FACEGLUED BLOCKBOARD—AN ALTERNATIVE TO PLYWOOD?[1]

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ABSTRACT

Faceglued blockboard, a European product similar to lumber core plywood (but with no edge gluing of core strips), was evaluated from both technical and economic perspectives as a general purpose structural panel. Blockboard was found to have strength and dimensional properties comparable to other wood-based structural sheet materials, though performance after accelerated aging suggests limits to exterior applications. Economic projections indicate little difference in costs of production between softwood plywood and blockboard.

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

INTRODUCTION

Lumber core plywood has long been manufactured in North America for use in production of furniture and cabinets. Today at least 160 mills in the United States and Canada manufacture this panel product; almost all of it is used for interior, decorative applications. Known in the international market as blockboard,[2] lumber core plywood is also manufactured in some 65 mills throughout the rest of the world (World Directory 1977). While most of these mills produce a decorative, interior product, several have recently begun production of structural blockboard panels. A publication of the Finnish Plywood Development Association lists applications for blockboard such as industrial shelving, benching and worktops, storage units, packing cases, doors and partitions, and specialty products (FPDA 1969).

It is interesting to note that though used in Europe for many of the same purposes as construction grade plywood, 18-mm and thicker blockboard sells for a somewhat lower price (Table 1). Moreover, the lumber core of this product is made up from narrow and relatively short length pieces, meaning that small and low-grade logs can be used as a raw material for the core. As the U.S. has a shortage of large, good quality timber and an abundance of small, low-grade roundwood, in addition to a continuing need for structural panel products, the prospect for a product such as blockboard appears promising.

In this study blockboard was evaluated both economically and technically to

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[2] Blockboard is a sandwich construction consisting of one or more veneers bonded to each side of a core of solid wood strips. In a three-ply panel, the grain direction of the face veneer is perpendicular-to-the-grain direction in the core. A five-ply panel is often made with the grain direction of all veneers at right angles to the grain direction of core strips. Boards are also manufactured, however, with perpendicular grain direction in adjacent veneers; grain of face plies may be either parallel or perpendicular to that in the core. Core strips may or may not be edge-glued.

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TABLE 1. *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 on the basis of the 29 June 1978 exchange rate) as reported in correspondence from the Finnish Plywood Development Association.

assess the potential for this product in U.S. markets. Specific questions addressed were:

1) What is the economic prospect for utility purpose blockboard manufactured from domestic species?
2) How do blockboard properties compare to those of panel products presently accepted in the U.S.?
3) How do manufacturing variables, such as width of core strips or the gluing system used, affect blockboard properties?

PREVIOUS INVESTIGATIONS

Use of short, narrow pieces of wood to manufacture larger structural products is not a new idea. The second FPRS Proceedings published in 1948 contains a report by Colucci dealing with utilization of waste slabs for plywood core stock. Colucci estimated that an average cord of slabs would yield 141 ft^2 of finished cores ranging from ⅝ inch to $1^1/_{16}$ inch in thickness.

Bethel and Woodrum in 1955 investigated methods of patching wood strip cores to permit use of No. 3 Common and Cull grade lumber in manufacture of core stock. They concluded that it was possible to patch the core of crossbanded and subsequently finished panels without occurrence of show through. Connelly in 1975 (Connelly 1975) reported improved rough-end yields as a result of removal and patching of core defects. In 1959 Hyler addressed the subject of "lumber core veneered stock" (Hyler 1959), discussing problems experienced in manufacture. In an obvious reference to production of high-quality appearance grade panels, Hyler cautioned against mixing species or even flat and plain sawn stock in the same panel core as such practice could result in differential thickness swelling and telegraphing with moisture content change. Also in 1959, Loetscher patented a method of manufacturing solid core flush doors; the use of nonedge glued core pieces was an integral part of the design (Loetscher 1959). Guiher observed the effects of moisture-induced stress in sections of lumber core panels. In a 1965 article (Guiher 1965), he presented regression equations that allow prediction of stress levels in panels where current moisture content, and moisture content at time of manufacture are known. In 1966 a patent was awarded to Bryant (Bryant 1966) for the concept of a thick structural lumber core panel faced with veneer or hardboard; the patented design incorporates core strips that are concave on both edges, creating void areas between strips to enhance dimensional stability.

