FACEGLUED BLOCKBOARD FROM LOW-GRADE NORTHERN HARDWOODS[1]

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ABSTRACT

Blockboard is a form of lumber core plywood, the latter a product that has for years been used in the United States and Canada in furniture and cabinet manufacture. A unique manufacturing process and the fact that gluelines in faceglued blockboard are found only between face veneers and core serve to distinguish this product from the typical lumber core panel. Blockboard panels have become increasingly popular in northern Europe in recent years, where they have found application in products such as industrial shelving, storage units, packing cases, doors and partitions, benching, worktops, and even combination subflooring/underlayment.

This report deals with a technical and economic evaluation of prospects for manufacture of blockboard panels from low-grade hardwoods of the United States. Faceglued blockboard was manufactured in various configurations from aspen (core) and elm (faces) and then evaluated as a general purpose structural panel. Test data indicate that blockboard panels made with a low-density hardwood core of short-length pieces would have strength and dimensional properties very similar to softwood plywood if manufactured to slightly greater thickness. Economic projections show that these thicker panels could be delivered to midwestern markets at a price very close to that of softwood plywood panels of comparable strength.

Keywords: Blockboard, lumber core, veneer, low-grade hardwoods, laminated panels strength, dimensional stability, economics.

INTRODUCTION

Blockboard is a panel product that has a core of solid wood sandwiched between two or more pieces of veneer, arranged such that the grain direction in the core is perpendicular to the grain direction in at least one pair of veneer plies (Fig. 1). Components of faceglued blockboard are held together only by gluelines between face veneers and core; there are no gluelines between core strips.

In the United States, an edgeglued version of the product described above is known as lumber core plywood, and it is widely used in the manufacture of furniture and cabinets. Excluding North America, blockboard is manufactured in approximately 65 mills throughout the world. While most such blockboard is also intended for decorative interior use, some is now being produced for use as structural panels. The Finnish Plywood Development Association (1969) lists applications for blockboard such as industrial shelving, benching and worktops, storage units, packing cases, doors and partitions, and specialty products.

Structural blockboard panels might have potential in North American markets. The United States is experiencing a growing domestic scarcity of large, good-quality timber in addition to continued strong demand for high-quality structural products made from such timber. Dimensionally stable and high-strength block-

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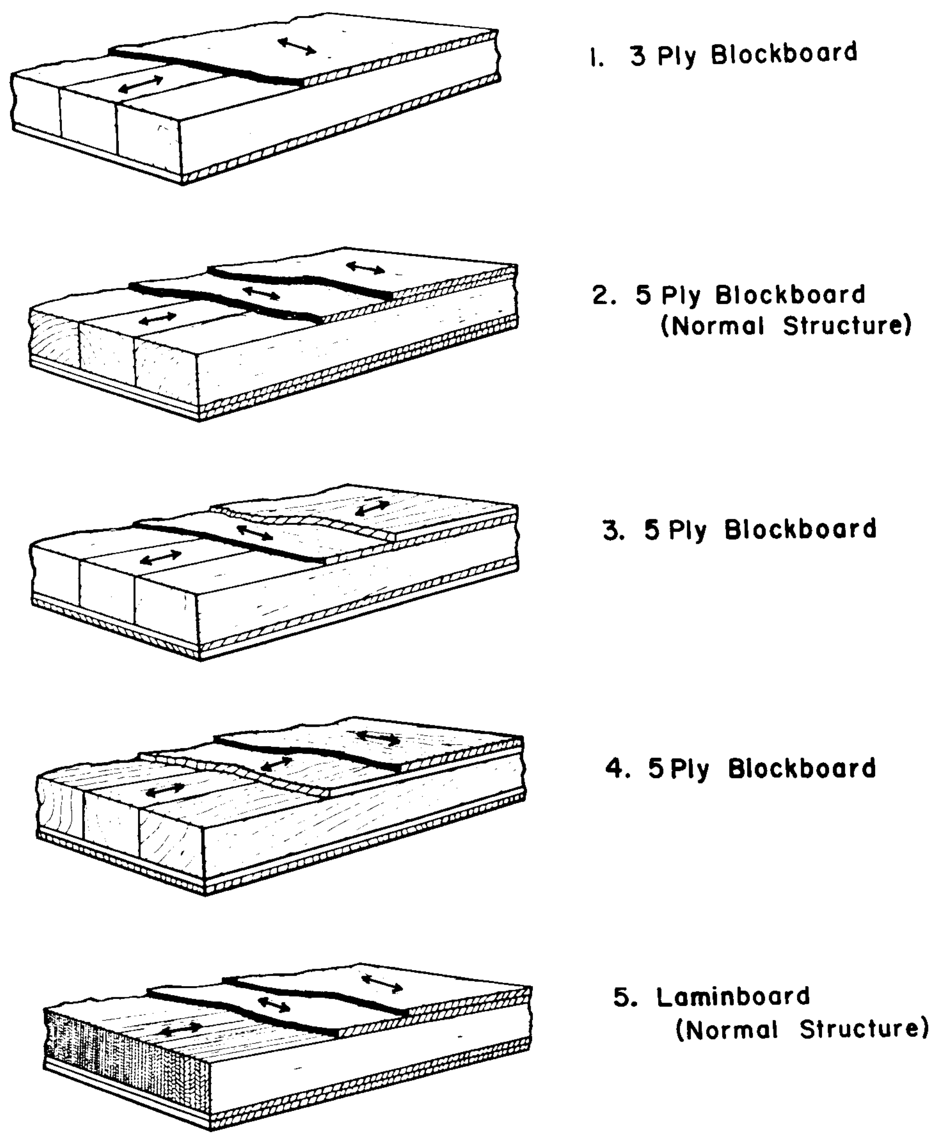

