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METHODS OF INCREASING DURABILITY OF PLYWOOD¹

By

DON BROUSE, Assistant Engineer

Ordinary casein and blood glues may give highly water resistant plywood joints that will stand considerable exposure to dampness, but these same joints ultimately weaken and fail when exposed continuously to warm, humid conditions. Whether the main cause of such weakening is action of microorganisms or hydrolytic decompositions of the protein of the glue is unknown. Although the weakening is treated here as though it were caused by microorganisms, the possibility of a purely chemical explanation should not be overlooked. In any event the usefulness of plywood could be greatly extended by the finding of a practical means of materially increasing its life under continuous exposure to dampness.

Initial Work

In tests started in December 1917 it was demonstrated that the durability of plywood, glued with blood glue and submitted to prolonged exposure to high relative humidities, was increased by treatment with such wood preservatives as sodium fluoride or mercuric chloride. In a second series of tests, started in 1920, panels glued with blood glue and subsequently treated with creosote retained a high percentage of their original strength for some 4-1/2 years (the entire duration of the test period).

Experiments With Glue Films

In an extensive series of experiments started in 1925 it was shown that mold growth on films of casein or blood albumin glues may be inhibited by adding suitable preservatives to the glue solution itself. Small quantities of some chemicals, even of the strong antiseptics, had little effect in preventing or retarding the growth of molds on the films and many compounds were ineffective in any concentration. However, certain chemicals, when added in sufficient quantity, were found effective in decreasing the action of mold and increasing the durability of the glue film when it was exposed in moist air. Of the compounds effective in

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reducing mold action, many so affected the working properties of the glue solution that good joints were difficult or impossible to obtain. Both ineffective compounds and chemicals injurious to the joint-making properties of the glue were eliminated from further consideration. Remaining were three compounds, namely, coal tar creosote, beta naphthol, and sodium chromate. Twenty parts of creosote or ten parts of beta naphthol to 100 parts by weight of dry glue added to casein glue greatly reduced mold growth on the glue film and yet the glue was not coagulated and its joint making properties were not greatly impaired. Ten parts of sodium chromate may be added to blood albumin glues with the same result.

Experiments With Plywood Joints

Drawing conclusions concerning the behavior of glue in joints from the behavior of the same glue in film form is unsafe. Therefore, after it had been established that certain compounds would inhibit the development of mold on glue films and that some of these compounds could be added to glue without destroying the joint-making properties, it seemed desirable to test their effectiveness further by exposing the treated glued joints to warmth and high humidity. Consequently a number of birch plywood panels were prepared, using glues treated with the effective preservatives. Other panels were glued with glues containing no added preservatives and were cut into test specimens; the specimens were then treated with these same preservatives or were dipped in asphalt. Still others, glued with treated glues, were coated with a water-resistant coating (aluminum powder in spar varnish). The materials used and the methods of treatment are shown in Tables 1 and 2.

Table 1.--Glues and formulas

Glues	Composition of mix	Parts by weight
A commercial casein	Dry glue	100
	Water	200
Forest Products Laboratory formula 4B (casein).....	Casein	100
	Lime	25
	Sodium silicate	70
	Water	325
Forest Products Laboratory para- formaldehyde blood albumin.....	Blood albumin	100
	Paraformaldehyde	15
	Ammonium hydroxide	5.5
	Water	190

Table 2.--Additions to the glue and treatments of the specimens with preservatives

Glue	Addition to glue	Treatment of glued specimens
Casein glues	:20 parts creosote to 100 parts : dry casein	: None
	:10 parts beta naphthol to 100 : parts dry casein	: None
	:20 parts creosote to 100 parts : dry casein	: Coated with aluminum powder : in spar varnish
	:10 parts beta naphthol to 100 : parts dry casein	: Coated with aluminum powder : in spar varnish
Both casein and blood ¹ glues	: None	: Treated with creosote
	: None	: Dipped in asphalt
	: None	: Treated with beta naphthol in : linseed oil
	: None	: None ²
Blood glues	:10 parts sodium chromate to 100 : parts dry blood	: None
	: 10 parts sodium chromate to 100 : parts dry blood	: Coated with aluminum powder : in spar varnish

¹The blood albumin glue, as a part of the formula, contains paraformaldehyde, which undoubtedly has a marked effect on the durability of joints.

