# PRELIMINARY DEVELOPMENT OF REMEDIAL TREATMENTS FOR THERMALLY DEGRADED FIRE-RETARDANT-TREATED WOOD

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ABSTRACT

Thermal degrade of fire-retardant-(FR-)treated plywood roof sheathing and roof-truss lumber is a complex function of wood and treatment chemistry and field exposure conditions. Because borate-based treatments inhibit or reduce the rate of thermal degradation in wood exposed to elevated temperatures, they may also be effective as a remedial treatment for FR-treated plywood if sufficient penetration and retention of the borate chemical can be obtained. To increase the penetration of a borate remedial treatment (without using excess water that might leach the FR chemicals), we applied the berates in a glyco/water mixture. Our preliminary results indicate that borate/glycol remedial treatments can partially mediate thermal degrade of FR-treated plywood. Further work is now underway.

Building codes can require the use of fire-retardant-(FR-)treated wood. For nearly 50 years, FR-treated lumber and plywood have often been successfully used in structures exposed to temperatures less than 100°F (38°C). When used as roof sheathing, some FR formulations undergo thermal decomposition in service due to the typical roof temperatures induced by solar radiation. The FR-treated plywood that has thermally degraded crumbles easily when abraded, often exhibits excessive cross-grain checking, and can turn a dark brown color with a dry rotted-like appearance.

Thermal degrade of FR-treated plywood roof sheathing and roof- truss lumber is a complex function of wood and treatment chemistry and field exposure conditions (7). Past work has shown that borate-based systems inhibit or reduce the rate of thermal degradation in wood exposed to elevated temperatures (5). Thus, using borate as a remedial treatment for FR-treated plywood might reduce further degradation if the borate chemical can sufficiently penetrate and be retained in the plywood. While berates are easily diffused into wet wood, borate penetration is inhibited in dry wood like that normally found in roof sheathing. To increase the penetration of a borate treatment (without using excess water that might leach FR chemicals), we applied the borates in a glycol/water mixture. Commercial borate/glycol/water treatments were used. In addition to retarding surface drying, such formulations promote wetting of the wood surface and interior plies, which allows mass flow of borate into lathe checks or capillary voids.

## PROBLEM

Nearly 750,000 structures using various types of FR-treated plywood roof sheathing have experienced field failures as a result of thermal degrade after exposure to the typical roof temperatures induced by solar radiation(6). The National Association of Home Builders (NAHB) predicts the cost of this problem to exceed $2.0 billion. To our knowledge, no remedial, in-place treatment is currently available. If such a treatment were developed, it might save millions of dollars in sheathing replacement costs.

## OBJECTIVE

This preliminary research used a laboratory-model system to prove the concept that simple, inexpensive remedial treatments can be developed. With further work, remedial treatments that inhibit thermally induced degrade of undamaged and semi-damaged FR-treated plywood roof sheathing and roof-truss lumber may be possible.

## METHODS

Side-matched specimens were cut from four 5-ply, 4-by 8-foot (1.22- by 2.44-m), southern pine, N-grade (no defects, patches, or voids) plywood panels. Each bending specimen was 5/8 inch thick by 3 inches wide by 24 inches long (16 by 76 by 610 mm) (l). Each tension specimen was 5/8 inch thick by 1 inch wide by 24 inches long (16 by 25 by 610 mm). Half of the specimens were untreated and half were treated with monoammonium phosphate (MAP), a commonly used fire retardant for lumber and plywood, to a retention of 3.5 pcf (56 kg/m$^3$). After treating, both treated and untreated tension specimens were necked down to 1/2 inch(13 mm) as required for ASTM D 3500-Type B specimens (3). Twenty-nine MAP-treated and 31 untreated plywood bending specimens and 18 MAP-treated and 18 untreated plywood tension specimens were assigned to groups **(Table 1).** One MAP-treated bending specimen was deleted because of delamination. Those remaining specimens designated for remedial treatment were brush-treated on their faces (with care to avoid edge contamination) with two coats of either a 10 or 20 percent solution of borate in a glycol/water solution. After two coats, gross remedial weight-gain

