

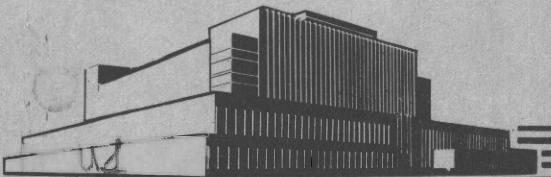
EFFECTS OF ELEVATED CURING TEMPERATURES ON THE STRENGTH AND DURABILITY OF YELLOW BIRCH PLYWOOD JOINTS MADE WITH ROOM-TEMPERATURE-SETTING UREA GLUES



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EFFECTS OF ELEVATED CURING TEMPERATURES ON THE STRENGTH

AND DURABILITY OF YELLOW BIRCH PLYWOOD JOINTS

MADE WITH ROOM-TEMPERATURE-SETTING UREA GLUES¹

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Introduction

Room-temperature-setting urea-formaldehyde resin glues produced in this country are generally formulated to cure at a minimum temperature of 70° F., at which many hours are required before pressure can be released. The curing of these room-temperature-setting urea glues can be hastened by elevated temperatures and, if the temperature is sufficiently high, the glue can be cured in a few minutes. To save time in the assembly of aircraft parts and other wood-fabrication work, the practice has developed of curing urea glues rapidly by the use of heated presses or jigs. Whether this practice of curing at elevated temperatures affects the quality of the glued joint is not known. Accordingly, this study is being conducted in an attempt to determine whether rapid curing of room-temperature-setting urea-formaldehyde resin glues by elevated temperatures affects the strength and durability of the joints significantly in comparison with joints made with the same glues cured at room temperature.

The general procedure was to make plywood with different urea glues, curing at several temperatures, testing specimens of the plywood so made for initial dry- and wet-joint strength, exposing specimens to various conditions of heat and moisture, and noting whether the rate of deterioration during exposure could be correlated with the original curing temperature.

This report presents the data obtained after the first year of exposure.

Procedures

Preparation of Specimen

This work was done on plywood for ease of preparation and rapid transfer of heat to the glue line. Three-ply panels were made with selected 1/16-inch yellow birch veneer, using five commercial glues, designated in this report by the letters A, B, C, D, and E. The glues were mixed in accordance with the manufacturers' instructions.

The gluing conditions employed were:

Moisture content of veneer when glued: About 12 percent.

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. Original report dated November 1945.

²Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Spread: 20 to 25 grams of liquid glue per square foot of glue line, applied to the core ply.

Assembly: All assemblies closed; 10 minutes when the curing temperature was 80° F.; 2 minutes when the curing temperature was 160° F.; 2 and 10 minutes when the curing temperature was 180° and 215° F.; 2, 10, and 45 minutes when the curing temperature was 250° F.

Pressing: Under 150 pounds per square inch between heavy wood cauls at room temperature, and between canvas cauls at elevated temperatures.

Curing: The panels were under pressure for 8 hours at 80° F.; for 25 minutes at 160° F.; for 9 minutes at 180° F.; for 7 minutes at 215° F.; and for 7 and 35 minutes at 250° F. For the four elevated temperatures, approximately 5 minutes was required to raise the glue line to the temperature indicated. For 80° F. the panels were held in a room at that temperature; for the higher temperatures the panels were pressed between platens heated by steam or hot water.

Conditioning: After removal from the presses, the panels were stored for about 1 week in a room held at 80° F. and 65 percent relative humidity, before being cut into standard shear test specimens.

Exposure of Specimens

The plywood specimens were divided into four groups, randomly selected, for exposure to the following conditions:

1. Continuous, 80° F. and 65 percent relative humidity.
2. Continuous, 158° F. and 20 percent relative humidity.
3. Continuous, 80° F. and 97 percent relative humidity.
4. Alternate soaking for 2 days in water at room temperature, followed by drying for 12 days at 80° F. and 30 percent relative humidity.