²Controls.

With each glue a sufficient number of 3-ply panels (12 by 12 by 3/16 inches -- all plies of 1/16-inch rotary-cut yellow birch veneer) were glued so that there resulted 15 panels for each one of the combinations shown in Table 2. For example, there were 15 panels glued with a commercial casein glue containing 20 parts of creosote to 100 parts of dry casein, 15 panels with Forest Products Laboratory formula 4B containing 10 parts of beta naphthol to 100 parts of dry casein, and so on.

Each panel was cut in to 30 test specimens,² thus producing 450 test specimens for each combination of glue and treatment. Treating operations, if any, were carried out after the panels had been cut into test specimens.

Treatment With Creosote

Designated specimens were immersed in coal tar creosote, heated to 95 degrees C., and were left for 1 hour during which time the temperature fell to 60 degrees C. The absorption averaged 16 pounds of creosote per cubic foot of plywood.

Treatment With Beta Naphthol

A bath was prepared containing 25 percent (by weight) of beta naphthol in linseed oil. The temperature was raised to 65 degrees C. to bring the beta naphthol into solution, the designated specimens were immersed, and the temperature was then raised to 95 degrees C. After this the source of heat was removed and the solution was cooled to 65 degrees C., at which temperature the specimens were removed to prevent the beta naphthol precipitating upon them as the solution cooled further to room temperature. The average absorption was about 15 pounds of solution per cubic foot of plywood.

Coating With Asphalt

Specimens selected for asphalt treatment were dipped once in a thick asphalt paint, drained, and dried at room temperatures. The weight of the coating averaged 6 grams per square foot of plywood.

Coating With Aluminum Paint

The selected specimens were dipped in a mixture containing 1.5 pounds of aluminum powder per gallon of spar varnish, were then removed, and were dried. The process was repeated once to produce a very heavy coat

²For the form of the specimen and of the testing equipment see U. S. Department of Agriculture Technical Bulletin No. 205. (This bulletin is out of print and can be consulted only in the larger libraries.)

Exposure and Test

After the treatments just outlined, the specimens were seasoned for about 2 weeks in 60 percent relative humidity, then one specimen from each panel was tested dry, and another was tested wet after it had soaked for 48 hours in water at room temperature. The average test value dry serves as a basis of comparison for subsequent tests made after exposure of the specimens to high relative humidity. (Figs. 1 and 2.) The remaining specimens were placed in a room where the relative humidity is maintained between 95 and 100 percent and the temperature at about 80 degrees F. Subsequently one specimen from each panel was withdrawn from exposure, at the intervals shown in Figures 1 and 2, and tested. The 15 test values from the 15 panels were averaged for each glue and each treatment at each of the test intervals to produce the average test values plotted in these figures.

The two casein glues, Forest Products Laboratory formula 4B and the commercial casein glue, behaved so nearly alike that they may be considered together. Their test values have therefore been averaged to give results that may be considered typical for the more water-resistant casein glues.

Results of Tests

The results obtained up to the forty-first month are shown graphically in Figures 1 and 2. In order to facilitate the comparison of one curve with another, each test value is plotted as a percentage of the control value, that is, a percentage of the average test value dry of the untreated, unexposed specimens. The curves representing the untreated controls, therefore, have initial test values of 100 percent.

The effect of the treatment on the initial strength of the dry joint is difficult to estimate. The departure of the initial values of the various curves from 100 percent may represent only normal variations in test values or it may possibly represent the effect of the treatment on the strength of joint. There is no reason, however, to think that treating the glued plywood affected the initial strength of joint.