From: Finnish Plywood Development Association Technical Publication No. 13

FIG. 1. Various types of blockboard and laminboard.

board panels can be manufactured largely from low-grade logs. Moreover, the level of investment associated with faceglued blockboard production is only about 10% of that needed for structural particleboard manufacture.

In this study, properties of three-ply, faceglued blockboard manufactured from

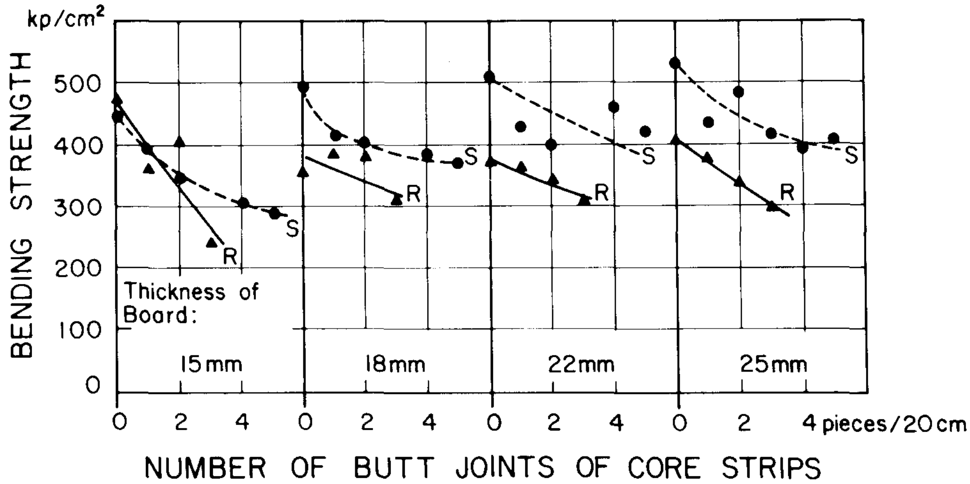

FIG. 2. Effect of the number of butt joints in the core on the bending strength parallel with the strips of five-ply blockboard (R) and laminboard (S) of normal structure (State Institute for Technical Research 1967).

northern hardwoods were evaluated and information concerning basic blockboard properties was expanded. Specific purposes of the project were:

1) To evaluate strength and dimensional properties of faceglued blockboard manufactured from aspen (core) and white elm (faces).
2) To expand upon earlier investigations into the effect on panel strength of random length, butt-jointed core pieces versus solid, full-panel width core strips.
3) To examine further the effect of width of core pieces upon strength parallel-to-the-grain of the panel face plies.

REVIEW OF PREVIOUS INVESTIGATIONS

Physical properties

Phase one of the project under which this study was conducted involved evaluation of three-ply blockboard manufactured from homogeneous and defect-free softwoods (Bowyer 1979). In this first phase it was found that: 1) strength of laboratory-manufactured blockboard approximates strength of commercially manufactured plywood of similar thickness and species; 2) board made using face

TABLE 1. *Average number of butt joints in the blockboards and laminboards of normal structure in the principal material (State Institute for Technical Research 1967).*

Nominal thickness (mm)	Number of butt joints (pieces/20 cm)		
	Blockboard 5-ply	Blockboard 3-ply	Laminboard 5-ply
12		1.4	
16	1.7	2.0	1.3
18	0.9	3.4	2.0
22	0.9	2.4	2.1
25	1.5	2.6	2.9

