

DURABILITY OF PLYWOOD JOINTS MADE WITH ONE MELAMIME-, ONE UREA-, AND FIVE RESORCINOL-RESIN GLUES

October 1947



This Report is One of a Series
Issued In Cooperation with the
ARMY-NAVY-CIVIL COMMITTEE
on
AIRCRAFT DESIGN CRITERIA
Under the Supervision of the
AERONAUTICAL BOARD

No. 1568

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin
In Cooperation with the University of Wisconsin

DURABILITY OF PLYWOOD JOINTS MADE WITH ONE MELAMINE--,
ONE UREA- AND FIVE RESORCINOL-RESIN GLUES¹

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Forest Products Laboratory Report No. 1530 (revised December 1946) summarizes durability data obtained at the Laboratory on several types of glues. That report includes data on only two resorcinol-resin glues and no data on acid-catalyzed melamine-resin glues or noncrazing urea-resin glues. The Laboratory was requested by the Army-Navy-Civil Committee on Aircraft Design Criteria to augment the information on resorcinol glues and also to obtain data on the durability of catalyzed melamine-resin glue and of noncrazing urea-resin glue.

Seven glues were selected for this study. Five of these were resorcinol-resin glues; one, an acid-catalyzed melamine-resin glue; and one, a urea-resin glue which was reportedly formulated to impart craze resistance to the glue joint. Six controlled exposure conditions were used, in addition to outdoor exposure. This report describes the preparation of test specimens and includes test data obtained over an exposure period of 18 months. The study is scheduled to continue for an additional 42 months.

Preparation and Exposure of Birch Plywood Test-Specimens

Six, three-ply, 25- by 25-inch panels were prepared with each of the seven glues, using 1/16-inch yellow birch veneers. The veneers contained about 12 percent moisture at the time of gluing and were glued under the conditions given in table 1. After conditioning for at least 7 days at 80° F. and 65 percent relative humidity, 140 standard plywood shear test specimens were cut from each panel, producing 840 specimens for each glue. Sixty specimens with each glue representing all 6 panels were tested as controls, 30 dry and 30 wet after soaking for 48 hours in water at room temperatures. The remaining specimens were placed in the following exposures, to be tested at intervals of 2, 4, 6, 9, 12, 18, 24, 30, 36, 42, 48, 54, and 60 months.

1. Continuously in air at, 80° F. and 65 percent relative humidity.
2. Continuously in air at 80° F. and 97 percent relative humidity.
3. Continuously in air at 158° F. and 20 percent relative humidity.
4. Continuously in water at room temperatures.

¹This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft. Results here reported are preliminary and may be revised as additional data become available.

5. A repeating cycle consisting of 2 weeks in air at 80° F. and 97 percent relative humidity, followed by 2 weeks in air at 80° F. and 30 percent relative humidity.
6. A repeating cycle consisting of 2 days in water at room temperatures followed by 12 days in air at 80° F. and 30 percent relative humidity.

After each exposure interval, five specimens were tested immediately and after exposures 1, 3, and 6, five additional specimens were tested wet after 48 hours soaking in water at room temperature. The specimens from exposure 6 were tested wet after the soaking part of the cycle.

Preparation and Exposure of Test Fence-Panels

Five-ply, yellow birch and Douglas-fir plywood panels were prepared from veneer 1/8- by 25- by 25 inches in size. The veneers contained about 12 percent moisture at the time of gluing and were glued under the same conditions as were the panels made for the plywood specimens. Two panels of each species were prepared with each glue. After conditioning for at least 7 days at 80° F. and 65 percent relative humidity, the panels were trimmed to 18 by 18 inches in area and placed on outdoor exposure racks near Madison. The panels were unprotected by any coatings and were mounted vertically in an open space facing south. The panels were examined for delamination after 10 months of exposure.

The trimmings from the panels were cut into standard plywood shear test specimens with saw cuts made to test the inner glue lines. Five specimens from each panel were tested dry, five tested wet after 48 hours soaking in water at room temperature, and five tested wet after the soaking-drying cycle prescribed for high moisture resistant bondage in "Commercial Standard CS35-42 for Hardwood and Eastern Red Cedar Plywood." This test involved soaking the specimens for 16 hours in water at room temperature and drying for 8 hours at 145° F. (plus or minus 5° F.), repeating for a total of three cycles, soaking the specimens for an additional 16 hours at room temperature, and then testing while wet. Average results of these tests are given in table 2.

