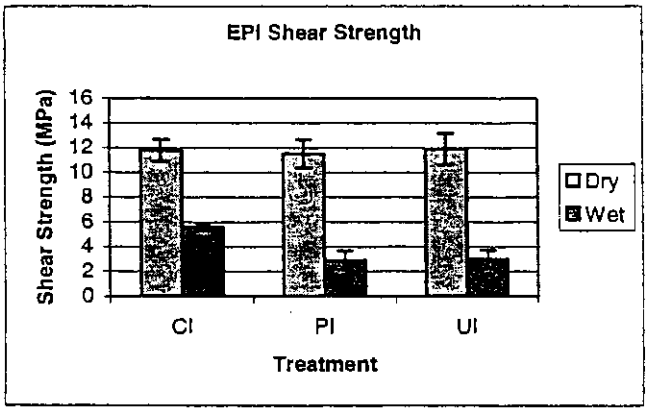

Figure 3. Shear Strength Values for EPI.

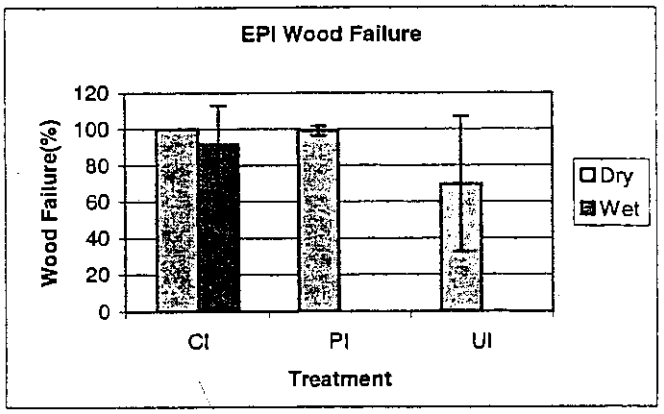

Figure 4. Wood Failure Values For EPI.

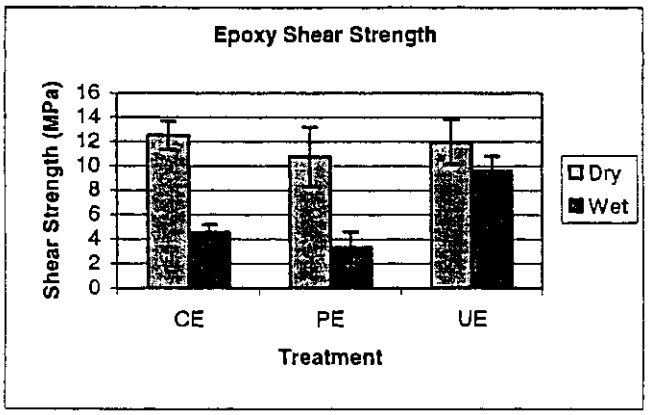

Figure 5. Shear Strength Values for Epoxy.

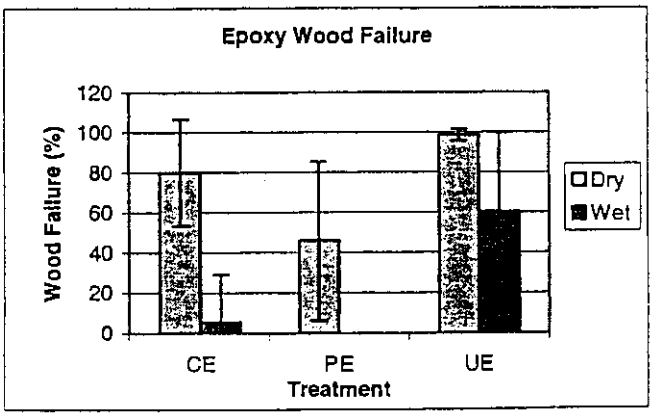

Figure 6. Wood Failure Values for Epoxy.

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