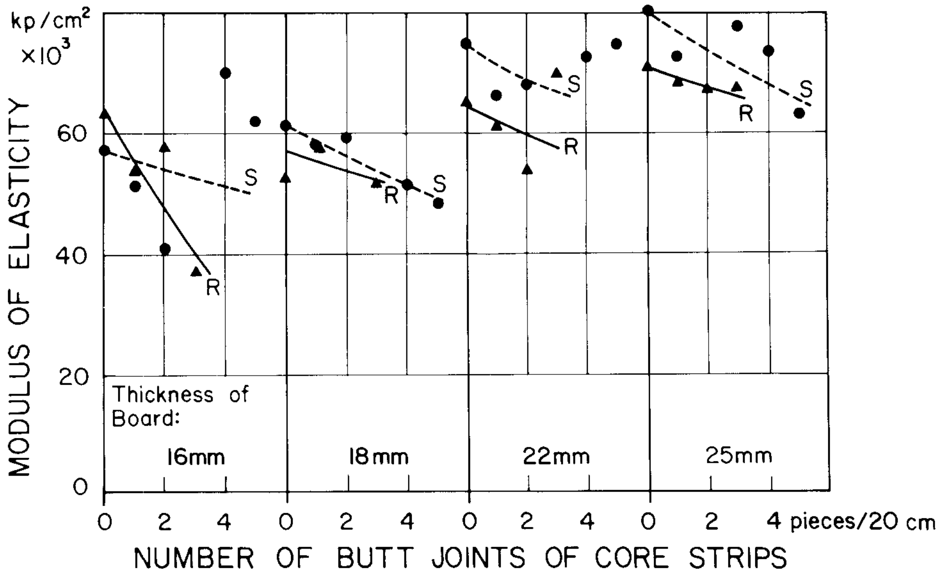

FIG. 3. Effect of the number of butt joints in the core on the modulus of elasticity parallel with the strips of five-ply blockboard (R) and laminboard (S) of normal structure (State Institute for Technical Research 1967).

gluing only is equal in strength to panels in which core pieces are edgeglued as well; 3) width of core strips does not influence flexural strength (in the range ¾–2-inch core strip width); 4) dimensional stability of panels with changes in moisture content is comparable to other accepted panel products; 5) edgegluing of core strips and core strip width both affect dimensional stability; 6) flexure values are significantly reduced after accelerated aging. The relatively poor performance of blockboard after accelerated aging provides emphasis to reports of Finnish investigators which state that blockboard is essentially an interior product (Lee 1966).

A report published by the Finnish State Institute for Technical Research (1967) addresses the subject of blockboard strength properties. Reported are results of tests conducted on three- and five-ply blockboard and laminboard (Fig. 1), made with pine core and birch face veneers. Of particular interest are data relating

TABLE 2. *Comparative prices of Finnish plywood and blockboard.*[a]

Plywood		Blockboard	
Thickness (mm)	Price ($/100 ft.²)	Thickness (mm)	Price ($/100 ft.²)
12	52.19	12	61.44
15	64.67	16	68.92
18	77.15	18	71.95
21	86.24	22	84.32
24	98.29	25	93.74

[a] Listed are June 1978 prices for the U.K. (expressed in U.S. $, calculated based upon 29 June 1978 exchange rate) as reported in correspondence from the Finnish Plywood Development Association.

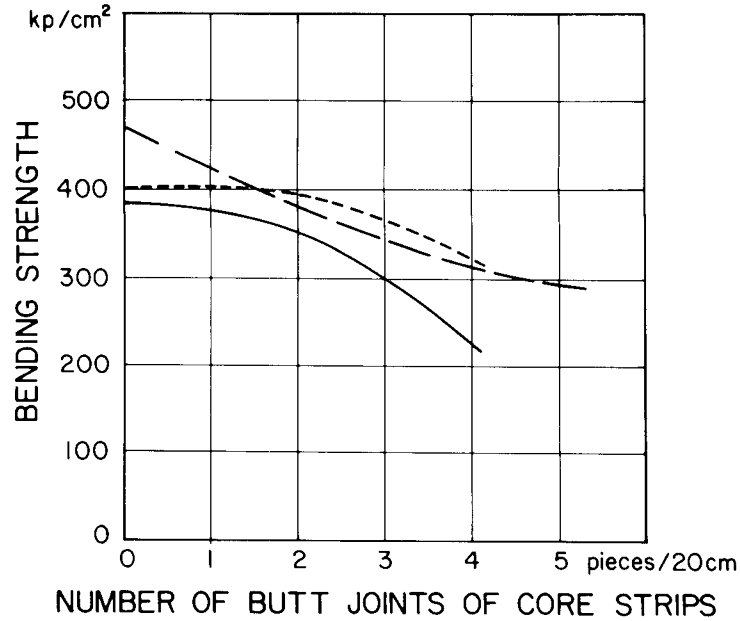

FIG. 4. Effect of the number of butt joints in the core on bending strength parallel with the strips of three- and five-ply blockboard (R) and laminboard (S) of normal structure as means of different thicknesses (State Institute for Technical Research 1967).