TABLE 2. *Permissible bending stress and elastic modulus for Finnish blockboard*[a] *(Lee 1966).*

No. of plies	Thickness (mm)	Parallel to face grain: Bending stress (lb/in²)	Parallel to face grain: Modulus of elasticity (10^6lb/in²)	Parallel to core strips: Bending stress (lb/in²)	Parallel to core strips: Modulus of elasticity (10^6lb/in²)
5	under 20	1,700	1.55	1,000	0.65
	over 20	1,150	1.15	1,000	0.78
3	under 20	1,550	1.40	1,250	0.71
	over 20	1,150	1.00	1,000	0.92

[a] Finnish blockboard is normally made using birch face veneers and European Red Pine cores.

Strength properties of 12–25-mm-thick birch/pine blockboard have been established through tests carried out at the State Institute for Technical Research at Helsinki, Finland. Strength figures for Finnish blockboard are impressive (Table 2), especially in view of the fact that full panel thickness is used in computations. Lee, of the Finnish State Institute for Technical Research, reported after reviewing test data that "blockboard gives a better balance between strength and rigidity for many uses (*than plywood*), particularly where it must resist bending as in floors and shelving." He also indicated that blockboard, unlike many sheet materials, "has very little tendency to take a permanent 'set' or deformation when continuously loaded" (Lee 1966).

ECONOMIC ASSESSMENT

The process

A preliminary look at the economic potential for blockboard produced in the U.S. was based upon blockboard production equipment available from a Finnish

TABLE 3. *Projected capital requirements for a manufacturing facility (Based on 1978 $U.S.).*

	MM ft.² (⅜-basis) stripboard	
Depreciable		
Building (20,280 ft² @ $12/ft²)	$ 243,000	
Equipment (F.O.B. Finland)	1,700,000*	
Utilities, Fire Protection Equipment, Air Piping	200,000	
Installation and Shipping	425,000	
Transport Equipment	70,000	
Office (2,000 ft² @ $25/ft²)	50,000	
	$2,688,000	
Nondepreciable		
Land (20 acres @ $3,000/ac.)	$ 60,000	
Grading, Excavation, Paving	48,000	
Working Capital (1 month product value)	360,000	
	$ 468,000	
	Total Investment	$3,156,000

* Price about $600,000–700,000 higher if veneer peeling and drying lines are incorporated into the mill.

