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Protein-Dialdehyde Starch Glue for Birch Type II Plywood

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A hot-press, protein-dialdehyde starch glue was used experimentally to prepare plywood from yellow birch veneers. Gluing conditions were similar to those that were previously effective for bonding southern pine veneers to form interior-type plywood test panels. Yellow birch plywood produced under the conditions so developed met the performance requirements for Type II hardwood plywood. The excellent tack that was obtained with cold-pressed panels would allow prepressing in mill operations. Further-more, yellow birch and southern pine veneers were sufficiently compatible with this moderately alkaline glue to permit mixing these species in the same plywood construction. Bleedthrough of glue was not observed in plywood panels having 1/26-in. birch face veneers. Results indicate that the protein-dialdehyde starch glue should be useful in the manufacture of birch Type II plywood.

(Zusammenfassung siehe Seite 62; Résumé à la page 62)

Introduction

Production costs in the hardwood plywood industry could be reduced significantly if suitable less expensive glues were available. Hardwood plywood glue cost in 1968 [1] was calculated at $ 3.23 per thousand sq ft of double glue line (MDGL) based on a 62-lb spread of urea-formaldehyde resin glue and a 21 % waste factor. In contrast, our previous study [2] on the bonding of southern pine veneers with a protein-dialdehyde starch (DAS) glue for interior-type plywood showed that glue cost was $ 1.88 per MDGL based on an 88-lb spread and a 20 % waste factor. The

similarity in surface wettability and acidity of southern pine and yellow birch veneers [3], together with the low cost of the protein-DAS glue, prompted studies on birch veneer bonding with this glue.

The specific study reported here was made to determine whether Type II plywood as defined in plywood standards [4, 5] could be made from birch veneers using protein-DAS glue. Attempts were also made in this investigation to find: (a) whether sapwood and heartwood birch veneers would bond similary; (b) if these veneers could be satisfactorily combined within the same plywood construction; (c) whether birch veneers could serve as face and back plies in a plywood panel having a southern pine core; (d) whether the smooth surface of birch veneer can tolerate a significant reduction in glue spread from that normally required for the coarser surface on southern pine veneer; and (e) if glue bleedthrough occurs with thin birch outer plies. Influence of veneer moisture, of glue aging and of a modified glue mixing procedure on glue bond quality was also investigated.

Table 1. Mixing Instructions for Interior-Type Protein-Dialdehyde Starch (DAS) Glue.

Ingredients	Parts by Weight
Water, approximately 75 °F	722
Soluble spray-dried blood (60 % pork—40 % beef, nominal moisture content 8 %)[1], short stir	100
Industrial defatted soy flour, 200-mesh (nominal moisture content 8 %)[2], short stir	100
Antifoam[3], stir 5 min	3
Silicate of soda, "N" grade[4], stir 5 min	41-1/2
Powdered borax	18-1/2
Water, approximately 75 °F, stir 5 min	207
DAS premix, 10 %, short stir	46
Sodium pentachlorophenate, beads, stir 25 min	9-1/4
Total	1247-1/4

Glue is ready for use 1 h after adding final ingredient.

1 Rath Packing Co., Waterloo, Iowa; 2 Chemurgy Division, Central Soya, Chicago, Illinois; 3 Hodag Antifoam TBX, Hodag Chemical Corp., Skokie, Illinois; 4 Philadelphia Quartz Co., Philadelphia, Pennsylvania.

Experimental

Veneer

Commercial, rotary cut veneer was used in this study. Yellow birch veneer, 1/26-in. and 1/16-in. thick, came from Birds Eye Veneer Company, Escanaba, Michigan[1]). Southern yellow pine veneer, 1/8-in. thick, was supplied by a Louisiana mill. Veneers were trimmed to 12-in. by 12-in. size and then conditioned to constant weight at selected temperatures and relative humidities in order to attain desired moisture levels for the gluing experiments. The 1/26-in. yellow birch and the 1/8-in. southern yellow pine veneers were all sapwood. The 1/16-in. yellow birch consisted of sapwood and heartwood veneers.

Glue Mixing

Glue ingredients and glue-mixing instructions are listed in Table 1 in order of addition. The DAS-premix is prepared on a weight basis by first slurrying 10 parts oven-dry basis DAS (Sumstar-190, Miles Laboratories, Inc., Elkhart, Indiana) in 85 parts water and heating to 194 °F. After agitating and heating the slurry for 10 min at 194 °F, the slurry is cooled to 167 °F and one part borax is added. This premix is stirred briefly before cooling to 77 °F when its weight is adjusted to 100 parts with water.