strength of blockboard to the occurrence of butt joints in the lumber core. Such joints were shown to significantly affect both MOE and MOR (bending strength) of small test specimens when stressed in bending parallel to core strips; the degree of strength loss was directly related to the number of butt joints per unit of length (Figs. 2, 3, and 4). Strength reductions as great as 55% were noted in 20-cm (8-inch)-wide samples having as many as 4 joints per 20 cm of length. Though Figs. 2 and 3 give data for tests of five-ply only, similar results can be expected for three-ply panels. A summary of tests of three-and five-ply panels of various thicknesses is presented in Fig. 4; panel configuration is outlined in Table 1.

Production economics

Manufacturing costs were projected for softwood blockboard in the phase one study referred to previously. It was estimated that ¾-inch panels could be produced at a cost only slightly higher than ¾-inch Douglas-fir plywood underlayment, with this projection based upon the assumption that softwood core lumber and face veneer would be purchased rather than produced as part of the manufacturing operation. A 40% before tax return on invested capital was used in

TABLE 3. *Configuration of blockboard panels manufactured.*

Panel configuration	Number of panels
Core strips 1½-inch wide, 24-inch long	12
Core strips 1½-inch wide, random length (2–24-inch long)	6
Core strips 3-inch wide, 24-inch long	6

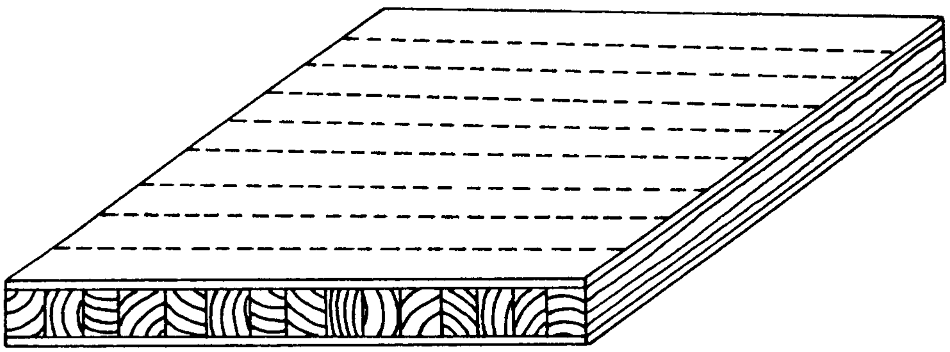

FIG. 5. Method of cutting faceglued blockboard panels into perpendicular-to-core bending samples.

estimating cost of manufacture. The projected small difference between blockboard and plywood prices is supported by European data, which show blockboard to be slightly cheaper than plywood at 18-mm and greater thicknesses (Table 2).

EVALUATION OF PHYSICAL PROPERTIES

Initial calculation of EI values for aspen/elm panels led to the conclusion that it would be necessary to manufacture the hardwood product to greater thicknesses than commercial softwood panels with which blockboard might compete if comparable stiffnesses were to be obtained. Thus, 1-inch-thick blockboard panels were manufactured in this study, and test results were compared to properties of ¾-inch Douglas-fir plywood.

Procedure

Board manufacture. Twenty-four 24- × 24- × 1-inch panels were manufactured with 0.1-inch-thick elm face veneers and 0.8-inch thick aspen core strips. Panels were made with 1½-inch width core strips, 3-inch width core strips, "ran-

TABLE 4. *Strength properties of blockboard and plywood as determined by static bending tests of narrow test strips.*

Product designation	Product description	Direction of loading in relation to face grain orientation	EI[1,2]	Load at failure (Pounds)[2]
A	¾-inch Douglas-fir plywood	perpendicular	57	330
B	¾-inch Douglas-fir plywood	parallel	57	274
C	1-inch elm/aspen blockboard (1½-inch width core strips)	perpendicular	161	571
D	1-inch elm/aspen blockboard (1½-inch width core strips)	parallel	95	323
E	1-inch elm/aspen blockboard (3-inch width core strips)	perpendicular	171	594
F	1-inch elm/aspen blockboard (3-inch width core strips)	parallel	109	339

[1] The moment of inertia, I, is calculated based upon full panel thickness, and EI is expressed in lb. in.² units.
[2] Each value is an average of eighteen tests.