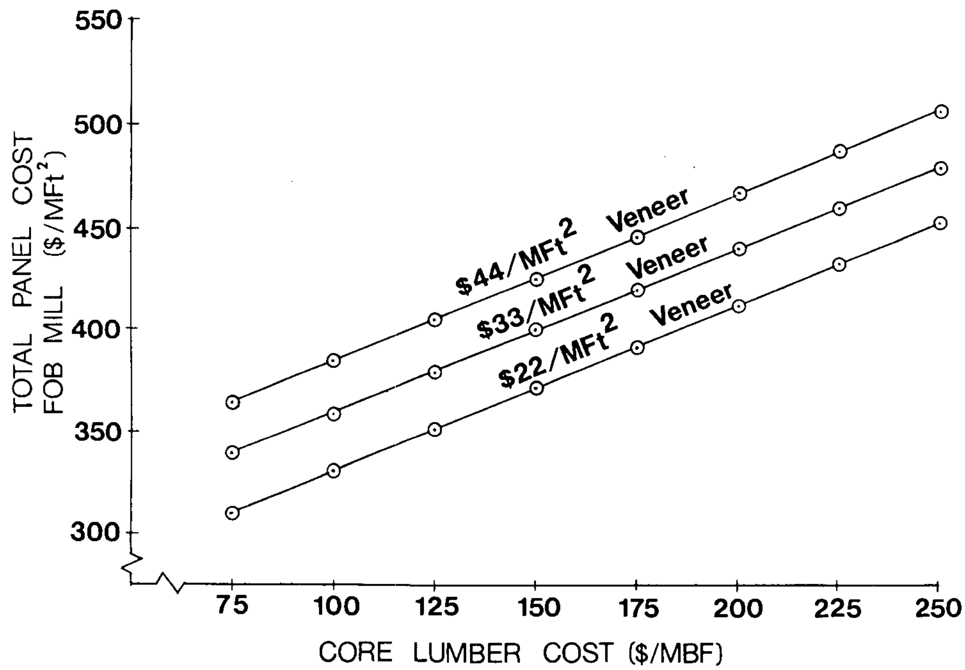

FIG. 1. Cost of producing ¾-inch blockboard as a function of core lumber and face veneer cost assuming 40% before tax return on investment.

manufacturer. For purposes of this analysis, it was assumed that only ¾-inch (19-mm) general purpose board would be produced. The process, which uses as input 4/4 rough, dry (8–9% MC) lumber and ¹/₁₀-inch (2.5-mm) veneer, involves cross-cutting lumber to a predetermined length of from 1.33 to 4.33 ft (400–1,300 mm) to remove serious defects, followed by ripping of pieces to strips ⁹/₁₆ inches (14 mm) wide; the ripping operation determines core thickness. Strips are then conveyed to a core composing device that employs lateral pressure to produce a tight core package. The core produced is of continuous length and is bound with twine prior to leaving the composer so that it remains tightly packed. Glue is next spread on both sides of the core, after which face veneers are added to the assembly. A tack press is followed by a mobile high speed hot press, edge trimmer, and stacker.

Investment requirements for a 50 MM ft²/annum plant (⅜-inch basis) are detailed in Table 3. Note the low capital costs as compared to a construction plywood operation that typically requires an $11–13 million investment.

Projected costs of production

Figures presented in Table 4 are projected production costs per 1 M ft² of unsanded ¾-inch panels, excluding cost of wood and allowance for profit. All calculations assume 3 shift/day, 325 day/yr operation. Operation as part of an existing firm is also assumed, and therefore no salary for a chief executive officer is included. Resin costs are low compared to either plywood or particleboard because of the need for only one double glue line.

TABLE 4. *Projected blockboard production costs.*

Item	Annual cost	Cost/M ft² (Based on 24.38 MM ft²/yr)
Adhesive 70#/M ft²DGL, liquid phenolic resin @ 8¢/#		5.60
Nylon String (for temporary binding of strip core) 8 oz. @ 5¢/oz		.40
Energy		
·Electrical—45–50 KWH/M ft² @ 3.5¢/KWH		1.60
·Thermal—300 million calories/M ft²		.80
Direct Labor—25 persons/shift or 195,000 man h/yr @ $6.65/h	$1,296,750	53.18
Administration and Overhead		
·Indirect Labor		
–Supervision		
1 Plant Manager	40,000	1.64
3 Shift Managers @ $26,000	78,000	3.19
2 Quality Control Tech/shift @ $8/h	124,800	5.11
–Shipping Janitorial, Maintenance		
4 Shipping Laborers/Shift @ $6.65/h	207,480	8.51
3 Maintenance Men/Shift @ $8/h	187,200	7.67
2 Janitorial/Shift @ $5.50/h	85,800	3.51
–Clerical		
3 Office Clerks @ $5.50/h	42,900	1.75
–Sales		
2 Sales People @ $20,000	40,000	1.64
·Occupancy Cost		
Heat, Light & Power	60,000	2.46
Insurance—1.25% of Bldg. Cost/yr		
Property Taxes	29,798	1.22
Maintenance—5.0% of Bldg. Cost/yr	14,650	.60
·Machinery and Equipment Cost		
Insurance—1.25% of value/yr	29,938	1.22
Repair and Maintenance—2.0% of Equip. Cost/shift/yr	106,200	4.35
·Other Expenses		
Telephone	15,000	.61
General Supplies	40,000	1.64
Miscellaneous	40,000	1.64
Selling and Advertising 0.75% of projected revenue	64,912	2.66
Interest on Working Capital, Land	42,000	1.72
Payroll additions (worker's compensation, social security, excise tax, and fringe benefits—30% of payroll)	630,879	25.87
·Depreciation		
Building (20 yr life to 0 salvage)	14,650	.60
Machinery (10 yr life to 10% salvage)	239,500	9.82
TOTAL Cost/M ft² (Excluding Wood Raw Material)		$149.01

