STRENGTH LOSSES OF PAPREG DUE TO BAG-MOLDING DEFECTS

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STRENGTH LOSSES OF PAPREG DUE TO BAG-MOLDING DEFECTS[1]

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Papreg is subject to wrinkling and puckering during bag molding of an assembly of uncured sheets of resin-treated paper. The single sheets are flexible and tend to slide readily upon each other, but they lack ability to stretch. Unless the sheets are carefully tailored or gored and unless the bag is drawn down on the surface with great care, defects will occur as a result of puckering of the sheets. It is important to determine the extent such defects affect the strength properties of papreg.

Cross-banded panels of papreg were bag-molded from a standard commercial high-strength resin-treated paper at 75 pounds per square inch molding pressure on a flat metal plate. Five types of defects were permitted to occur on the bag-molded surface of part of the panels: (1) shallow wrinkles with thickened zones on each side of the depression, (2) folded wrinkles in which the paper is folded back on itself, (3) peaked wrinkles, (4) puckered area beneath burlap attached to the bleeder of the bag, and (5) zones exposed to bag leaks when molding under steam pressure. Figure 1 illustrates these types of defects in papreg.

Specimens cut from these panels and from control panels free from defects were subjected to flexural tests using a cantilever-beam stiffness tester provided with an extension arm so that the tests could be made at spans of 6 inches or more.[2] All specimens were nominally 1/2 inch wide and were tested at spans of either 6 or 7 inches. The specimens were cut so that the defects were in the region where the bending moment in testing is the greatest. Emery cloth was used to dress the edges of the specimens at the vise end to insure uniform clamping. The specimens were tested flatwise with the face ply fibers parallel to the span length. The specimens were not conditioned prior to test. All of the tests were, however, made on the same day to eliminate conditioning variables.

Table 1 gives the results of the flexural tests on six control specimens free from defects.

Table 2 gives the values for five specimens with shallow wrinkles, all tested with the defect on the face of the specimen subjected to tension. The

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[1] This mimeograph is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

[2] Forest Products Laboratory restricted Mimeograph No. 1388, Cantilever-beam Stiffness Tester.

thickness of the specimens, measured from the valley of the wrinkles, was about the same as the thickness of the normal part of the specimens (0.09 inch). The thickened portion to each side of the wrinkle was 0.003 to 0.005 inch thicker than the rest of the specimen. The shallow wrinkles had no adverse effect upon the mechanical properties as is shown in table 7. Because the specimens were thickened slightly on each side of the wrinkle, the load at the proportional limit and at 0.05 percent offset was increased slightly while the variations in the modulus of rupture and modulus of elasticity were well within the range of experimental accuracy. The specimens failed in tension in the wrinkle. The first crack occurred at 60 to 70 percent of the maximum load.

The more seriously wrinkled panels of the second and third type showed a decrease in all of the flexural properties. This seems to be, at least in part, because the plies in these extremely wrinkled specimens were not all bonded together within the wrinkle as they were in the shallow wrinkles. This condition did not permit the plies to act simultaneously in stiffening the members.

Five specimens were prepared with folded wrinkles by slightly staggering the plies along one edge of the assembly and holding them in this position with paper staples. Two of these specimens were tested with the wrinkle on the tension side and two with the wrinkle on the compression side. The data are given in table 3 and the values relative to the controls in table 7. The loss in all flexural properties was quite large. Similar reductions in the flexural strength properties were obtained in specimens with high-peaked wrinkles (table 4 and table 7).

The puckered area occurring under the bag nipple from the rough burlap backing also showed a significant change in the mechanical properties as is shown in tables 5 and 7.

A zone on one side of several specimens was exposed to moisture during the molding as a result of a leak in the molding bag. The combination of moisture and heat had detrimental effect upon the flexural properties of the panels when the exposed face was tested either under tension or under compression (tables 6 and 7).

Conclusions and Recommendations

The limited data given show that several different molding defects which may occur in the bag molding of papreg greatly reduce the flexural strength properties. Shallow wrinkles in which the effective thickness is not reduced and in which the plies are well bonded give no reduction in strength properties. More severely wrinkled specimens in which the bonding of the plies is not so perfect, however, may cause from 30 to 80 percent loss in strength properties. Even the roughened area of a panel caused by the pressure of a rough burlap support around a bleeder valve may cause 20 to 40 percent loss in flexural properties. Bag leaks during molding with steam pressure also cause large reductions in flexural properties due to the combined effect of moisture and heat on the material.