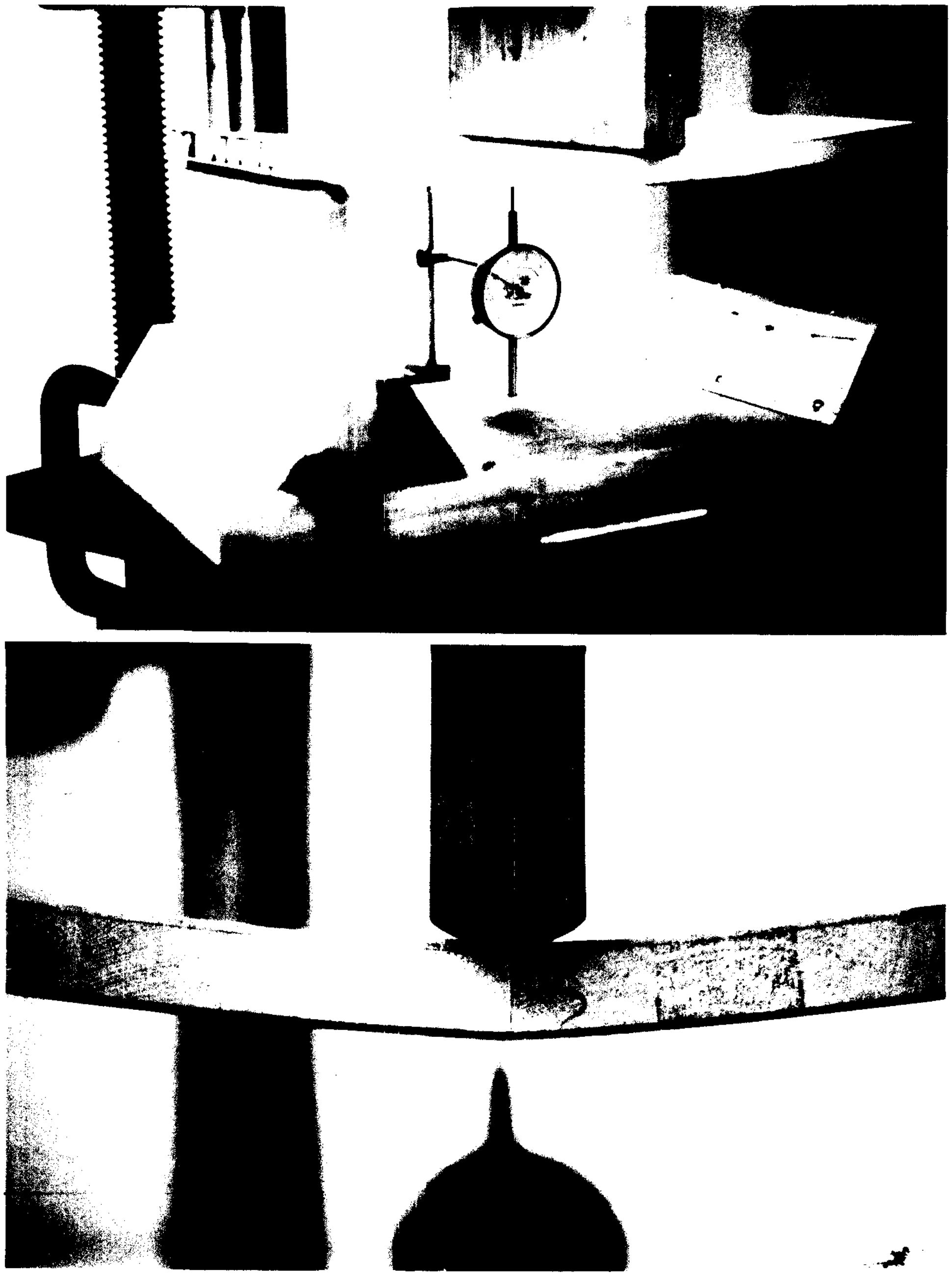

FIG. 6. (A) (B) Set-up for testing of one-half sized panels.

dom length" butt jointed core strips, and with core strips extending full panel width (Table 3). Gluelines were made only at the core/face-veneer interface, and a thermo-setting phenolic exterior plywood resin was used.

Aspen core strips were cut from 4/4 rough, dry, 25% No. 2A and better aspen

TABLE 5. *Statistical design employed in data evaluation.*

Treatment (i)	Panel (j)	Observations (k)
	1	1 2 3 4 5 6
Core strips	2	1 2 3 4 5 6
1½-inch wide	3	1 2 3 4 5 6
	1	1 2 3 4 5 6
Core strips	2	1 2 3 4 5 6
3-inch wide	3	1 2 3 4 5 6

lumber that had been equilibrated to 5% moisture content and surfaced to 0.8-inch thickness. (In commercial production of blockboard in Europe, lumber used for core strips is commonly not surfaced. Precision ripping determines thickness of strips that are thus as wide as the thickness of lumber from which they were produced.) Planed lumber was then ripped to 1½-inch and 3-inch width strips before crosscutting to remove serious defects. The primary defect eliminated was knots; knots were cut from strips when they extended one-half or more of the way across the strip width or when they were loose or unsound.