Test Periods

For control values, 14 specimens for each glue and gluing condition were tested dry, and 14 were tested wet after soaking in water at room temperature for 48 hours. The tests were made by pulling the specimens in shear in standard plywood testing grips loading at approximately 750 pounds per minute.

At the end of 2, 4, 6, and 12 months of exposure, from each of exposure conditions 1, 2, and 3, five specimens were tested dry after conditioning in a room at 80° F. and 65 percent relative humidity, and five were tested wet after soaking for 48 hours in water at room temperature. At these same times, five specimens from exposure condition 4 were tested wet.

Enough specimens were prepared and exposed to continue the experiment for 3 years with testing periods at 18, 24, 30, and 36 months.

Results

The average values of the shear strength and wood failure data obtained from the plywood shear tests are presented in tables 1 through 7.

From the data for glues B, C, and D, there appears to be no significant difference in the quality of the joints cured at the different temperatures and tested as controls. For these three glues, there is little or no evidence in the data of tables 1 and 2 that the plywood joints, made at any of the several curing temperatures, fell off in joint quality during the 12-month exposure to 80° F. and 65 percent relative humidity. These urea glues deteriorated in joint quality when exposed to 158° F. and 20 percent relative humidity according to the data of tables 3 and 4, and there is some difference in the rates of deterioration in the joints set at different temperatures, but the differences are not pronounced. What evidence there is indicates no ill effect by curing these glues at elevated temperatures and perhaps even some slight benefit. Also, from the effects of the continuous exposure to 97 percent relative humidity (tables 5 and 6) and alternate soaking and drying (table 7), the differences in the durability of these three glues due to differences in curing temperature are not pronounced and may not be significant.

The joints made at 250° F. with glue A exhibited poorer performance, generally, under the exposures than those made at 80° and 180° F., but the control specimens made at 250° F. with this glue were poorer in quality than those made at 80° F. or 180° F.

The joints made with glue E and cured at 215° F. and at 250° F. for 2 minutes after 2 minutes assembly time were, in general, of poorer durability than those made at lower temperatures or at 250° F. with longer assembly time or longer curing time. The comparative quality of the joints in the control specimens, however, was in this same order.

In the case of glues A and E, therefore, there was a difference in durability in the plywood specimens cured at different temperatures, but there was a parallel difference in the quality of the control joints. To ascertain more conclusively whether the curing temperature was responsible for the mediocre quality of certain of the control joints, two to five additional sets of panels were prepared with these two glues under the same conditions at different times, cut into shear specimens, and tested for joint strength. The data from these experiments are given in table 8, in which each value represents the averaged results for one set of panels. From these data it is apparent that low or high wood failure was not consistently associated with any particular curing temperature or combination of curing time, temperature, and assembly period, but that panels that gave relatively low wood failure occasionally occurred at the different temperatures. From the available evidence, it would be expected that the occasional panels showing low original wood failure would exhibit relatively poor joint durability under exposure, and this might happen with glues A and E with any of the curing temperatures.

As a broad conclusion from the data thus far obtained in this study, it appears that, for the five glues tested and the particular exposure conditions employed, there was no important effect on the original joint strength or joint durability by the temperature of curing within the range 80° F. to 250° F.

Table 1.—Results of dry¹ shear tests of three-ply, 3/16-inch yellow birch plywood bonded with room-temperature-setting urea glues at various temperatures, before and after exposure to 80° F. and 65 percent relative humidity