In Fig. 1 the effect upon production cost/unit of log and veneer cost and requirements for return on investment are shown. Note that if lumber costs $175/MBF and if face veneer costs $33/M ft^2, the cost for blockboard (f.o.b. mill) is $419/M ft^2.[3] Though blockboard panels might compete in a variety of markets, comparison of blockboard production costs with current market prices of plywood sheathing and underlayment provides an indication of blockboard's economic potential. The $419 figure cited previously is very close to the July 1978 price for ¾-inch Douglas-fir plywood underlayment and about 16% higher than the price of CD-X sheathing. Also note in the previous example that if the lumber price increases 30% to $225/MBF, the cost/M ft^2 for blockboard increases to $462; wood cost, particularly for the lumber core, is critical. The finished product price changes approximately ±$11/M ft^2 (¾ inch) for each 10% change in the before tax return on investment.

Looking to the future, it seems likely that the price of low-grade logs (from which blockboard core lumber can be manufactured) will increase at a slower rate than the price of high-quality veneer logs. If this is the case then the economics of blockboard production relative to plywood will become increasingly favorable. Moreover, should it be technically possible to manufacture an acceptable blockboard product from abundant low-grade (and generally low value) hardwoods that are close to northern and northeastern markets,[4] the economic potential for U.S. blockboard manufacture might become instantly attractive.

EVALUATION OF PHYSICAL PROPERTIES

It is almost impossible to discuss the economic potential for a product without carefully defining the market within which it will compete. Similarly, definition of market potential is difficult if product properties are not known. An important part of this evaluation of blockboard was, therefore, to determine basic physical properties of this product.

Procedure

Board manufacture.—Thirty 20-inch × 20-inch blockboards were manufactured using 0.110-inch-thick dry Douglas-fir veneer and ponderosa pine lumber strips that had been dried and then surfaced to 0.530-inch thickness. Core strips were cut to widths of ¾-inch, 1 inch, 1½ inches, and 2 inches. Six three-ply boards were made using ¾-inch wide strips. The core strips of two of these were edge-glued along their full length, the core strips of another two were spot-glued each several inches along their length, and the core strips of two boards were not edge-glued. Likewise, six boards each were made of core strips of the remaining widths. Also manufactured were six boards having a "random" arrangement of various width strips in the core. A cold setting melamine resin was used for all edge-gluing while a thermo-setting, exterior phenolic resin was used for core/veneer bonds.

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[3] Assumed in calculating this figure is 0.82 MBF of core lumber, 2,420 ft^2 of veneer, and a 40% before tax return on invested capital.

[4] Assuming rail transportation from the West Coast and motor freight from northern Minnesota, the August 1978 shipping cost differential between plywood and blockboard shipment to Minneapolis/St. Paul favors blockboard by $22/M f^2 (¾ inch).

TABLE 5. *Flexural properties of blockboard tested perpendicular to the grain direction in the core for five core types and three gluing systems, with boards either equilibrated, watersoaked, or subjected to accelerated aging prior to test.*