The precise length and placement of all core pieces were recorded during assembly of those panels made with random length core strips. All panels were laid-up inside of frames, which insured that core strips were kept pressed together edgewise during hot pressing.

In addition to the blockboard manufactured, two 4- × 8-ft sheets of ¾-inch, 5-ply, A-C, sanded, exterior Douglas-fir plywood were cut into 24- × 24-inch panels. Twelve of these 2-ft square panels were selected for subsequent testing.

Test sample preparation. Three of the blockboard panels made with 1½-inch wide and full length core strips, and three panels made with 3-inch width core strips were cut perpendicular-to-the-grain direction in the core into 2¼-inch-wide pieces (Fig. 5); three more of each type of board were similarly cut parallel-to-the-core grain direction. Other blockboard panels were simply cut into two pieces of equal size, half of them cut parallel-to-the-grain direction of core strips and half perpendicular-to-the-core grain orientation. Plywood panels were prepared in a like manner.

After a portion of the blockboard and plywood panels had each been divided into nine 2¼-inch width pieces, these pieces were randomly separated into two piles of six and three samples each. The largest of these piles was marked for testing in static bending after equilibration, with the smaller marked for testing to determine linear expansion properties. All samples were equilibrated at 68 F and 65% R.H. prior to testing.

Testing. Static bending of 2¼-inch-width pieces was conducted in accordance with ASTM Standard D-3043-76, except that the span/depth ratio was 22:1. ASTM Standard D-1037-72, sections 107-110, was followed in evaluating linear expansion with moisture content change.

Half size (12-inch × 24-inch) panels were supported along their two 12-inch edges, then subjected to an increasing load applied to the center of the span; the loading block was designed such that the load was applied across the full unsupported width (Fig. 6). In these tests a span of 22 inches was maintained; the span/

TABLE 6. *Strength properties of blockboard and plywood as determined by static bending tests of 12- × 24-inch panels.*

Designation		Direction of loading in relation to face grain orientation	EI[1,2]	Load at failure (pounds)[2]
A	¾-inch Douglas-fir plywood	perpendicular	372	1,199
B	¾-inch Douglas-fir plywood	parallel	386	1,111
C	1-inch elm/aspen blockboard (full length core strips)[3]	perpendicular	975	2,987
D	1-inch elm/aspen blockboard (full length core strips)[3]	parallel	544	1,626
G	1-inch elm/aspen blockboard (random length core strips)[3]	perpendicular	731	1,618
H	1-inch elm/aspen blockboard (random length core strips)[3]	parallel	590	1,630

[1] The moment of inertia, I, is calculated based upon full panel thickness and EI is expressed in lb in² units.
[2] Each value is an average of six tests.
[3] All panels were made with 1½-inch-wide core strips.

depth ratio was therefore 22:1 for blockboard and 29:1 for plywood. Equilibration prior to testing was again at 68 F, 65% R.H. The rate of loading and design of the test apparatus was as specified in ASTM D-3043-76.

RESULTS AND DISCUSSION

Results of physical testing of static bending strips are shown in Table 4. A favorable comparison of aspen-elm blockboard to ¾-inch Douglas-fir plywood is shown. An increase in the face veneer/core thickness ratio for blockboard would have resulted in more equal strength properties in the parallel- and perpendicular-to-core directions. Statistical analysis to determine effect of core strip width upon strength parallel-to-the-face-veneer grain direction indicated no significant difference between 1½-inch and 3-inch core strip widths (i.e. between products designed "D" and "F"). This result is consistent with earlier findings relating strength parallel-to-the-face grain to core strip width (Bowyer 1979). An analysis of variance based upon a one-way nested classification (Snedecor and Cochran 1967) was employed in data evaluation (Table 5).

Panel tests showed the same general relationship between plywood and blockboard as determined in the strip tests (Table 6), though the magnitude of difference was slightly less (likely due to the higher span/depth ratio employed in testing the plywood). Of primary interest in these test results is the effect of butt-jointed core strips on strength perpendicular-to-the-face grain. Comparison of products designated "C" and "G" shows a 25% reduction in stiffness and a 46% reduction in breaking strength (as compared to panels having no joints in the area spanned) due to inclusion of the random-length core. Note, however, that strength values of the random length product are still far above those recorded for ¾-inch plywood.

