PRELIMINARY RESULTS OF PROMISING NEW STRUCTURAL SANDWICH WOOD PANELS FOR FLOORS AND OTHER APPLICATIONS[1]

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ABSTRACT

Very promising results of preliminary tests that concern the mechanical behavior of new structural sandwich wood panels for house floors are presented. It is of great significance that manufacture and utilization of such sandwich wood panels would contribute directly to conservation of our national forest resources through more efficient wood utilization. For cores, wood of lower quality, species of less commercial demand, and wood residue from other wood industries are utilized. Of equal importance is the fact that cost in place of these sandwich panels for house floors is expected to be considerably lower than cost of floors currently used.

Very encouraging preliminary test results are presented from research that concerns two national needs of high priority: first, the increasing need in America for housing at reasonable prices, as documented by the Congressional Housing Act of 1968; and second, the widely recognized need for conserving our national forest resources through more efficient wood utilization.

Preliminary test results clearly indicate both structural and economic advantages of the new wood panel[2] design for floor systems in housing. The proposed floor (without finish) consists of a sandwich panel with particleboard core reinforced on either side with select veneer of southern yellow pine. Completion of this research is expected to demonstrate that a proper sandwich panel construction can: (a) meet accepted structural floor requirements for housing; (b) reduce appreciably both manufacturing and installation costs of floors compared with the corresponding cost of floors currently used in housing construction; and (c) utilize efficiently wood of lower quality, species of less commercial demand, and wood residue from other wood industries.

More specifically, results of preliminary experimental tests indicate that a structural sandwich wood floor panel ⅞-inch thick (⅝-inch particleboard core reinforced with ⅛-inch southern pine veneer faces) is 236% stronger and 285% stiffer in flexure than the widely used two-layered floor system (½-inch plywood subfloor + ⅝-inch particleboard underlayment). Conservative estimates indicate that the manufacturing cost of the sandwich floor panel could be 30% less and the installation cost 35% less than corresponding costs of the two-layered floor system.

Additional preliminary results indicate that flexural properties of such structural sandwich wood panels, in the grain direction of face veneer, are equal to or greater than corresponding flexural properties of plywood panels of equal total thickness and with face veneer of equal quality and thickness. Flexural stiffness across the face grain (4-ft width) of the sandwich panels tested

[1] The authors acknowledge with gratitude the assistance given by Mr. Ward Hoseid, Vice President and General Manager, Great Northern Plywood Co., Cedar Springs, Ga., and Mr. Charles Hamilton, Plywood Operations Manager, Scotch Lumber Co., Fulton, Ala., for fabricating all experimental sandwich and plywood panels in their mills.

[2] Sandwich wood panels with particleboard core have long been used in furniture, mostly as nonstructural components faced with decorative hardwood veneers or plastic laminates. This is the first time, however, that a structural sandwich wood panel is proposed with particleboard core and softwood veneer faces.