Core strip width = A	Pre-test treatment = C	Gluing system = B: Core face—veneer glueline only	Core strips edge-glued full length	Core strips edge-glued spot gluing
		Values are MOE and (MOR)[1]		
¾ inch	Equilibration at 72 F, 50% R.H.	852[2] (5,780)[3]	776 (5,020)	874 (5,570)
	Water soak	574 (2,680)	564 (2,620)	622 (3,060)
	Accelerated aging & re-equilibration	647 (3,220)	651 (3,400)	711 (3,800)
1 inch	Equilibration at 72 F, 50% R.H.	822 (5,060)	805 (5,250)	873 (5,570)
	Water soak	571 (2,540)	536 (2,590)	648 (2,620)
	Accelerated aging & re-equilibration	625 (3,410)	683 (3,580)	747 (3,580)
1½ inch	Equilibration at 72 F, 50% R.H.	920 (6,290)	723 (4,990)	800 (5,040)
	Water soak	608 (2,730)	537 (2,730)	524 (2,320)
	Accelerated aging & re-equilibration	763 (3,140)	598 (3,310)	719 (3,950)
2 inch	Equilibration at 72 F, 50% R.H.	1,099 (6,600)	868 (4,980)	764 (5,230)
	Water soak	690 (2,810)	553 (2,740)	532 (2,570)
	Accelerated aging & re-equilibration	887 (4,050)	708 (4,220)	641 (3,740)
Random width ¾ inch–2 inch	Equilibration at 72 F, 50% R.H.	890 (5,390)	930 (5,800)	802 (5,220)
	Water soak	670 (2,860)	619 (3,100)	600 (2,690)
	Accelerated aging & re-equilibration	699 (3,580)	745 (3,940)	697 (3,620)

[1] Both MOE and MOR calculated based upon full panel thickness. Each value is an average of two samples from each of two boards.
[2] 1000 psi.
[3] psi.

Testing.—Samples from each board were tested by the following tests: (1) static bending, (2) static bending after submersion in water (samples tested wet), (3) static bending after accelerated aging, and (4) linear expansion with moisture content change. Static bending tests of the center point loading type were con-

TABLE 6. *MOE and (MOR) of commercial Douglas-fir plywood and laboratory manufactured blockboard.*

Product	MOE and (MOR)[1] Parallel-to-grain of face plies	Perpendicular-to-grain of face plies
¾ inch Douglas-fir plywood (5 Ply)[2]	720[3] (5,370)	720[3] (6,450)
¾ inch Douglas-fir/Ponderosa pine blockboard (3 Ply)	853[4] (5,450)	698[5] (6,710)

[1] Both MOE and MOR calculated based upon full panel thickness. MOE expressed in 1000 psi units, MOE in psi.
[2] Values obtained from tests of strips from A–C, exterior panels.
[3] Averages of test values for 9 samples representing 2 separate sheets of plywood.
[4] Averages of test values for 60 samples representing 30 laboratory manufactured panels.
[5] Averages of test values for 12 samples representing 6 laboratory manufactured panels.

ducted in accordance with ASTM Standard D-3043-'76 except that the span/depth ratio for all tests was 24:1. Water soak cycles, accelerated aging procedures, and methods of determining linear stability were as specified in ASTM Standard D-1037-72. A 50% rather than 65% relative humidity condition and 72 F were used for all base-point equilibration of samples.

RESULTS AND DISCUSSION

Results of physical testing are shown in Tables 5–9. Examination of Table 5 and the statistical analyses of ungrouped test data (Table 10) reveals that the gluing system employed has no significant effect upon board strength. Thus, blockboards made with gluelines only at the veneer/core interface are as strong as those manufactured with edge-to-edge gluing of core strips. The test data further show no significant effect of core strip width (in the ¾-inch–2-inch core strip width range) upon strength.

MOE and MOR figures for control boards (equilibrated at 72 F, 50% R.H.) presented in Table 5 have been averaged and shown in Table 6. Also shown in Table 6 are similar data for blockboard tested parallel-to-the-grain direction in the core, and Douglas-fir plywood tested both perpendicular- and parallel-to-the-grain

TABLE 7. *Flexural properties of blockboard bending specimens tested parallel-to-the grain direction in the core which have been either equilibrated, watersoaked, or subjected to accelerated aging prior to test.*

Core strip width	Pre-test treatment: Equilibration at 72 F, 50% R.H.	Water soak	Accelerated aging and re-equilibration
	Values are MOE and (MOR)[1]		
1 inch	699[2] (6,630)[3]	443 (3,860)	552 (5,030)
2 inch	697 (6,800)	525 (4,630)	563 (5,370)

[1] Both MOE and MOR calculated based upon full panel thickness. Each value is an average of three samples from each of two boards.
[2] 1000 psi.
[3] psi.