The placement of core joints was examined to obtain an indication of the effect of the number of joints per unit length (Fig. 7). The majority of strength loss is shown to have occurred as a result of the first few joints appearing in the span; strength loss continued thereafter as the number of joints increased, but the rate

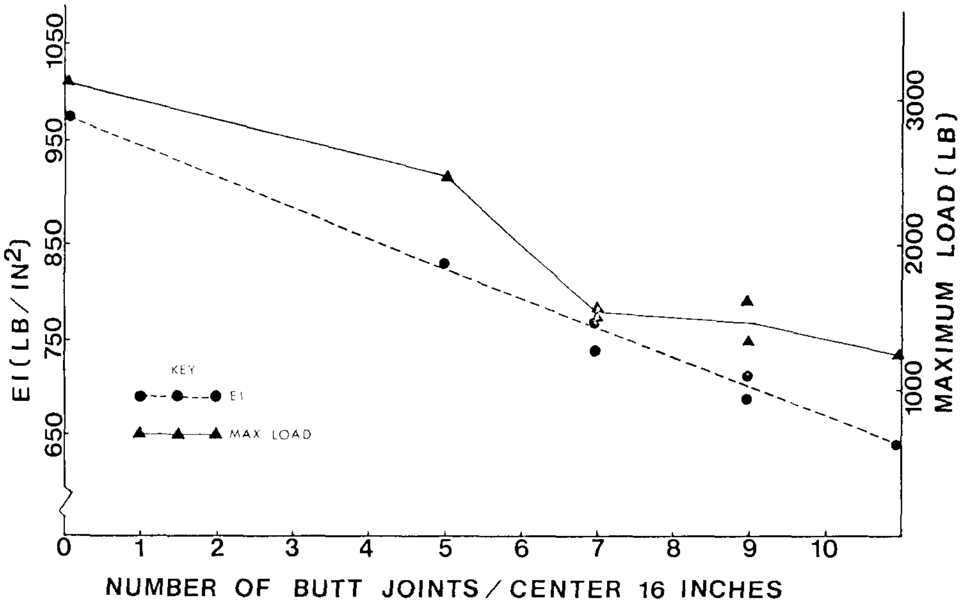

FIG. 7. Effect of butt joints in core on strength of faceglued blockboard.

of loss decreased. Occurrence of as many as 5 joints over a 16-inch span and a 12-inch panel width resulted in reduction of only about 14% for both stiffness and maximum load carrying capability compared to specimens having full-length core pieces. An increase to 7–8 points per 16-inch span brought EI and maximum load capacity down from original values 24% and 38%, respectively. These results are similar to those obtained in tests of five-ply Finnish blockboard that were reviewed earlier (Figs. 2 and 3). In those tests, the presence in a 25-mm panel of two joints over a 20-cm span and 20-cm width reduced stiffness 6% and bending strength 15%. The occurrence of three joints over the same span and width reduced stiffness and bending strength 7% and 25%, respectively.

If it is assumed that strength in various width panels is affected by core joints in the same way as long as the number of joints per unit width remains constant,

TABLE 7. *Probabilities of butt-joint occurrence in blockboard core for various length core strips.*

Number of butt-joints per 16-inch span over a 12-inch width	Probability of this number or less joints occurring		
	16-inch core strips	20-inch core strips	24-inch core strips
0	0.000	0.000	0.001
1	0.000	0.001	0.011
2	0.000	0.011	0.061
3	0.000	0.058	0.201
4	0.001	0.194	0.445
5	0.011	0.448	0.718
6	0.085	0.745	0.910
7	0.403	0.942	0.987
8	1.000	1.000	1.000

TABLE 8. *Linear expansion[1] of aspen/elm blockboard vs. commercially manufactured softwood plywood.*

Designation	Product description	Direction of expansion in relation to face grain orientation	Expansion as a percent of original length[2,3]
A	Douglas-fir plywood	perpendicular	0.031
B	Douglas-fir plywood	parallel	0.071
C	elm/aspen blockboard (1½-inch width core strips)	perpendicular	0.076
D	elm/aspen blockboard (1½-inch width core strips)	parallel	0.087
E	elm/aspen blockboard (3-inch width core strips)	perpendicular	0.094
F	elm/aspen blockboard (3-inch width core strips)	parallel	0.076
–	aspen waferboard (1½-inch wafers—all xylem)	–	0.13[4]
–	aspen flakeboard (½-inch flakes—all xylem)	–	0.08[4]

[1] From 50% to 90% relative humidity.
[2] Values are expressed as a percent of the dimension at 72°F, 50% R.H.
[3] Each value is an average of three samples from each of three boards.
[4] From Gertjejansen and Haygreen (1973).

a calculation of joint occurrence within a given span can be made. These data are needed when evaluating the probable yield of useable core material from a given quality of lumber. Table 7 details probability of joint occurrence within a 16-inch span and 12-inch width, when using 1½-inch wide and constant length core strips. Under these conditions, for example, core pieces of 24-inch length would be needed to give a 70% probability of five joints or less in any given 16-inch span. If a high probability of eight butt joints per unit area were deemed acceptable (which would still yield 1-inch panels stronger than ¾-inch Douglas-fir plywood), then core pieces as short as 16 inches could be used. Comparable data for random length pieces could be generated, given a distribution of various length core strips to be used.