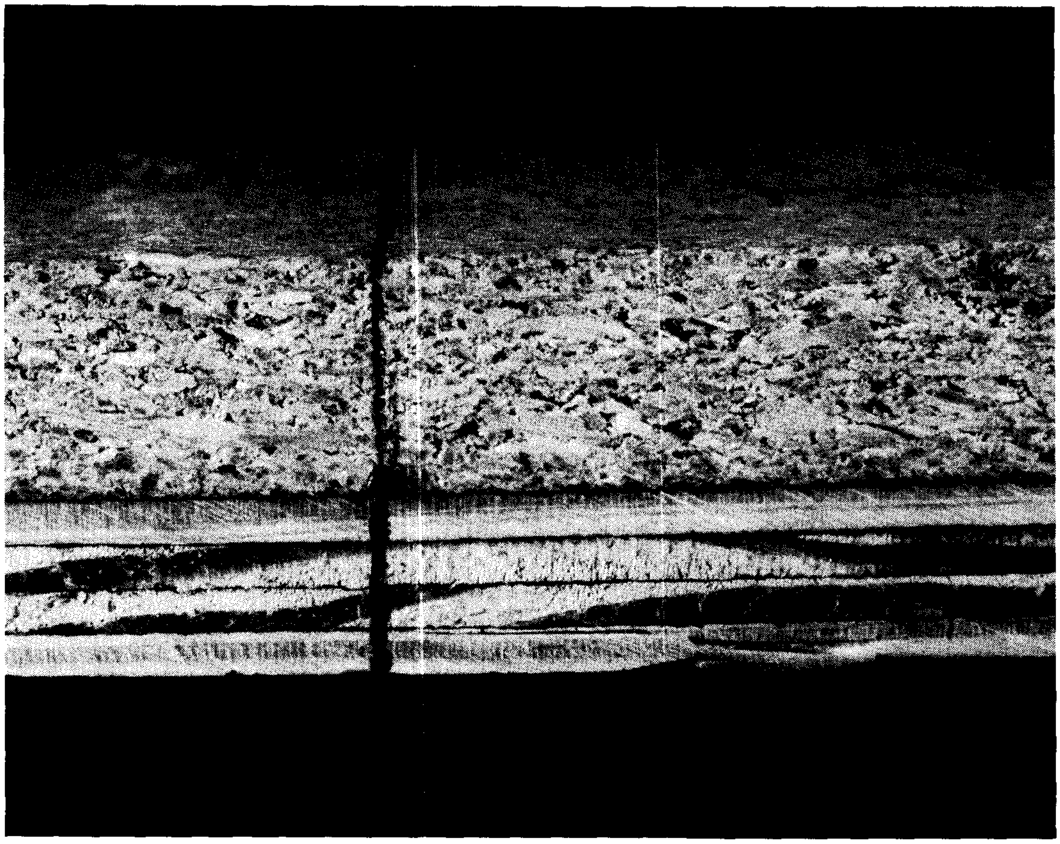

FIG. 1. Two-layer floor system consisting of ½-inch plywood subfloor and ⅝-inch particleboard underlayment.

with a concentrated load is equal to or better than for plywood panels of the same thickness and quality. Shear moduli (both edgewise and flatwise) of these sandwich panels are larger than the corresponding values of plywood panels of the same thickness and quality. These additional preliminary results indicate that such a sandwich panel will meet or exceed present structural requirements, could economically replace single-layer plywood floors and, in certain geographical regions with heavy snowfalls, could also replace plywood roofing.

OBJECTIVE AND JUSTIFICATION

The overall objective of continued research is to develop a new and more efficient wood floor system for medium and low cost housing. The new system should be more economical than systems presently used and is expected to show superior structural properties.

The national need for increased housing construction cannot be disputed. It has been stressed that the nation needs to build twice as many living units per year for the next ten years as we have been building. To meet this goal, 2.6 million new houses must be built each year until 1980. In addition to adequate financing, materials must be made available, efficient components must be designed, and proficient construction methods must be developed, in order to make housing available to all and particularly to low income families. A survey by Phelps (1970) indicated that 70% of all houses started in 1968 were built with wood joists. Approximately 75% of those houses had plywood subfloors, with or without underlayment. The average floor area for all houses built or sold in 1968 (FHA-inspected) was 1,400 square feet. Facts such as these emphasize the importance of developing and improving floor systems for housing.

Wood floor systems for residential housing in the United States have undergone substantial changes within the last twenty years, and there are certain indications (Anderson 1967, 1969, 1970; Phelps 1970) that even more changes will take place in the future. Originally, nearly all floors on wood foundations consisted of a two-layer lumber system. For a while, a two-layered plywood floor system was introduced consisting of (a) standard ½-inch plywood as a subfloor and (b) plywood underlayment, ⅜-inch thick. The two-layered plywood floor was partially replaced by a single-layer plywood floor, mostly ⅝-inch thick. However, the ⅝-inch thickness of the single-layer plywood floor did not provide full customer satisfaction. Godshall (1969) reported that the coefficient of sound absorption of ½-inch Douglas-fir plywood is only 50% of the coefficient of particleboard of the same thickness and species. Currently the most widely accepted floor system under flexible finish or carpet is a new two-layered system that combines plywood with particleboard. This latest two-layered floor consists of (a) a plywood subfloor,[3] ½-inch thick, and (b) a particleboard underlayment, ⅝-inch thick, for a total thickness of 1⅛ inch, shown in Fig. 1. This floor system, however, does not utilize structurally the ⅝-inch particleboard underlayment. Since the two layers are not laminated, they resist flexural loads independently, and thus the particleboard's structural contribution is negligible.