Glue exposure	Period of exposure	Curing conditions													
		Assembly time (closed)			10 minutes : 2 minutes : 10 minutes : 2 minutes : 10 minutes : 2 minutes : 10 minutes : 45 minutes			Assembly time (open)			10 minutes : 2 minutes : 10 minutes : 2 minutes : 10 minutes : 45 minutes				
Months															
A	0 (Controls)	2/453-79	2/	2/	2/453-83	2/	2/	2/410-48	2/	2/	2/	2/	2/	2/	
	2	394-69			432-85			371-12							
	4	522-91			522-94			424-15							
	6	487-81			453-90			395-12							
	12	414-46			414-54			355-5							
	18														
B	0 (Controls)	473-81	519-96	479-88	551-100	487-87	440-85	515-94	471-86	551-92	423-100	478-85	483-100	483-100	
	2	477-97	530-98	538-100	560-100	478-97	562-100	564-100	477-100	574-100	448-100	464-100	448-99	448-99	
	4	445-99	551-89	560-100	527-100	562-100	584-100	519-90	444-100	534-100	512-96	532-100	506-99	506-99	
	6	518-95	588-90	588-98	538-97	589-99	560-99	539-97	480-97	544-85	525-100	524-97	506-98	530-99	
	12	482-79	505-72	566-95	575-96	520-82	522-98	530-89	515-98	561-98	525-100	581-86			
	18														
C	0 (Controls)	403-79	468-100	451-96	463-97	451-84	483-80	458-87	439-100	416-83	413-100	402-78	370-99	370-99	
	2	472-95	513-100	481-90	486-96	469-82	487-87	521-87	508-100	462-77	460-97	460-95	486-98	486-98	
	4	448-78	462-100	453-100	498-98	521-81	521-79	506-79	508-97	482-99	483-99	483-97	501-96	501-96	
	6	493-100	477-100	532-100	582-95	540-99	547-94	613-95	551-99	501-61	544-100	504-81	518-98	518-98	
	12	501-100	486-98	535-94	548-98	523-85	514-73	561-97	517-95	470-51	518-100	547-83	547-83	547-83	
	18														
D	0 (Controls)	498-98	529-67	496-88	519-90	536-91	469-99	464-95	498-92	195-95	449-98	499-93	505-93	505-93	
	2	407-94	508-91	464-86	441-85	477-92	467-92	586-98	481-100	486-96	193-100	490-100	510-77	467-96	467-96
	4	418-100	467-99	508-84	472-87	496-90	499-100	473-100	481-100	433-81	518-76	517-98	579-97	421-100	421-100
	6	467-99	507-98	505-94	504-98	518-93	553-95	518-93	501-98	193-90	516-90	493-91	443-94	443-94	443-94
	12	485-98	505-91	505-94	505-95	518-93	518-93	511-100	511-100	560-97	475-100	535-91	497-98	497-98	497-98
	18														
E	0 (Controls)	483-94	436-73	456-47	439-59	416-20	411-46	371-53	400-77	441-57	402-59	415-93	458-93	458-93	
	2	422-85	425-45	404-46	400-39	316-59	392-64	367-21	472-55	470-57	415-90	391-92	456-84	456-84	456-84
	4	501-100	542-66	523-34	497-29	467-13	507-34	429-33	505-58	520-66	528-96	512-96	568-94	568-94	568-94
	6	435-99	442-51	431-17	409-10	380-2	463-4	311-16	404-47	461-61	450-81	433-60	464-71	464-71	464-71
	12	462-98	451-29	422-21	443-10	369-6	425-1	395-13	427-64	450-47	452-79	452-79	446-68	446-68	446-68
	18														
Z	24														
	30														
4620 W	36														

¹/ Tested dry after removal from exposure.

²/ The first value is the average shear strength in pounds per square inch; the second value is the average wood failure in percent.

Table 2.—Results of wet¹ shear tests of three-ply, 3/16-inch yellow birch plywood, bonded with room-temperature-setting urea glues at various temperatures, before and after exposure to 80° F., and 65 percent relative humidity.