Results

Average results of shear tests made on the plywood specimens that were under controlled exposure conditions are given in table 3. The results were obtained at 0, 2, 4, 6, 9, ¹²and 18 months of exposure.

Eighteen months of exposure was not long enough to permit drawing final conclusions concerning ultimate durability, but the following trends were evident in the data for the 18-month period.

The five resorcinol-resin glues generally showed similarity in behavior. There appeared to be some superiority in Glues C and E in maintaining very high wood failures, but there was no consistent difference in shear strength between the resorcinol-resin glues.

Continuous exposure at 158° F, and 20 percent relative humidity proved to be the most damaging condition for the plywood glued with resorcinol resin. The shear strength might be expected to fall in this exposure because of possible heat damage to the wood. The average wood failure in the dry tests of the joints glued with three of the resorcinol-resin glues, however, decreased appreciably,

In the other exposures, some of the joints made with resorcinol-resin glue decreased in shear strength while maintaining relatively high percentages of wood failure. It appeared, however, that this decrease in shear strength resulted from the effect of the exposure conditions on the strength properties of the wood rather than from deterioration of the glue itself. The data on two resorcinol-resin glues given in Report No. 1530 agree closely with that obtained on the five resorcinol-resin glues of this study.

Joints made with the acid-catalyzed melamine-resin glue generally showed somewhat greater deterioration than those made with the resorcinol-resin glues. Marked decreases in shear strength or wood failure, and usually in both, were observed when the specimens were tested after exposure to the more severe conditions. Slight decreases in shear strength and wood failure were also observed upon testing those specimens that were exposed continuously for 18 months in air at 80° F. and 65 percent relative humidity. Comparison with the data presented in Report No. 1530 tends to indicate this acid-catalyzed melamine-resin glue to be less durable than the average more neutral, hot-press melamine-resin glue.

Joints made with the urea-resin glue deteriorated to a much greater extent than did joints made with the other glues used in this study. Exposure to high temperature and to high humidity was particularly injurious to the joints in specimens made with urea-resin glue. A marked decrease in wood failure resulted even in the mild exposure of 80° F. and 65 percent relative humidity. Of the plywood panels exposed to the weather, only the birch panels glued with the urea-resin glue G developed visible delamination in the first 10 months (table 2). Comparisons with the data presented in Report No. 1530 show Glue G to be generally about as durable as the average urea-resin glue which meets the requirements of Specification AN-G-8.

Table 1.--Gluing conditions used in preparation of plywood panels

Glue	Average spread	Assembly time (closed)	Pressure	Curing temperature	Pressure period
	Grams per square foot	Minutes	Pounds per square in.		Hours
A (resorcinol-resin)	25.6	20 to 30	175	Room ¹	18
B (resorcinol-resin)	24.3	21 to 30	175	Room ¹	18
C (resorcinol-resin)	25.9	20 to 29	175	Room ¹	17
D (resorcinol-resin)	24.9	25 to 34	175	Room ¹	17
E (resorcinol-resin)	22.1	20 to 30	175	Room ¹	17
F (acid-catalyzed melamine-resin)	27.1	14 to 20	175	140° F.	3
G (noncrazing urea-resin)	26.2	15 to 24	175	Room ¹	17

¹The temperature of the room varied between 75° and 90° F. during the pressure period.

Table 2.--Average results of initial tests of specimens from panels prepared for outdoor exposure and inspection of panels after 10 months' exposure to the weather