According to simple beam theory, the highest tension and compression stresses develop at the top and bottom surfaces of a beam. Therefore, an efficient floor design would be a structural sandwich faced with a strong softwood veneer (such as southern yellow pine), as shown in Fig. 2. Such a structural sandwich panel with veneer grain perpendicular to the direction of supporting joists would perform as well as or better than the presently favored two-layered system of plywood and particleboard or the single-layer plywood floor system at a considerably lower in-place cost.

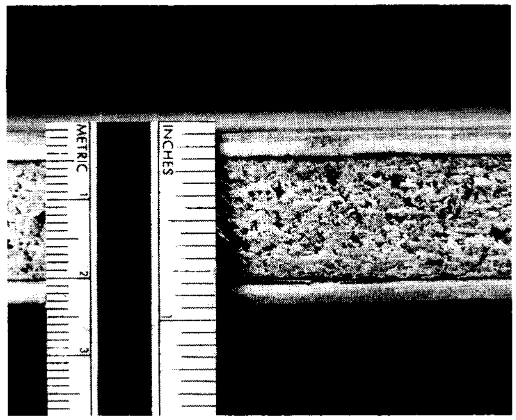

FIG. 2. Sandwich floor system consisting of ⅝-inch particleboard core reinforced on each face with ⅛-inch southern pine veneer.

Manufacture of such structural sandwich wood panels in the South is favored by the following advantages: (a) availability of raw material, (b) existence of efficient and adequate manufacturing capacity, and (c) proximity to large housing markets. According to the Southern Forest Resources Analysis Committee Report (1969), it has been estimated that the southern forest has the biological capacity to double its present growth on the same acreage, thereby producing almost 40% of the nation's present capacity. The South, equipped with modern manufacturing facilities, already produces 45% of the nation's particleboard (Stapelaere 1971) and approximately 27% of the softwood plywood (Guttenberg 1970). It has been estimated that by 1980 the South could, under the most favorable conditions, account for 59% of the nation's softwood plywood production (Holley 1969).

[3] Like 80% of all southern yellow pine ½-inch plywood sheathing, manufactured with 4 plies (Biblis et al. 1972).

Furthermore, the South enjoys an advantage in freight rates to the large northeast and north-central housing markets. Freight rates from the southern region to New York are 60% lower than from the West Coast, 45% lower to Chicago (Stapelaere 1971).

PRELIMINARY EXPERIMENTAL RESULTS

In support of a proposed formal research project, a limited number of preliminary tests were conducted to estimate flexure and shear properties of the proposed sandwich panels.

Material: Two panels (4 × 8 ft) from each of the following were fabricated in a southern pine plywood mill.

Sandwich panel total thickness	Southern pine face thickness	Particleboard core thickness
7/8"	1/8"	5/8"
5/8"	1/8"	3/8"
0.960"	1/6"	5/8"
0.710"	1/6"	3/8"

Two plywood panels (4 × 8 ft) from each of the following were also fabricated: a) 1/2" thick, 4-ply, b) 5/8" thick, 5-ply, and c) 7/8" thick, 7-ply. The sandwich panels were fabricated in the following manner: Clear southern pine veneer, dried to less than 5% MC, was used for all panels. Particleboard (underlayment quality) was used for cores after conditioning to approximately 7% MC. Commercial grade extended phenolic resin (equivalent to that used in manufacturing southern pine plywood) was used for gluing veneer faces to particleboard cores. Resin was applied only to the veneers. A spread of 100 lbs per MDGL was applied with rollers to 1/8" thick veneers, while 105 lbs spread per MDGL was applied to 1/6" thick veneers with a curtain sprayer.[4] Sandwich panels with 1/8" veneer were cold pressed with 165 psi. for approximately 3 min, then pressed with 200 psi. at 295 F for 5 min. Cured panels were cooled under pressure, then stored in a conditioned room at 50% RH and 72 F until testing.

The three plywood constructions were manufactured simultaneously with the sandwich panels of equal total thickness, under the same pressing conditions, and with the same quality of select veneer in all plies (including core and crossbands) as face veneers of the sandwich panels.

In addition, seven specimens, each 3" in width and 20" in length, were constructed by nailing 5/8" particleboard underlayment to 1/2" plywood subfloor. Nails were driven along the long axis at a spacing of 5½ inches.