Glue	Period of exposure	Curing conditions									
		80° F.: 8 hours	160° F.: 20 minutes	180° F.: 4 minutes	215° F.: 2 minutes	250° F.: 2 minutes	250° F.: 2 minutes	250° F.: 30 minutes	250° F.: 30 minutes	250° F.: 30 minutes	250° F.: 30 minutes
A	0 (Controls)	2657-93 476-100 443-93 447-62 453-92	2/ 45-40 394-76 385-44 395-28	2/ 460-83 452-100 432-100 435-92	2/ 482-99 522-100 482-100 486-91	2/ 495-98 528-93 462-100 471-92	2/ 467-100 51-98 415-100 449-98	488-100 570-100 501-100 456-100	540-89 512-96 513-100 500-84	480-98 489-99 498-100 469-91	480-98 489-99 498-100 512-100
B	0 (Controls)	468-88 456-99 459-100 469-99 488-87	572-97 550-92 513-100 519-66 522-87	552-91 532-95 525-97 545-92 528-96	466-100 522-100 483-100 486-91 435-90	512-99 482-99 529-100 471-92 517-97	467-100 475-99 462-100 447-81 507-98	488-100 570-100 501-100 491-100	540-89 512-96 513-100 512-100	480-98 489-99 498-100 469-91	480-98 489-99 498-100 512-100
C	0 (Controls)	391-88 427-100 406-100 414-80 437-100	464-100 502-100 462-100 459-97 460-100	428-100 517-96 424-100 427-92 473-98	542-100 510-99 448-100 430-97 435-96	520-99 483-96 483-100 489-79 462-98	486-100 489-99 509-100 502-98 536-100	418-100 496-73 493-100 385-84 405-88	446-100 519-99 480-100 430-94 479-100	451-100 455-99 493-100 401-95 426-98	451-100 455-99 493-100 401-95 426-98
D	0 (Controls)	490-93 472-100 433-100 452-98 439-98	501-100 516-95 511-100 486-99 479-91	546-100 521-99 511-95 475-98 483-95	527-99 535-98 504-91 465-98 451-74	517-91 485-95 478-95 425-98 490-93	433-100 482-100 534-100 460-98 443-100	439-99 468-97 466-90 439-99 456-98	483-88 514-97 483-100 458-98 487-99	480-100 517-98 530-100 476-94 469-94	478-91 517-90 481-100 455-88 445-93
E	0 (Controls)	440-100 456-81 440-98 386-100 413-94	507-90 499-74 469-79 442-39 411-21	495-75 477-31 464-36 422-25 411-21	446-19 429-7 409-6 412-39 405-4	515-94 502-96 432-52 435-18 413-23	483-63 523-84 438-64 432-78 409-6	501-65 472-84 413-56 416-2 424-44	498-100 480-99 484-100 420-68 459-63	469-99 468-98 418-96 465-100 439-90	469-99 468-98 418-96 465-100 439-90
		24									
		30									
		36									

¹ Specimen soaked for 48 hours in water at room temperature after removal from exposure.

² The first value is the average shear strength in pounds per square inch, the second value is the average wood failure in percent.

Table 3.—Results of dry¹ shear tests of three-ply, $\frac{1}{16}$ -inch yellow birch plywood, bonded with room-temperature-setting urea glues at various temperatures, before and after exposure to 158° F. and 20 percent relative humidity.