Untreated plywood glued with untreated casein glue (Fig. 1,A) failed completely after 24 months of exposure to conditions of high relative humidity and high mold concentration. Within the first 3 months the strength had dropped to half its original value. The failure seemed to be primarily in the glue line, although the wood had rotted by the time of complete failure.

With the specimens glued with casein glue and coated with asphalt the rate of failure was even more rapid than that of the untreated specimens

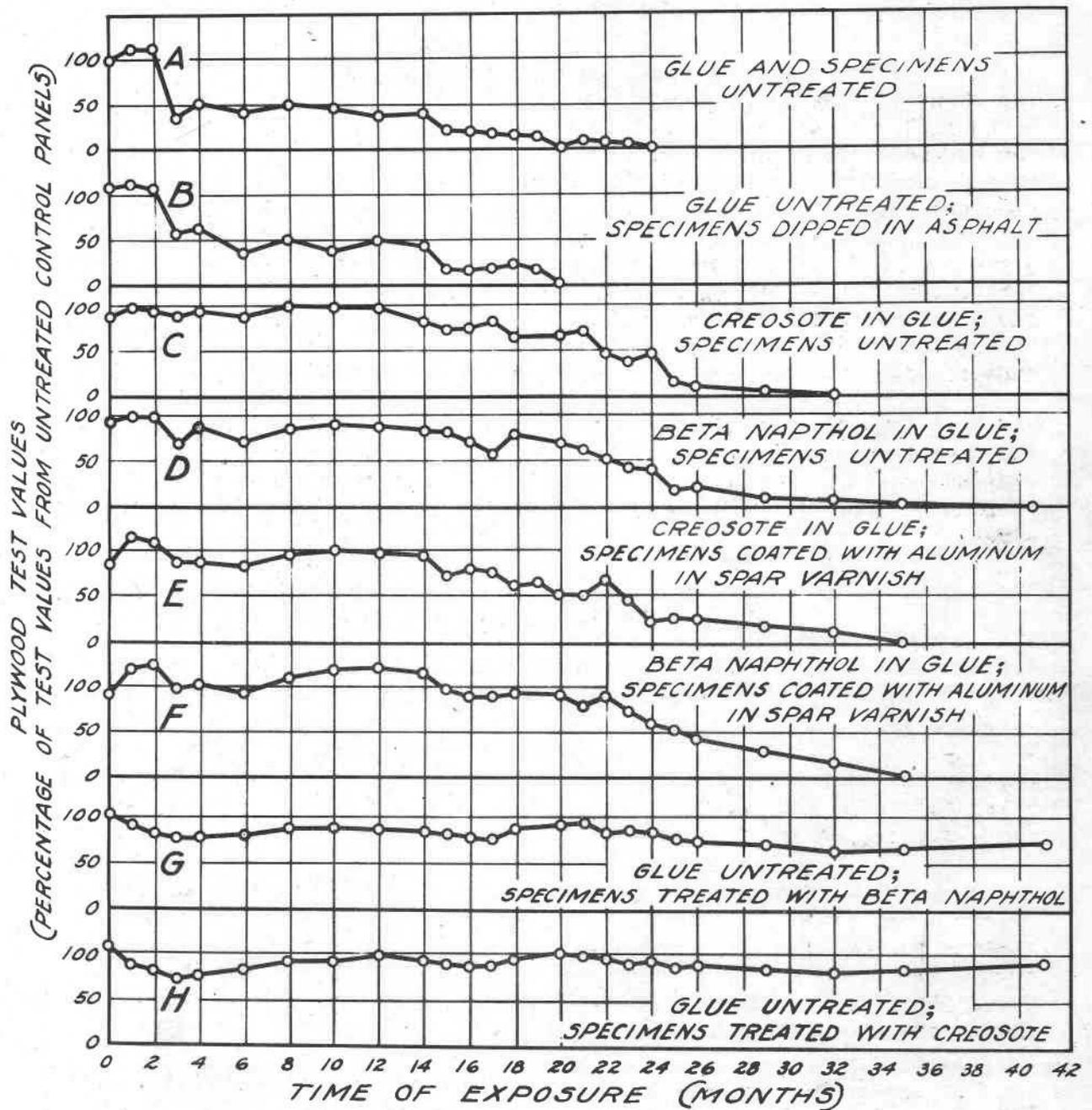


Figure 1.--Effect of preservatives on the durability of glue joints made with casein glue and exposed to relative humidities between 95 and 100 percent.

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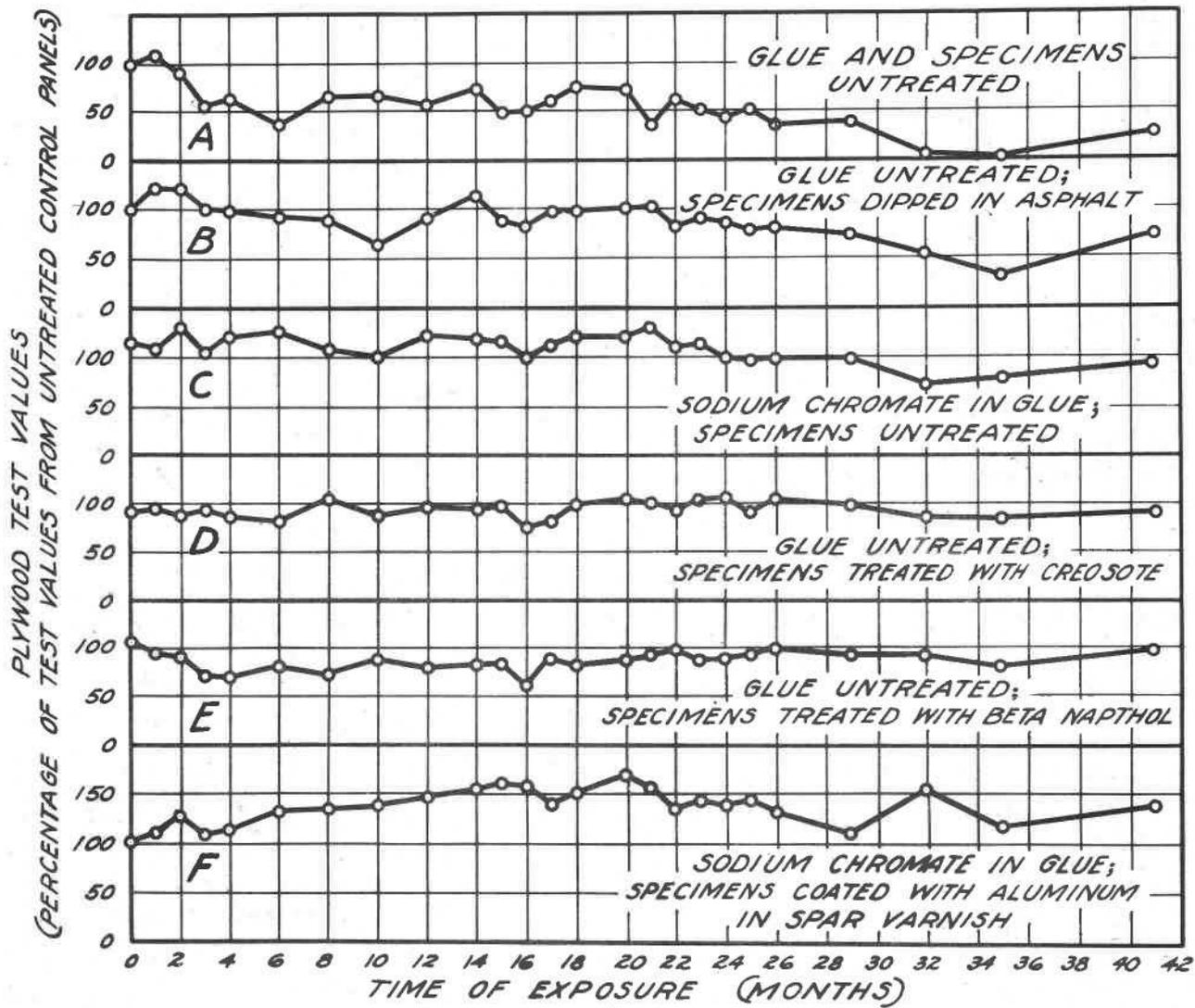