TABLE 8. *Ratios of MOE and (MOR) values after accelerated aging to original[1] MOE and MOR values.*

Core strip width	Gluing system			Total
	Core face—veneer glueline only	Core strips edge glued full length	Core strips glued—spot gluing	
¾ inch	.76[2] (.56)[2]	.84 (.68)	.81 (.68)	.80 (.64)
1 inch	.76 (.67)	.85 (.68)	.86 (.64)	.82 (.66)
1½ inch	.83 (.50)	.83 (.66)	.90 (.78)	.85 (.65)
2 inch	.81 (.61)	.82 (.85)	.84 (.71)	.82 (.72)
¾ inch–2 inch	.79 (.66)	.80 (.68)	.87 (.69)	.82 (.68)
Total	.74 (.60)	.83 (.71)	.86 (.70)	.82 (.67)

[1] Strength values of "equilibrated only" samples used as a denominator.
[2] Values based upon performance of two samples from each of two boards.

direction in the face plies. Though data represent tests of only a few samples, they do suggest that blockboard can be manufactured that approximates the strength properties of commercially manufactured plywood made of similar thickness and species.

The analysis detailed in Table 10 indicates that the pretest treatment (i.e. water soaking or accelerated aging and reconditioning) did have a significant effect upon strength. Though this result was expected, the extent to which accelerated aging affected strength (Table 8) was not. MOR values were particularly influenced by the aging cycles. While retention values of both MOE and MOR are lower than retention values reported for laboratory-manufactured flakeboard (Lehman 1974) these figures meet or exceed the 50% retention requirement for exterior rated particleboard as listed in commercial standard CS236 (USDC 1966).

TABLE 9. *Linear expansion[1] of blockboard tested perpendicular-to-the-grain direction in the core for five core types and three gluing systems.*

Core strip width	Gluing system		
	Core face-veneer glueline only	Core strips edge-glued full length	Core strips edge-glued-spot gluing
¾ inch	0.030[2,3]	0.092	0.055
1 inch	0.046	0.113	0.037
1½ inch	0.068	0.088	0.095
2 inch	0.072	0.061	0.068
Random width			
¾ inch–2 inch	0.075	0.071	0.090

[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 two samples from each of two boards.

TABLE 10. *Analysis of variance for MOE and MOR data (Table 5).*

Modulus of elasticity				Modulus of rupture			
Term[1]	DF	Sum of squares	Mean square	Term[1]	DF	Sum of squares	Mean square
A	4	1.08154E + 11	2.70384E + 10	A	4	2.38654E + 06	5.96634E + 05
B	2	1.50793E + 11	7.53967E + 10	B	2	5.47697E + 05	2.73848E + 05
C	2	2.09438E + 12	1.04719E + 12	C	2	2.33487E + 08	1.16743E + 08
AB	8	4.83469E + 11	6.04336E + 10	AB	8	6.06030E + 06	7.57537E + 05
AC	8	3.77200E + 10	4.71500E + 09	AC	8	1.51702E + 06	1.89627E + 05
BC	4	3.00601E + 10	7.51501E + 09	BC	4	4.56535E + 06	1.14134E + 06
ABC	16	6.97228E + 10	4.35767E + 09	ABC	16	6.09325E + 06	3.80828E + 05
ERROR-1	40	1.12053E + 12	2.80132E + 10	ERROR-1	40	2.34997E + 07	5.87493E + 05

F Tests[2]	F tests[2]
A-F(4, 40) = .9652	F(4, 40) = 1.016
B-F(2, 40) = 2.691	F(2, 40) = .4661
C-F(2, 40) = 37.38*	F(2, 40) = 198.7*
AB-F(8, 40) = 2.157	F(8, 40) = 1.289
AC-F(8, 40) = .1683	F(8, 40) = .3228
BC-F(4, 40) = .2683	F(4, 40) = 1.943
ABC-F(16, 40) = .1556	F(16, 40) = .6482

[1] A = Core Configuration
B = Gluing System
C = Pre-Test

[2] Values of F:

Numerator	Denominator	F(.05 conf. level)	F(.01 conf. level)
2	40	3.23	5.18
4	40	2.61	3.83
8	40	2.18	2.99
16	40	1.90	2.75

Statistical analysis of the raw data used in compiling Table 8 yielded a significant[5] difference in the percent MOE retained after aging between edge-glued and non-edge-glued boards, the former performing better in this regard.