Dimensional stability tests (Table 8) indicated that aspen/elm blockboard is quite stable dimensionally, performing similarly to commercially manufactured plywood and flake-type particleboard. Results are comparable to earlier tests of Douglas-fir/ponderosa pine blockboard (Bowyer 1979).

PHYSICAL PROPERTIES SUMMARIZED

Faceglued blockboard can be manufactured from low-strength hardwoods such that strength and stability properties are comparable to commercially manufactured plywood of slightly lesser thickness. Even when short-length pieces are included in the blockboard core, 1-inch blockboard panels compare favorably to ¾-inch softwood plywood. From this study, it appears likely that low-density hardwood blockboard could meet or exceed ¾-inch Douglas-fir strength properties if manufactured to a thickness of about 0.9-inch. Aspen/elm panels of 0.9-inch thickness would weigh approximately 9.5 pounds (or 13%) more per 4 × 8 sheet at 15% moisture content than ¾-inch Douglas-fir plywood.

The matter of panel strength vs. inclusion of short core pieces should be further

TABLE 9. *Projected costs of 0.9-inch blockboard panels vs. ¾-inch western softwood plywood.*

	Price/M ft²	
	⁹⁄₁₀-inch blockboard	¾-inch D-fir plywood
Core stock—972 BF @ \$170/MBF[1]	\$165	
Face veneer—2.42 M ft.² @ \$20/M ft.²[2]	48	
Veneer shipment from West Coast	20	
Production cost[2]	149	
Profit—40% before tax[2,3]	46	
Selling price—at mill[5]	\$428	\$345[4]
Shipping cost—mill to Mpls.-St. Paul[6]	12	63
Delivered price—Mpls.-St. Paul	\$440	408

[1] 700 BF of 4/4 rough, dry aspen needed per 1 M ft.² of panel; 72% yield is used in obtaining 972 BF figure.
[2] From earlier study of blockboard feasibility.
[3] Figure increases or decreases approximately \$11 for each 10% fluctuation in pre-tax profit.
[4] 23 March 1979 price for ¾-inch D-fir as reported in *Random Lengths*.
[5] Mill sites assumed to be Portland, Oregon, and Virginia, Minnesota.
[6] Shipment assumed via rail from West Coast, via truck from northern Minnesota.

investigated since this factor would undoubtedly significantly influence the economics of production. Work is needed to establish relationships between butt-joint occurrence and strength for various core strip and panel widths and lengths of span.

ECONOMIC POTENTIAL

Production costs for blockboard were projected using the basic assumptions that (1) core lumber and face veneer would be purchased at prevailing market prices and that (2) the before-tax return on invested capital would be 40%. Using these guidelines, analysis of manufacturing costs for 0.9-inch three-ply blockboard made with 0.1-inch faces indicates that blockboard sold as sheathing would cost about 8% more than ¾-inch Douglas-fir plywood delivered to the Minneapolis/St. Paul area (Table 9). Since quotations for sheathing grade hardwood veneer (comparable to C and D grade softwood) are difficult to obtain, the veneer price used in this analysis is based upon the current (23 March 1979) price for random width fir veneer delivered to a northern Minnesota manufacturing site.

The price of blockboard relative to plywood would obviously be improved if raw materials could be purchased for less than amounts indicated in Table 8. If raw material prices could be reduced \$32 per M ft.² to \$201 total (for core lumber *and* face veneer), the delivered price for blockboard and plywood would be roughly the same in the Upper Midwest. Such prices may be obtainable even in today's market in view of the fact that short-length core pieces may be used in blockboard manufacture.

It appears that manufacture of hardwood blockboard as a competitor in the sheathing market would currently be a marginal operation at best. However, should the prices of peeler logs and resin continue to rise faster than the price of low-grade and low-density lumber (as they probably will), then blockboard would become an economically attractive alternative in this highly competitive market.

As economics relative to plywood appear to improve with increased product thickness, the greatest potential for blockboard in the U.S. may be in specialty markets for high-strength products. Industrial shelving and a combination subfloor, underlayment product (for which blockboard is now employed occasionally in Scandinavia) are examples of specialty products that require high strength.

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