Glue Period of exposure	Month	Curing conditions									
		80° F. 8 hours		160° F. 20 minutes		180° F. 4 minutes		215° F. 2 minutes		250° F. 2 minutes	
		10 minutes	2 minutes	10 minutes	2 minutes	10 minutes	2 minutes	10 minutes	2 minutes	10 minutes	45 minutes
A	0 (Controls)	2/453-79	2/...	2/453-83	2/...	2/453-87	2/...	2/410-48	2/...	2/410-100	2/...
	2	282-19	...	250-42	...	491-87	...	393-78	...	366-68	...
	4	252-7	...	270-50	...	362-24	...	406-12	...	350-24	...
	6	261-4	...	329-23	...	434-10	...	396-6	...	356-10	...
	12	216-2	...	233-2	...	286-1	...	311-0	...	312-9	...
	18	...	...	...	...	298-2	...	275-1	...	274-1	...
	24	...	...	...	...	...	...	257-1	...	257-1	...
	30	...	...	...	...	...	...	251-1	...	251-1	...
	36	...	...	...	...	...	...	248-87	...	247-86	...
B	0 (Controls)	413-81	...	519-96	...	551-100	...	440-85	...	551-92	...
	2	389-39	...	497-48	...	491-87	...	382-72	...	456-64	...
	4	365-37	...	399-14	...	378-4	...	401-25	...	381-50	...
	6	364-34	...	415-29	...	386-2	...	396-6	...	393-26	...
	12	242-4	...	286-1	...	286-1	...	311-0	...	312-9	...
	18	...	...	...	...	...	...	275-1	...	274-1	...
	24	...	...	...	...	...	...	257-1	...	257-1	...
	30	...	...	...	...	...	...	251-1	...	251-1	...
	36	...	...	...	...	...	...	248-87	...	247-86	...
C	0 (Controls)	403-79	...	468-100	...	451-96	...	463-80	...	439-100	...
	2	352-64	...	347-66	...	249-16	...	344-90	...	353-64	...
	4	376-76	...	317-59	...	429-55	...	382-26	...	370-18	...
	6	369-1	...	378-52	...	392-4	...	402-24	...	377-10	...
	12	263-0	...	291-27	...	287-0	...	265-9	...	295-6	...
	18	...	...	...	...	...	...	305-4	...	304-5	...
	24	...	...	...	...	...	...	283-3	...	283-3	...
	30	...	...	...	...	...	...	264-5	...	264-5	...
	36	...	...	...	...	...	...	257-1	...	257-1	...
D	0 (Controls)	498-98	...	529-67	...	496-88	...	519-90	...	469-99	...
	2	317-84	...	345-75	...	367-15	...	306-13	...	312-34	...
	4	295-40	...	348-11	...	330-26	...	324-16	...	327-13	...
	6	342-34	...	345-3	...	315-11	...	333-3	...	345-45	...
	12	252-4	...	291-3	...	267-2	...	242-0	...	357-32	...
	18	...	...	...	...	...	...	284-2	...	303-4	...
	24	...	...	...	...	...	...	283-4	...	253-2	...
	30	...	...	...	...	...	...	264-2	...	251-10	...
	36	...	...	...	...	...	...	257-1	...	257-1	...
E	0 (Controls)	483-94	...	438-73	...	456-47	...	439-59	...	416-20	...
	2	277-2	...	271-0	...	241-0	...	239-0	...	334-0	...
	4	261-7	...	270-5	...	229-2	...	252-3	...	229-0	...
	6	270-5	...	213-0	...	244-0	...	227-0	...	212-0	...
	12	213-0	...	188-0	...	166-0	...	134-0	...	213-0	...
	18	...	...	...	...	...	...	168-0	...	113-0	...
	24	...	...	...	...	...	...	134-0	...	113-0	...
	30	...	...	...	...	...	...	134-0	...	113-0	...
	36	...	...	...	...	...	...	134-0	...	113-0	...

¹/ Tested after 2 days at 80° F. and 65 percent relative humidity.

²/ The first value is the average shear strength in pounds per square inch; the second value is the average wood failure in percent.

Table 4.—Results of wet¹ shear tests of three-ply, 7/16-inch yellow birch plywood, bonded with room-temperature-setting urea glues at various temperatures, before and after exposure to 158°F. and 20 percent relative humidity.