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*TABLE 1. — Mechanical properties of southern pine plywood treated with remedial borate/glycol treatments prior to 60-day exposure at 150°F and 75 perccnt relative humidity.*

| FR treatment | Borate/glycol solution concentration[a] | Number of Specimens Tension | Bending | Property[b] UTS | MOE | MOR | WML | MC | SG |
|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | (psi) | ($x10^6$ psi) | (psi) | (in.-lb/in$^3$) | (%) | |
| Control[c] | .. | 6 | 8 | 5,241 (1,462) | 1.573 (208) | 9,665(2,256) | 7.2 (3.2) | 10.0 | 0.60 |
| Untreated | none | 6 | 8 | 5,575 (973) | 1.535(312) | 10.603(1,969) | 7.2 (2.4) | 12.4 | 0.60 |
| | 10 | | 8 | -- | 1.533(379) | 9,545(2,245) | 5.7 (3.2) | 12.5 | 0.60 |
| | 20 | 6 | 7 | 5,532 (933) | 1.336(340) | 9,093(1,245) | 6.3 (2.3) | 12.6 | 0.59 |
| MAP-treated | none | 9 | 10 | 2,705 (532) | 1.192(219) | 5,050(1,145) | 1.7 (0.7) | 13.9 | 0.59 |
| | 10 | | 9 | -- | 1.261(334) | 5,202(1,086) | 1.6(0.5) | 13.9 | 0.60 |
| | 20 | 9 | 10 | 2,945 (665) | 1.448(205) | 5.886 (789) | 1.8 (0.3) | 13.9 | 0.61 |

[a] Approximately 5 to 6 percent weight of 10 or 20 percent borate in glycol/water solution.

[b] Mean values are reported with standard deviations in parentheses. UTS = ulimate tensile strength; MOE = modulus of elasticity; MOR = modulus of rupture; WML = work to maximum load;MC = moisture content;SG =specific gravity. 150°F = 66°C; 1 psi = 6.895 kPa: 1 in -lb/in.$^3$ = 6.895 kJ/m$^3$.

[c] No thermal exposure.

averaged about 6 percent, which was approximately 0.6 percent for the 10 percent borate solution and 1.2 percent for the 20 percent borate solution.

Eight untreated bending and six untreated tension specimens were retained at 68°F (20°C)/65 percent relative humidity (RH) and served as untreated, unexposed controls. The remaining specimens were then exposed at 150°F (66°C)/75 percent RH for 60 days. After the appropriate exposure, all specimens were equilibrated to constant weight at 74°F (23°C)/65 percent RH, and tested in bending (2) or tension (3) as appropriate.

Following mechanical testing, specimens for analysis of borate penetration were cut lengthwise parallel to the face grain, then lightly sanded (to remove saw-pull of borate from the surface to the cut face). They were then sprayed with a standard borate color indicator (4) to visually quantify the penetration and distribution of borate resulting from the borate/glyeol/water treatments.

## RESULTS AND DISCUSSION

Visually, no color difference was noted between the borate-treated specimens and the untreated plywood specimens after the 60-day, high-temperature exposure.

The borate indicator turns a deep red on direct contact with boron. Specimens brushed with the 20 percent borate solution exhibited pink to deep red coloration throughout much of the surface plies and virtually complete red coloration of the second ply. This suggested substantial movement of borate along the grain and through lathe checks. The center ply had sporadic red coloration over approximately 25 percent of the cut face, indicating that borate applied via a glycol/water mixture may adequately penetrate up to one-half the thickness of 5-ply, 5/8- inch plywood.

The mechanical property results showed that a surface-applied remedial treatment of a 10 percent borate solution had only a minimal positive effect in arresting thermal degradation for MAP-treated plywood **(Table 1).** However, both the bending and tension property results showed that application of a 20 percent borate solution in glycol and water, yielding approximately a 1.2 percent borate weight gain, had a notable positive effect in buffering the magnitude of thermal degradation for MAP-treated southern pine plywood. This positive influence was about 17 percent in bending strength and 9 percent in tension strength. In addition, the 1.2 percent weight-gain retention of borate had a significant influence ($\alpha \leq 0.10$) on retarding a loss in modulus of elasticity (+21%), but little effect on retarding a loss in work to maximum load. No beneficial strength-retaining effects were noted in untreated plywood. This suggested that borate was active in reducing the rate of FR-related thermal degradation when more than 1 percent weight-gain of borate was evident.

While these indications are not indisputable, they are encouraging. More importantly, they show a potential for borate-based remedial treatments to mediate thermal degrade of FR-treated plywood roof sheathing and roof-truss lumber. Additional work is now underway to further substantiate, quantify, and define both the time-temperature relationship and the phosphate- borate concentration relationship, as well as refine application methods of borate to plywood surfaces.

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