It is thus important to take great pains to avoid wrinkles in the assembly of resin treated paper by properly tightening and drawing the bag down on the surface with considerable care. Limited experience indicates that in the molding of thin double curvature shells it is desirable to lay the concave surface of a previous molding over the convex surface of the paper assembly before inserting in the bag. This tends to hold the paper to the approximately correct molding contour. This practice, however, does not permit as even distribution of pressures in all directions as in unrestrained bag molding.

It is important, in avoiding puckered areas of reduced strength, to have the bag bleeder valve and the area of undersupport surrounding it to one side of the object being molded or in an area that will later be a cut out.

Precautions should also be taken to avoid bag leaks by careful handling and inspection of the bags prior to use to avoid degrade in the product. Bag leaks are more serious in molding impregnated paper than in molding veneer.

Table 1.--Flexural tests on control specimens of bag-molded papreg free from defects

Width	Depth	Proportional limit	Yield stress at 0.05 percent offset	Modulus of rupture	Modulus of elasticity
Inches		Pounds per square inch			1,000 pounds per square inch
0.508	0.094	9,950	14,450	28,600	2,320
.503	.091	12,400	16,710	28,600	2,360
.500	.092	11,720	15,850	27,900	2,310
.503	.094	10,800	15,720	29,500	2,570
.505	.092	10,460	15,100	28,200	2,620
.507	.093	10,690	14,280	28,000	2,520
Average		11,003	15,351	28,433	2,450
Standard deviation		861	872	420	12.4

Table 2.--Flexural tests on shallow-wrinkle specimens[1] of bag-molded papreg

Width	Depth	Proportional limit	Yield stress at 0.05 percent offset	First crack in wrinkle	Modulus of rupture	Modulus of elasticity	Direction of stress[2]
Inch		Pounds per square inch				1,000 pounds per square inch	
0.508	0.092	12,130	15,850	20,500	28,400	2,470	T
.508	.091	12,610	16,300	18,090	28,600	2,460	T
.507	.093	12,800	16,400	19,620	28,800	2,380	T
.509	.092	14,880	17,600	18,400	28,800	2,260	T
.509	.092	13,720	17,680	16,730	27,800	2,260	T
Average....		13,228	16,772	18,668	28,480	2,370	
Standard deviation		946	775	---	369	9.16	

[1] Calculations are based on dimensions of the normal part of the specimen.

[2] Direction of stress indicates whether defects were in compression or tension.

Table 3.--Flexural tests on folded-wrinkle specimens[1] of bag-molded papreg

Width	Depth	Proportional limit	Yield stress at 0.05 percent offset	First crack	Modulus of rupture	Modulus of elasticity	Direction of stress[2]
Inch		Pounds per square inch				1,000 pounds per square inch	
0.507	0.131	2,900	3,480	5,790	6,760	1,120	T
.510	.134	3,280	3,890	5,240	7,600	1,190	T
.511	.133	1,540	1,910	--	3,180	1,640	C
.505	.133	2,690	4,080	--	4,300	1,380	C

[1] Calculations are based on dimensions of the normal part of the specimens.

[2] Direction of stress indicates whether defects were in compression or tension.

Table 4.--Flexural tests on high-peaked-wrinkle specimens[1] of bag-molded papreg

Width	Depth	Proportional limit	Yield stress at 0.05 percent offset	Modulus of rupture	Modulus of elasticity	Direction of stress[2]
Inch		Pounds per square inch			1,000 pounds per square inch	
0.497	0.131	3,035	3,480	4,510	1,310	T
.511	.131	3,700	4,200	4,790	1,220	T
.510	.133	---	---	3,320	1,170	T
.511	.132	4,180	4,710	6,740	1,360	C
.512	.133	5,180	5,980	7,970	1,400	C

[1] Calculations are based on dimensions of the normal part of the specimens.

[2] Direction of stress indicates whether defects were in compression or tension.

Table 5.--Flexural tests on specimens of bag-molded papreg showing puckered area under bag nipple[1]

Width	Depth	Proportional limit	Yield stress at 0.05 percent offset	Modulus of rupture	Modulus of elasticity	Direction of stress[2]
Inch		Pounds per square inch			1,000 pounds per square inch	
0.503	0.077	7,440	11,070	20,920	1,710	T
.505	.075	8,660	11,700	21,550	1,770	T
.502	.077	7,860	10,800	20,600	1,650	T

[1] Calculations are based on dimensions of the normal part of the specimens.

[2] Direction of stress indicates whether defects were in compression or tension.