		Curing conditions									
Glue	Period of exposure	80° F., 8 hours		160° F., 20 minutes		180° F., 4 minutes		215° F., 2 minutes		250° F., 2 minutes	
		10 minutes	2 minutes	10 minutes	2 minutes	10 minutes	2 minutes	10 minutes	2 minutes	10 minutes	2 minutes
Assembly time (closed)											
A	0 (Controls)	2/157-93	2/...	2/...	2/...	2/460-83	2/...	2/...	2/...	2/432-26	2/...
	2	308-15				340-22				273-0	
	4	282-26				300-16				223-2	
	6	269-3				245-1				200-1	
	12	152-4				179-1				176-0	
	18										
	24										
	30										
	36										
B	0 (Controls)	168-88	572-97	465-91	466-100	512-99	495-98	467-100	563-100	488-100	510-89
	2	398-54	452-54	461-56	477-85	452-76	426-65	445-94	432-91	433-99	432-69
	4	357-12	359-12	361-42	384-73	420-93	409-46	407-32	388-93	388-93	396-74
	6	316-21	318-5	342-24	337-20	385-57	307-17	343-39	361-65	375-34	374-55
	12	224-8	258-4	236-1	244-5	283-10	283-14	293-2	283-0	287-1	256-35
	18										
	24										
	30										
	36										
C	0 (Controls)	391-88	461-100	428-100	433-100	512-100	520-99	540-100	486-100	446-100	462-98
	2	304-70	407-79	473-85	387-88	422-77	399-72	447-95	394-64	352-21	378-80
	4	371-43	380-72	405-33	374-18	386-64	358-62	402-46	359-62	354-100	326-46
	6	358-9	361-43	339-36	336-20	364-32	354-14	377-44	311-11	354-68	312-60
	12	285-34	517-20	294-11	322-7	265-15	283-5	307-9	282-9	304-6	233-3
	18										
	24										
	30										
	36										
D	0 (Controls)	190-93	501-100	546-100	527-99	517-91	512-99	433-100	527-84	433-99	481-88
	2	345-65	398-69	320-42	362-37	361-50	369-71	374-19	321-19	332-99	369-14
	4	312-68	330-35	374-36	320-16	349-47	352-65	314-18	295-21	295-21	295-19
	6	314-50	348-25	341-7	320-23	351-41	332-37	280-26	298-5	283-10	291-21
	12	238-46	290-14	257-7	266-13	258-9	274-7	252-2	231-18	203-19	234-13
	18										
	24										
	30										
	36										
E	0 (Controls)	140-100	507-90	495-75	497-88	446-19	515-94	483-63	486-86	501-65	498-100
	2	264-27	240-6	215-1	238-2	232-0	187-0	216-0	293-28	291-8	469-99
	4	226-14	250-0	196-0	202-0	181-0	187-0	169-0	236-2	234-2	365-59
	6	194-3	228-0	149-0	114-1	76-0	103-0	164-0	206-1	204-2	253-18
	12	166-1						120-0	165-1	121-2	181-9
	18										
	24										
	30										
	36										

¹ Specimen soaked for 48 hours in water at room temperature after removal from exposure.

² The first value is the average shear strength in pounds per square inch; the second value is the average wood failure in percent.

Table 5.—Results of dry^{1/} shear tests of three-ply, 3/16-inch yellow birch plywood, bonded with room-temperature-setting urea glues at various temperatures, before and after exposure to 80° F. and 97 percent relative humidity.

Glue exposure	Period of exposure	Curing conditions											
		10 minutes : 2 minutes											
		Months											
A	0 (Controls)	2/453-79	2/...	2/...	2/453-83	2/...	2/...	2/...	2/...	2/...	2/...	2/...	2/...
	2	348-19			403-29								
	4	321-98			392-59								
	6	264-100			308-100								
	12	141-100			142-100								
	18												
B	0 (Controls)	473-81			551-100								
	2	415-90	519-96	479-88	487-87	440-85	515-94	471-86	554-92	423-100	478-85	483-100	
	4	357-97	506-93	503-46	547-97	520-89	510-63	495-98	509-91	463-100	500-93	500-93	
	6	311-100	309-100	499-95	475-99	432-100	434-82	413-100	487-74	453-100	485-94	485-94	
	12	154-100	185-100	357-99	342-100	306-100	361-100	424-80	349-100	344-100	381-82	402-93	
	18			208-100	222-100	180-100	201-100	197-100	226-100	163-100	191-100	236-100	
C	0 (Controls)	403-79	468-100	451-96	463-97	451-84	481-80	458-87	439-100	416-83	413-100	402-78	370-99
	2	498-83	505-100	547-90	509-97	564-93	559-92	595-100	582-99	470-85	491-100	561-91	496-95
	4	312-100	528-100	536-100	513-100	418-100	510-100	550-100	513-100	422-100	546-100	469-94	509-96
	6	311-100	390-100	378-100	385-100	390-100	390-100	422-100	377-100	361-88	419-100	491-85	394-100
	12	186-100	196-100	200-100	180-100	195-100	185-100	245-100	204-100	192-100	216-100	253-100	215-100
	18												
D	0 (Controls)	496-98	496-88	512-90	536-91	469-99	464-95	498-93	495-95	449-98	499-93	505-93	
	2	515-70	522-86	568-88	481-91	526-98	527-98	513-79	532-96	496-96	524-89	483-88	
	4	561-94	518-70	569-91	577-65	582-92	562-98	540-94	544-96	478-97	532-41	496-95	
	6	473-69	481-44	511-71	494-75	501-27	535-78	522-98	442-5	453-69	516-27	502-40	
	12	244-100	278-100	304-100	302-100	188-100	257-84	350-100	356-100	346-100	401-49	333-61	
	18												
E	0 (Controls)	483-94	438-73	456-47	439-59	416-20	417-46	400-77	441-57	402-89	445-93	458-87	
	2	463-90	376-4	426-1	411-15	368-3	447-0	436-29	433-51	465-13	462-25	440-91	
	4	455-43	422-1	391-0	448-8	392-2	390-2	385-10	362-8	418-37	425-29	463-85	
	6	405-50	348-0	326-0	365-4	286-4	359-2	300-3	389-15	414-13	388-15	415-13	
	12	286-100	278-90	271-52	279-85	184-22	235-41	221-54	273-66	303-45	289-47	287-70	
	18												
ZM 644 F	24												
	30												
ZM 644 F	36												