Panel Preparation

a. All-birch panels. The procedure was to prepare 12-in. square, 3-ply, 3/16-in. all-birch panels containing sapwood, heartwood, or a combination of sapwood and heartwood veneers.

Gluing conditions used in preparing the all-birch panels consisted of: (a) 1/16-in. birch veneer at approximately 9 % moisture; (b) glue spread of 88 lb per MDGL; (c) a 20-min closed assembly time which included a cold prepress of 3 min at 150 psi and stand times of 3 min minimum before and 5 min after the prepress; (d) hot-press temperature of 270 °F; (e) specific pressure of 175 psi; and (f) hot-press times of 3 and 5 min for panels pressed two per press opening.

The internal or innermost glue line temperature (IGLT) of a panel during the hot-press cycle was determined with a thermocouple centered at the appropriate glue line. Veneer moisture content and glue spread were varied independently from the gluing conditions listed above to discover the influence on glue bond quality of changes made in each of these gluing conditions.

b. Pine-core panels. Also fabricated were 12-in. square, 3-ply panels in which 1/8-in. thick southern yellow pine was the core ply with 1/26-in. or 1/16-in. birch sapwood veneers serving as outer plies. Four panels were prepared for each birch veneer thickness. Gluing conditions included those applied initially in preparing all-birch panels except that all the mixed veneer species panels were hot-pressed for 5 min at two panels per press opening. This study on mixing of veneer species in plywood construction was prompted by the provision in the interim industry hardwood plywood standard [5] for inclusion of softwood veneer core in standard constructions, and by Amendment No. 2 to Product Standard PS 1—66 [6] which adds sweet and yellow birch veneer to the Group 1 classification of species.

Variation of Veneer Moisture Content

Veneer lots were preconditioned to average moisture contents of approximately 3, 5.4 and 9 %, and each was sealed in polyethylene bags until just before gluing. Veneer having

1 Mention of firm names or trade products does not imply an endorsement or recommendation by the Department of Agriculture over other firms or similar products not mentioned.

approximately 3 % moisture content was obtained by heating it for 4 h in a forced draft oven at 125 °F. Final relative humidity within the oven was approximately 18 % as measured by the Precision Model Relative Humidity Indicator (Bacharach Industrial Instrument Co., Pittsburgh, Pennsylvania). When exposed several days at 80 °F and 30 % relative humidity, veneers had approximately 5.4 % moisture. If relative humidity was increased to 50 %, veneers reached approximately 9 % moisture. Veneers exposed to laboratory humidity conditions were tested for moisture content before gluing and found to have 5 % moisture.

Variation in Glue Spread

Changes in glue spread over the range 58—88 lb per MDGL were made when plywood was made from yellow birch veneers at approximately 9 % moisture content. Six glue spread levels within the range of 58—88 lb per MDGL were evaluated for their effect on plywood glue bond quality. Glue spread was calculated from the weight difference recorded for a core ply before and after passing through the glue-filled spreader.

Variation in Glue Mixing and Aging

Variation in the normal single-stage glue mixing instructions (Table 1) was evaluated by delaying for 24 h the addition of the DAS-premix and the sodium pentachlorophenate to a partially completed glue mix. Such a technique of two-stage glue mixing, if proven feasible, would permit large-scale temporary storage of partially completed batches of glue. Glue requirements could then be met as needed by continuing the usual final glue mixing instructions commencing with the addition of the DAS-premix and the sodium pentachlorophenate in quantities proportionate to the amount of partial glue mix selected.

The influence of glue age on glue bond quality of birch plywood was determined for a single-stage glue mix, freshly formulated and after aging 24 h.

Test Methods

Determination of moisture content (oven-drying method) is described in the Interim Industry Standard for Hardwood and Decorative Plywood, HPMA-S-69 [5]. Tests for water-resistant bond were made initially by two procedures. They were (a) the 15-cycle cold-soak test for delamination outlined in Commercial Standard CS 35—61 [4] which requires that the bond shall be of such quality that specimens shall withstand an average of 10 cycles; and (b) the 3-cycle soak as described in Interim Industry Standard HPMA-S-69 [5] requiring that 95 % of the test specimens shall pass the first cycle, and 85 % shall pass the third cycle.

Each panel was cut to provide one 6-in. by 6-in. specimen for the 15-cycle cold-soak test [4] and four 2-in. by 5-in. specimens for the 3-cycle test [5]. Panels to be evaluated exclusively by the 3-cycle method were cut to yield ten 2-in. by 5-in. specimens each.