Figure 2.--Effect of preservatives on the durability of glue joints made with paraformaldehyde blood glue and exposed to relative humidities between 95 and 100 percent.

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(Fig. 1,B). The coating was evidently ineffective in increasing the durability of the joints.

Adding preservative (either beta naphthol or creosote) to the glue increased the durability so that final failure was delayed until at least the end of the thirty-second month (Fig. 1, C and D). Further, the test values remained above 50 percent of the original for at least 22 months. The final failure in these cases seemed to be due to a rotting of the untreated wood. It seems safe to assume that the addition of preservative to the glue caused the glue at least to equal the wood in durability.

Adding preservative to the glue and then coating the untreated plywood with aluminum powder in spar varnish did not markedly delay the final failure in comparison with specimens similarly glued but uncoated (Fig. 1, C and D). For at least the first 18 months, however, the test values of the aluminum-coated specimens were appreciably higher and the specimens were in better condition than the similar uncoated specimens. Coating plywood with aluminum powder in spar varnish generally increased the water resistance, as determined by the usual method of soaking for 2 days. This is to be expected to the extent that the coating retards the absorption of moisture during the soaking period.

Treating casein-glued specimens with beta naphthol was very effective in increasing durability (Fig. 1, G). At the end of the forty-first month these specimens still retain about 75 percent of their original strength when dry. Treating with creosote seemed even more effective (Fig. 1,H). At the end of the forty-first month the average test values are almost as high as the initial test values.

Specimens glued with untreated blood glue are still hanging together at the end of the forty-first month. However, Figure 2,A indicates that they approached complete failure at 32 and 35 months. In other words, the resistance of the untreated paraformaldehyde blood glue resembles that of casein glue to which creosote or beta naphthol has been added (compare Fig. 2,A with Fig. 1, C and D). This is not surprising since paraformaldehyde, which forms a part of the blood-albumin glue formula, undoubtedly has a beneficial effect on the durability of the joints.

Dipping plywood, glued with blood glue, in asphalt was noticeably effective in increasing durability (Fig. 2, A and B). The effectiveness of the asphalt dip was markedly greater on plywood glued with blood glue than on plywood glued with casein glue (Fig. 1,B). The experimental factors causing this discrepancy are unknown.

Several of the preservative treatments of blood glue and of plywood glued with blood glue have so increased the durability that, at the end of the forty-first month, the specimens are still intact and strong and it is difficult to judge their relative effectiveness (Fig. 2, C, D, E, and F). The sodium chromate treatments, however, are outstanding among the treatments involving the addition of preservatives to the glue.

Wood Decay

At the end of the twenty-sixth month, samples of the test specimens were examined for the presence of rot and at least traces of wood-destroying fungi were found in all specimens. The conditions of exposure are apparently very favorable to the development of wood-destroying organisms, for wood treated with creosote seldom exhibits traces of fungus growth within a period of 2 years after treatment. Some of the less effectively treated specimens were so completely rotted that the wood lost the greater part of its strength. Obviously the testing of specimens of wood so decayed can give no indication of the strength of the glued joint, for the test is necessarily affected by the mechanical strength of the wood. These experiments were conducted on panels entirely of birch, which is not a decay-resistant wood. If a more durable species had been used, wood decay would have contributed less to the early failures and somewhat longer life might have been obtained when the glue alone was treated.