Glue	Species	Initial Test No. 1 ¹	Initial Test No. 2 ²	Initial Test No. 3 ³	Delamination around edges of panel after 10 months of outdoor exposure ⁴
					Percent
A (resorcinol-resin)	: Yellow birch:	⁵ 586-98	⁵ 478-100	⁵ 478-98	: 0
	: Douglas-fir:	333-96	304-84	301-80	: 0
B (resorcinol-resin)	: Yellow birch:	478-60	416-88	403-96	: 0
	: Douglas-fir:	290-92	326-86	318-92	: 0
C (resorcinol-resin)	: Yellow birch:	570-82	494-97	512-100	: 0
	: Douglas-fir:	274-96	239-76	258-90	: 0
D (resorcinol-resin)	: Yellow birch:	488-76	435-92	455-92	: 0
	: Douglas-fir:	338-94	278-94	298-92	: 0
E (resorcinol-resin)	: Yellow birch:	534-60	406-92	415-92	: 0
	: Douglas-fir:	330-98	362-70	316-95	: 0
F (acid-catalyzed melamine-resin)	: Yellow birch:	464-98	428-100	409-90	: 0
	: Douglas-fir:	287-90	264-100	258-100	: 0
G (noncrazing urea-resin)	: Yellow birch:	467-80	436-92	232-24	: 2
	: Douglas-fir:	262-88	259-30	99-1	: 0

¹Tested dry.

²Tested wet after soaking in water at room temperature for 48 hours.

³Tested wet after soaking-drying cycle described for high moisture resistant bondage in Commercial Standard CS35-42 for Hardwood and Eastern Red Cedar Plywood.

⁴The average for two panels.

⁵The value before the dash is the average shear strength in pounds per square inch; the value after the dash is the average wood failure in percent. Each value represents an average of 10 specimens, 5 from each of 2 panels.

Table 3.--Average results of shear tests of yellow birch plywood¹ specimens made with seven glues and subjected to six conditions of exposure