^{1/} Tested dry after removal from exposure.

^{2/} The first value is the average shear strength in pounds per square inch; the second value is the average wood failure in percent.

Table 6.—Results of wet/¹ shear tests of three-ply, $\frac{1}{16}$ -inch yellow birch plywood, bonded with room-temperature-setting urea glues at various temperatures, before and after exposure to 80° F. and 97 percent relative humidity.

Glue	Period of exposure	Months	Curing conditions																
			80° F. 8 hours			160° F. 20 minutes			180° F. 4 minutes			215° F. 2 minutes			250° F. 2 minutes				
Assembly time (Closed)																			
			10 minutes : 2 minutes : 10 minutes : 2 minutes : 10 minutes																
A	0 (Controls)	2/457-93 488-35	2/.....	2/.....	2/.....	2/460-83 434-52	2/.....	2/.....	2/.....	2/432-26 467-2	2/.....	2/.....	2/.....	2/.....	2/.....	2/.....			
	2	225-100				327-51				360-73									
	4	215-100				213-100				209-100									
	6	140-100				111-100				119-100									
	12																		
	18																		
	24																		
	30																		
	36																		
B	0 (Controls)	468-88 493-72	572-97 511-57	543-61 332-68	535-93 413-85	552-91 394-85	466-100 292-94	512-99 298-98	467-25 416-100	495-98 305-98	467-100 167-100	563-100 177-100	488-100 177-100	510-89 264-100	420-100 154-100	511-75 390-100	422-99 168-100	480-96 183-100	
	2	348-100	288-98	238-100	244-97	292-94	168-98	164-100	176-100	167-100	177-100								
	4	139-100	170-100	157-100															
	6																		
	12																		
	18																		
	24																		
	30																		
	36																		
C	0 (Controls)	391-88 450-98	464-100 452-100	463-99 433-60	408-99 310-100	413-100 290-100	428-100 161-100	433-100 170-97	523-100 149-100	422-99 174-100	540-100 184-100	486-100 149-100	418-100 146-100	446-100 168-100	474-100 146-100	491-97 168-100	455-97 182-100	451-100 183-100	
	2	292-100	284-85	310-100	294-85	318-98	290-100	318-96	402-99	410-100	386-99	427-100	389-96 264-100	439-100 149-100	474-100 168-100	506-97 168-100	442-99 202-100	359-99 182-100	
	4	161-100																	
	6																		
	12																		
	18																		
	24																		
	30																		
	36																		
D	0 (Controls)	490-93 467-95	501-100 467-95	520-86 434-96	486-92 433-98	520-71 480-85	470-85 226-100	524-100 243-100	527-99 489-100	517-91 481-71	512-99 461-100	433-100 454-66	413-100 447-62	427-94 202-100	425-99 145-100	425-99 145-100	425-99 147-53	453-99 230-100	460-100 280-100
	2	385-100	333-6	385-100	404-23	442-65	470-85	243-100	436-83 240-100	428-100 187-100	433-100 187-100	433-100 202-100	433-100 253-100	433-100 253-100	433-100 253-100	433-100 253-100	433-100 280-100	453-91 314-80	
	4	171-100																	
	6																		
	12																		
	18																		
	24																		
	30																		
	36																		
E	0 (Controls)	440-100 422-89	495-75 390-17	356-14 333-6	497-88 385-100	365-13 336-1	478-1 294-0	446-19 235-50	356-0 392-4	356-8 392-3	515-94 307-1	486-86 372-2	486-86 331-1	501-65 223-24	496-100 197-42	453-99 262-81	469-99 234-81	469-99 234-81	
	2	385-100	333-6	385-100	404-23	365-13 336-1	398-1 294-0	478-1 235-50	356-0 392-4	356-8 392-3	515-94 307-1	486-86 372-2	486-86 331-1	501-65 223-24	496-100 197-42	453-99 234-81	469-99 234-81		
	4	171-100																	
	6																		
	12																		
	18																		
	24																		
	30																		
	36																		