Results and Discussion

All-birch Plywood Panels

Maximum glue bond ratings were obtained for 3-ply, 3/16-in. birch panels prepared with 9 % moisture veneers and hot-pressed for 3- and 5-min periods (Table 2). Glue bleedthrough was not evident in these panels. Because test results obtained by the two procedures for water-resistant glue bond were in good agreement, only the newer test, HPMA-S-69, was followed. There is no question that birch Type II plywood panels of good quality can be made with protein-DAS glue. Panels made by mixing sapwood and heartwood veneers gave test results no different than those obtained with the all-sapwood or all-heartwood panels.

Table 2. Test Results of 3-Ply, 3/16-In. Birch Type II Plywood Panels Made with Protein-DAS Glue[1]).

Veneer	Number of Planels	Hot-Press Time (min)	Test Cycles Passed CS 35-61 Test	HPMA-S-69[2]) Test
Sapwood	2	3	15	3
	2	5	15	3
Heartwood	2	3	15	3
	2	5	15	3
Sapwood (outer plies)-heartwood (core)	2	3	—	3
Sapwood (core)-heartwood (outer plies)	2	3	—	3

1 For interpretation of test see Test Methods. Gluing conditions included veneer at 9 % moisture; glue spread, 88 lb per MDGL; closed assembly time of 20 min including a 3-min prepress at 150 psi; a hot-press cycle consisting of two panels per press opening, press temperature of 270 °F and a specific pressure of 175 psi.

2 All 2-in. by 5-in. specimens passed the third test cycle.

The IGLT for the birch panels at different press times is shown in Figure 1. Satisfactory plywood glue bonds that resulted from the use of 3- and 5-min hot-press periods indicate that an IGLT range of 212—217 °F is adequate.

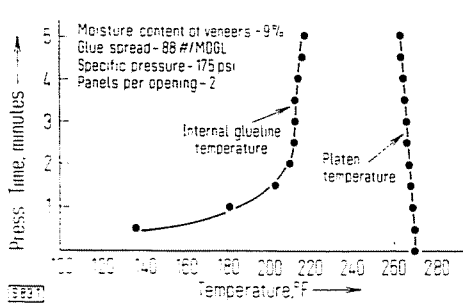

Figure 1. Internal glueline temperature of 3-ply, 3/16-in. birch panels at different hot-press periods.

Panels Containing Mixed Wood Species

Eight 3-ply panels containing 1/8-in. thick southern pine cores were prepared, four each with 1/26-in. and 1/16-in. thick birch sapwood veneers as the outer plies. Like the all-birch panels, these evidenced no glue bleedthrough. Knife test of the air-dry plywood showed a firm glue bond with separation occurring principally as wood failure within the core ply.

Ten 2-in. by 5-in. specimens from each panel were evaluated in the 3-cycle soak test for Type II plywood and no specimen failures occurred. The southern pine veneer used as core ply in this study falls into Category 2 [5], medium density species (0.43 through 0.55 specific gravity).

Variation in Veneer Moisture Content

Results of the 3-cycle test on Type II panels prepared from birch veneer lots having different moisture levels at time of gluing are summarized in Table 3. Gluing conditions,

Table 3. Influence of Veneer Moisture Content on Glue Bond Quality of Birch Heartwood Plywood Panels[1].

Veneer Moisture (%)	Number of 3-Ply, 3/16-In. Panels	Number of Specimens Passing[2]	Plywood Rating[3] (%)
3.2	4	24	60
5.0	4	38	95
5.4	4	40	100
9.0	4[4]	40	100

1 Footnote[1], Table 2, lists gluing conditions except the variation in veneer moisture content and a 3-min hot-press time for all panels; 2 Tested 10 specimens from each of four panels; 3 Test for Type II plywood, HPMA-S-69, with 10 specimens per test panel; 4 One panel had a glue spread of only 83 lb per MDGL.

with the exception of veneer moisture content are the same as described in Table 2. Apparently a veneer moisture content range of 5 to 9 % is preferred when gluing conditions given in Table 2 are followed.

Variation in Glue Spread

Birch plywood panels, which met the test requirements for Type II plywood described in HPMA-S-69, were made from veneers having 9 % moisture content and with a glue spread range of 66 to 88 lb per MDGL. Panels from such veneers but at less than 66 lb per MDGL decreased rapidly in rating as glue spread approached 58 lb per MDGL (Fig. 2). Attempts to spread glue at 68–70 lb per MDGL with veneers at 6 % moisture level gave inconsistent glue bond ratings for seven panels having an average rating of 54 %. Thus, the higher veneer moisture content of 9 % is preferred when glue spread was at the low end of the 66–88 lb range. However, veneer at 6 % moisture produced acceptable plywood when glue spread was 88 lb per MDGL (Table 3).