Dimensional stability of blockboard (Table 9) is comparable to both plywood and flake-type particleboard. Linear expansion percentages noted for blockboard in this study averaged 0.071% perpendicular-to-the-grain direction in the core and 0.076% parallel to the core grain direction with relative humidity cycling from 50 to 90%.

Analysis of linear expansion data revealed that two factors significantly affect expansion with moisture cycling. These are: (1) width of core strips, and (2) whether core strips are or are not edge-glued. The result is shown graphically in Fig. 2. If it is assumed that small gaps between non-edge-glued core strips function in relieving moisture-induced stress, both the difference in the degree of expansion between edge-glued and non-edge-glued boards and the increasing expansion as core strip width increases are easily explained. More difficult to explain is the decrease in linear expansion noted for board with edge-glued core as core strip width increases; further investigation is needed to determine the causes of this phenomenon.

SUMMARY

Blockboard has strength and dimensional properties comparable to other structurally utilized sheet materials. It appears to have promise as a substitute for

[5] Significant at the .05 level.

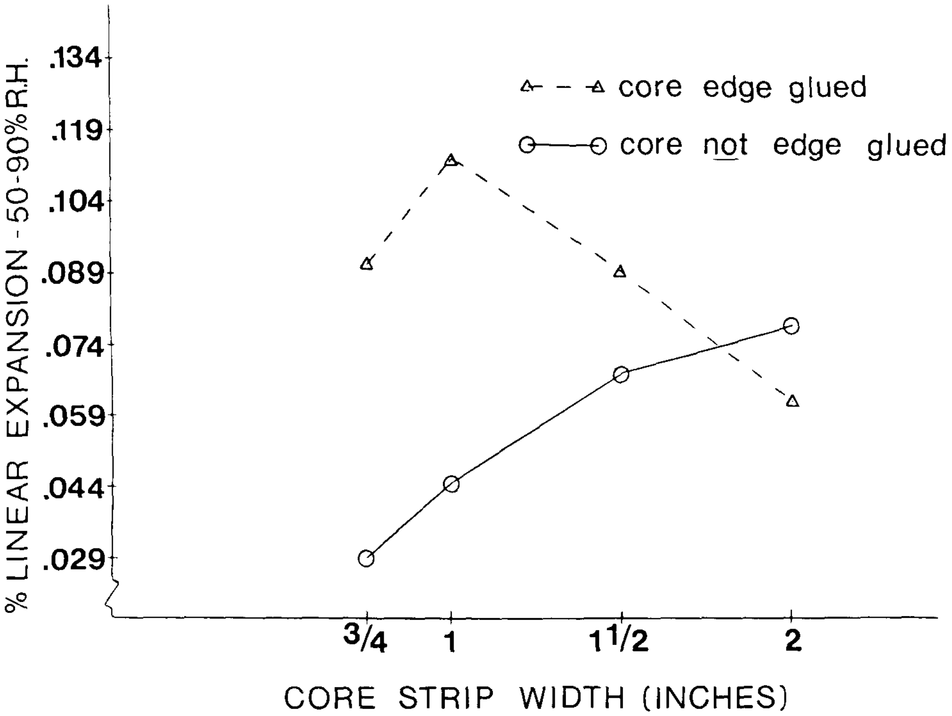

FIG. 2. Linear expansion of blockboard as a function of core strip width and gluing system.

these other sheet materials, with perhaps the greatest potential for use as sheathing, subflooring, and other products for which performance after accelerated aging is not important.

Tests conducted in this study indicate that neither edge-gluing of core strips nor the width of these strips influences strength of blockboard. Moreover, though both edge-gluing of core and core strip width affect dimensional stability, both factors favor the non-edge-glued core. Ability to use wide (or random width) core strips and to dispense with edge-gluing of core material can in both cases be expected to have a favorable influence upon the economics of production.

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