¹/ Specimens soaked for 48 hours in water at room temperature after removal from exposure.

²/ The first value is the average shear strength in pounds per square inch; the second is the average wood failure in percent.

Table 7.—Results of wet/¹ shear tests of three-ply, 3/16-inch yellow birch plywood, bonded with room-temperature-setting urea-formaldehyde resin at various temperatures, before and after exposure to alternate soaking for 2 days in water at room temperature and drying for 12 days in air at 80° F., and 30 percent relative humidity.

1 Specimens tested immediately after the soaking part of the cycle.

Table 5.—Results of shear tests on specimens of three-ply $\frac{3}{16}$ -inch birch plywood glued with room-temperature-setting urea glues at various curing temperatures and assembly times.

Glue	Curing temperature	80° F.	150° F.	180° F.	215° F.	250° F.	250° F.	250° F.	250° F.	
A	Dry Shear Test Results	2453-79 455-13 411-50 316-2 486-98	2122-64 152-82 165-72 473-91	2459-100 468-40 481-70 504-100	2462-97 420-81 448-61 465-100	2476-99 440-50 472-22 476-87	2441-97 456-34 458-17 469-36	2420-78 449-93 472-63 459-99	2449-79 421-88 473-54 460-80	2428-99 423-91 440-85 468-93
A	Wet ¹ Shear Test Results	457-93 504-65 522-50 470-98	486-81 514-64 488-97	495-73 484-74 497-100	451-9 500-81 480-98	508-58 422-40 484-95	512-83 424-48 510-99	432-26 456-60 510-99	463-95 464-95 500-100	467-53 485-96 472-91
E	Dry Shear Test Results	483-34 453-91 452-77 428-69	438-73 438-66 421-56 418-34	456-47 483-83 428-59 382-22	439-59 423-59 428-77 418-34	416-20 421-81 426-52 426-52	417-46 429-48 426-52 426-52	374-33 429-33 434-86 442-88	441-37 425-95 426-88 463-76	415-93 400-75 388-86 422-52
E	Wet ¹ Shear Test Results	440-100 528-77 540-99	507-90 554-90 437-44	495-75 500-88 473-37	497-88 500-87 450-15	514-19 489-36 497-56	515-94 483-100 514-88	486-86 483-100 554-94	501-65 481-96 563-95	469-99 424-70 458-89

¹Tested dry after at least one week at 80° F. and 65 percent relative humidity.

²The first value is the average shear strength in pounds per square inch; the second value is the average wood failure in percent.

³Tested wet after soaking in water at room temperature for 48 hours.

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