Table 6.--Flexural tests of specimens of bag-molded papreg exposed to moisture during steam-pressure molding because of a bag leak[1]

Width	Depth	Proportional limit	Yield stress at 0.05 percent offset	Modulus of rupture	Modulus of elasticity	Direction of stress[2]
Inch		Pounds per square inch			1,000 pounds per square inch	
0.506	0.077	6,630	8,860	16,180	1,530	T
.505	.077	7,210	9,420	16,670	1,620	T
.504	.079	6,100	8,600	18,300	1,610	T
.507	.078	6,540	8,970	17,130	1,510	T
.507	.077	4,790	7,990	16,780	1,590	C
.504	.077	4,820	8,040	16,880	1,600	C
.502	.079	4,600	7,540	18,480	1,520	C

[1]Calculations are based on dimensions of the normal part of the specimens.

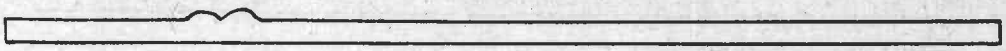
[2]Direction of stress indicates whether defects were in compression or tension.

Table 7.--Summary of effect of surface defects on bag-molded papreg in cantilever bend tests

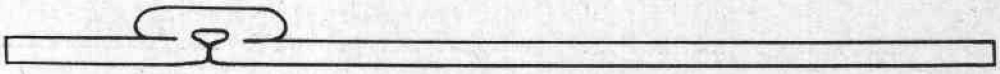
Defect description	Loss in strength[1]				Direction of stress with respect to defect[2]
	Proportional limit	Yield stress at 0.05 percent offset	Modulus of rupture	Modulus of elasticity	
	Percent	Percent	Percent	Percent	
Shallow wrinkle	+17	+8.5	0	0	T
Folded wrinkle	-77	-77	-87	-50	T
Folded wrinkle	-84	-82	-87	-37	C
High-peaked wrinkle	-75	-77	-85	-49	T
High-peaked wrinkle	-65	-68	-74	-42	C
Puckered area caused by bag exhaust nipple	-40	-33	-26	-29	T
Steam stain caused by bag leak	-50	-46	-40	-34	T
	-64	-53	-41	-34	C

[1] Calculations are based on dimensions of the normal part of the specimens relative to the values for the defect free controls.

[2] T = tension; C = compression

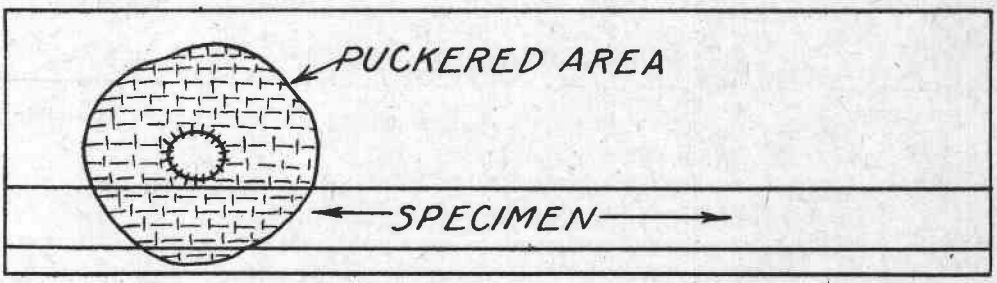


SHALLOW WRINKLE

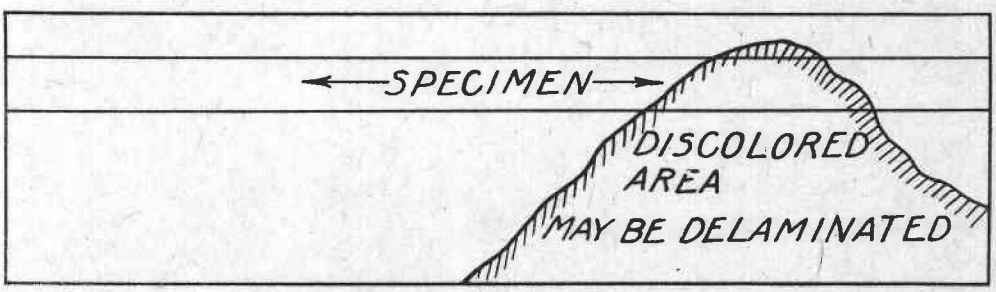


FOLDED WRINKLE

PEAKED WRINKLE



PUCKERED AREA BENEATH BURLAP AT BAG BLEEDER



ZONE EXPOSED TO BAG LEAK IN STEAM-PRESSURE MOLDING

Figure 1.--Five types of imperfections in bag-molded papreg due to bag-molding defects.

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