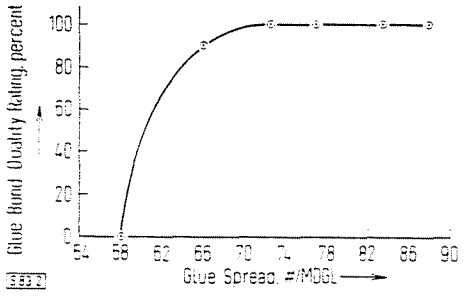

Figure 2. Influence of glue spread on glue bond quality of 3-ply, 3/16-in. birch heartwood panels having a moisture content of 9 % at time of gluing.

Glue Aging and Modification of Glue Mixing Procedure

The single-stage procedure for preparing the glue (Table 1) was followed except that the glue was allowed to stand for 24 h at 75 °F before applying. The 24-h glue thickened and gelled, but under the shear of the glue spreader rolls it became fluid enough for satisfactory application to veneers. Test results (Table 4) for plywood panels prepared

Table 4. Effect of Glue Aging and Glue Mixing on Quality of the Glue Bond in Birch Type II Plywood Panels.

Glue Mix	Heartwood Panel No.	Percent of Test Specimens Passing 3-Cycle HPMA-S-69 Test[1]
Single-stage, fresh	1	100
	2	100
	3	100
	4	100
Single-stage, 24 h	5	70
	6	90
Two-stage, fresh[2]	7	100
	8	100
	9	100
	10	100

1 Ten specimens tested per 3-ply, 3/16-in. panel.

2 Glue mixing was suspended for 24 h following addition of borax and water (see list of ingredients, Table 1).

with the 24-h glue under the conditions used initially with all-birch panels indicated a reduction in glue bond quality as a result of glue aging.

In the two-stage glue mixing procedure, the bulk of the glue ingredients were mixed and allowed to stand 24 h at 75 °F before adding the DAS-premix and sodium pentachlorophenate. Gluing performance was equal to that obtained with the fresh single-stage glue mix. All test specimens (10 specimens per panel) of the four heartwood panels prepared with the two-stage glue mix passed the 3-cycle test for Type II hardwood plywood.

Glue Cost

Cost calculations for the protein-DAS glue formulation based on 3-ply 3/16-in. yellow birch plywood are given in

Table 5. The value of $ 1.62 per MDGL obtained, which includes the waste factor, is one-half the cost of the comparable urea-formaldehyde formulation.

Table 5. Cost Calculations for the Protein-DAS Glue.

Ingredients	Lb	Unit Price $	Cost $
Water, approximately 75 °F	722		
Soluble spray-dried blood (60 % pork-40 % beef, nominal moisture content 8 %)	100	0.105	10.50
Industrial defatted soy flour, 200-mesh (nominal moisture content 8 %)	100	0.065	6.50
Antifoam	3	0.35	1.05
Silicate of soda, "N" grade	41-1/2	0.015	0.62
Powdered borax	18-1/2	0.025	0.46
Water, approximately 75 °F	207		
DAS premix, 10 %	46	0.084[1]	3.86[1]
Sodium pentachlorophenate, beads	9-1/4	0.285	2.64
Total	1247-1/4		25.63

Cost per lb, $ 0.0205; average spread 66 lb per MDGL. Cost per MDGL, $ 1.35; cost plus 20 % waste per MDGL, $ 1.62.

1 Basis Sumstar-190 (11 % moisture) at $ 0.75 per lb.

Zusammenfassung

Protein-Dialdehydstärkeleim für Typ-II-Sperrholz aus Birke. *Furniere aus dem Holz der Gelbbirke können zu niedrigen Kosten zwecks Herstellung von akzeptablem Typ-II-Sperrholz durch Protein-Dialdehydstärkeleim miteinander verbunden werden. In ebenso zufriedenstellender Weise können Bretter mit Birkenauflage und einem Kern aus südlichem Pinienholz mit Hilfe dieses Leimes hergestellt werden. Bei keinem der Sperrholz-Versuchstafeln wurde ein Durchbluten des Leimes beobachtet.*

Résumé

Colle à base de protéine-amidon dialdéhyde pour le contreplaqué du bouleau du type II. *Le bois de placage du bouleau jaune peut être lié avec des colles à base de protéine-amidon dialdéhyde à des bas prix de reviens pour produire du contreplaqué acceptable du type II. De façon aussi satisfaisante on peut fabriquer avec cette colle des lattes de placage de bouleau avec une âme de pin maritime. Dans aucun cas de ces essais on a observé une transfusion de la colle vers l'extérieur.*

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[5] Anon.: HPMA-S-69, Hardwood Plywood Manufacturers Association, Arlington, Virginia (1969).
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