Glue	Duration of exposure	Exposure 1 ²		Exposure 2 ³		Exposure 3 ⁴		Exposure 4 ⁵		Exposure 5 ⁶		Exposure 6 ⁷
		Tested dry	Tested wet	Tested wet								
		Months										
A (resorcinol-resin)	0	559-93	532-100	559-93	559-93	532-100	532-100	559-93	532-100	532-100	559-93	532-100
	2	478-98	551-93	543-98	411-68	536-90	475-87	458-86	563-91	506-95	506-95	506-95
	4	570-97	513-92	571-91	446-84	504-93	482-86	490-85	500-90	513-90	513-90	513-90
	6	499-96	505-95	526-100	393-76	430-99	484-98	465-85	502-93	485-97	485-97	485-97
	9	513-97	503-95	499-98	365-98	417-99	441-98	477-94	483-93	448-95	448-95	448-95
	18	474-100	533-99	487-100	337-79	405-100	480-97	458-87	498-98	455-99	455-99	455-99
	18	440-58	483-100	468-100	312-40	358-100	457-99	452-78	460-100	395-100	395-100	395-100
B (resorcinol-resin)	0	504-84	491-100	504-84	504-84	491-100	491-100	504-84	491-100	491-100	504-84	491-100
	2	484-76	500-94	514-91	406-69	466-95	481-93	457-84	472-93	487-93	487-93	487-93
	4	525-86	497-91	514-98	414-79	470-94	463-94	455-85	491-91	479-92	479-92	479-92
	6	453-79	467-92	501-96	359-95	396-98	464-98	441-75	470-94	477-98	477-98	477-98
	9	485-89	476-95	495-98	341-75	389-99	433-99	444-89	471-91	423-95	423-95	423-95
	18	448-97	512-100	471-100	328-80	397-100	465-92	427-79	480-98	392-98	392-98	392-98
	18	406-54	463-98	406-100	300-61	323-100	437-96	418-67	441-100	386-100	386-100	386-100
C (resorcinol-resin)	0	526-98	536-93	526-98	526-98	536-93	536-93	526-98	536-93	536-93	526-98	536-93
	2	485-98	495-87	522-98	427-96	477-99	501-99	457-91	499-95	512-100	512-100	512-100
	4	538-99	545-89	525-99	398-99	492-99	510-97	463-92	493-98	503-96	503-96	503-96
	6	530-91	520-95	482-99	370-96	453-100	511-97	427-95	527-99	486-99	486-99	486-99
	9	511-100	499-100	443-100	326-98	376-100	455-93	466-98	506-98	437-100	437-100	437-100
	18	477-99	528-100	440-100	331-100	397-100	456-100	416-99	494-98	389-100	389-100	389-100
	18	435-100	490-100	386-100	294-100	315-100	451-99	422-100	426-100	344-100	344-100	344-100
D (resorcinol-resin)	0	575-90	551-97	575-90	575-90	551-97	551-97	575-90	551-97	551-97	575-90	551-97
	2	507-76	523-96	577-98	430-52	553-90	533-94	440-63	573-96	542-99	542-99	542-99
	4	517-92	598-92	570-96	397-81	537-94	545-96	475-87	553-97	550-96	550-96	550-96
	6	485-95	536-97	560-94	359-95	474-100	508-97	404-95	524-92	508-97	508-97	508-97
	9	507-98	529-99	540-97	347-78	438-100	496-99	468-82	516-99	503-99	503-99	503-99
	18	486-84	558-100	500-100	339-65	464-100	503-99	427-64	524-98	481-99	481-99	481-99
	18	428-89	525-99	496-98	325-38	368-100	456-100	437-43	485-100	370-100	370-100	370-100
E (resorcinol-resin)	0	542-91	499-94	542-91	542-91	499-94	499-94	542-91	499-94	499-94	542-91	499-94
	2	500-95	522-87	538-100	421-93	477-85	521-90	415-89	505-91	515-92	515-92	515-92
	4	511-93	545-98	575-96	390-91	494-98	524-88	445-94	513-97	463-95	463-95	463-95
	6	496-79	522-96	516-95	397-91	423-84	465-98	484-70	499-92	460-89	460-89	460-89
	9	558-85	502-98	490-95	379-86	418-96	468-90	470-86	447-94	463-90	463-90	463-90
	18	451-87	519-100	496-100	331-93	429-100	471-96	473-98	500-95	447-100	447-100	447-100
	18	440-96	496-100	465-100	337-79	378-100	441-85	447-98	483-98	389-100	389-100	389-100
F (acid catalyzed melamine-resin)	0	449-76	435-92	449-76	449-76	435-92	435-92	449-76	435-92	435-92	449-76	435-92
	2	456-73	440-63	436-82	368-52	355-65	442-82	401-80	393-65	393-65	393-65	393-65
	4	415-71	433-84	403-19	311-62	365-80	384-50	345-67	388-65	406-71	406-71	406-71
	6	458-91	386-89	383-45	329-64	337-100	415-73	394-52	397-98	389-81	389-81	389-81
	9	446-82	377-95	356-47	301-78	320-98	327-48	394-63	364-98	289-41	289-41	289-41
	18	414-94	408-87	297-67	304-22	329-90	331-0	356-35	403-71	280-40	280-40	280-40
	18	382-62	356-70	285-80	283-52	251-100	330-52	377-42	352-72	298-85	298-85	298-85
G (noncrazing urea-resin)	0	514-94	526-80	514-94	514-94	526-80	526-80	514-94	526-80	526-80	514-94	526-80
	2	457-99	507-82	431-30	338-87	389-72	468-86	401-91	481-25	431-71	431-71	431-71
	4	464-89	524-75	350-10	304-63	394-91	506-47	359-40	434-45	425-20	425-20	425-20
	6	460-100	500-86	333-2	204-16	267-100	458-67	380-55	432-75	418-32	418-32	418-32
	9	435-62	435-81	315-6	223-4	250-100	423-60	330-12	364-6	358-22	358-22	358-22
	18	417-65	465-61	296-5	207-0	245-80	426-55	303-19	384-38	350-43	350-43	350-43
	18	391-64	439-39	214-0	187-37	196-62	411-96	298-14	330-2	299-53	299-53	299-53

¹Three-ply, 3/16-inch birch plywood.

²Exposed continuously in air at 80° F. and 65 percent relative humidity.

³Exposed continuously in air at 80° F. and 97 percent relative humidity; tested immediately upon removal from this condition.

⁴Exposed continuously in air at 158° F. and 20 percent relative humidity, tested at room temperature.

⁵Exposed continuously in water at room temperature.

⁶A repeating cycle of 2 weeks exposure in air at 80° F. and 97 percent relative humidity followed by 2 weeks exposure in air at 80° F. and 30 percent relative humidity.

⁷A repeating cycle of 2 days exposure in water at room temperature, followed by 12 days exposure in air at 80° F. and 30 percent relative humidity.

⁸The value before the dash is the average shear strength in pounds per square inch; the value after the dash is the estimated wood failure in percent. Each value is the average for 5 specimens.