TESTING

From each sandwich and plywood construction, seven flexure strip specimens were cut, each 3" wide and 20" long, and then tested with central loading and direction of face grain parallel to a 16" span. In addition, from each sandwich and plywood construction, seven flexure specimens were cut, each 3" in width and with a length 48 times their thickness plus 4". These specimens were tested nondestructively in flexure at five span-to-depth ratios for determination of flatwise (interply) shear modulus according to a method used previously by Biblis (1965), Preston (1954), and Wangaard (1964). For determination of edgewise shear modulus, four small square shear panels were cut from each construction. Side length was 30 times the panel's thickness. This test was conducted according to ASTM-D805-63.

Additional critical flexure tests were conducted with full panels, for elastic behavior as panels, with concentrated loads. One 4 × 8 ft sandwich panel (composed of 3/8" particleboard core faced on each side with 1/8", select veneer) and one 5/8" southern pine plywood panel (select veneer) were tested nondestructively in flexure. A concentrated load of 100 lbs was applied through a disc of 3½" diameter at the cen-

[4] Amounts of glue spread were heavier than those normally used for plywood of the same species and veneer thickness. It is now believed that glue spreads lighter than those normally used for plywood would give satisfactory bonding of southern pine veneer to particleboard.

TABLE 1. Flexural and shear properties of various floor specimens from preliminary tests.[1]

Type of specimen	Spec. depth (inches)	Max. load (lbs)	Load causing 0.1-inch middle span deflection[2] (lbs)	Shear modulus Edgewise (psi)	Shear modulus Interply (psi)
⅝″ particleboard nailed to ½″ plywood[3]	1.115	377	90	—	—
Sandwich ⅝″ particleboard core with ⅛″ veneer	0.870	889	258	130,000	25,200
Sandwich ⅜″ particleboard core with ⅛″ veneer	0.616	453	90	125,000	21,500
Sandwich ⅝″ particleboard core with 1/6″ veneer	0.940	1130	337	—	26,260
Sandwich ⅜″ particleboard core with 1/6″ veneer	0.708	824	204	123,680	33,500
⅞″ plywood	0.839	838	255	105,300	20,300
⅝″ plywood	0.604	445	82	98,000	20,500
½″ plywood	0.482	349	64	93,700	13,400

[1] Each value is the average of 4–7 specimens tested at approximately 7% moisture content. Flexure specimens were 3″ in width and, tested with central loading, freely supported over a 16″ span along the veneer grain.

[2] This deflection is within the elastic region.

[3] Tested with the plywood on the tension side as subfloor.

ter of a 24″ span (middle panel's portion). The panel was supported freely crosswise by two full width supports.

Prior to testing, all specimens and panels were conditioned to approximately 7% MC.

RESULTS AND DISCUSSIONS

Results of these tests are summarized in Table 1. Flexural behavior of each construction is reported both by the maximum load and the load causing 0.1″ midspan deflection over 16″ span. These quantities are more meaningful for making direct comparisons of flexural capacity among the various panels of different thicknesses than are modulus of elasticity and modulus of rupture.

On the basis of the results in flexure, which is the principal requirement of a floor system, the sandwich panels exhibited structural qualities superior to the two-layer floor system. The sandwich panels were capable of withstanding approximately equal maximum flexural loads as plywood panels of the same thickness and quality. It should be noted, however, that the plywood panels tested were constructed with all plies of clear veneer as the sandwich faces. It is expected that plywood panels, if constructed with their inner plies of lower veneer quality (C or D) would show lower flexural properties than sandwich panels of equal thickness and quality of face veneer.

It is also interesting to note that a sandwich panel 0.708″ thick (composed of ⅜″ particleboard core reinforced on each side with 1/6″ southern pine veneer) has been estimated to have higher flexural properties in the direction of face grain than a ¾″ plywood panel with face veneer equal in quality to that of the sandwich panel. Thus such a sandwich panel could economically replace ¾″ plywood floors over a 24″ span.

The flexural behavior of sandwich panels, stressed as panels, with concentrated loads is of great interest. Much work remains to be done on this aspect for conclusive answers. Results of limited tests, however, are very encouraging. Figure 3 shows graphically that deflection of a sandwich panel ⅝″ thick and loaded with a 100-lb concentrated load at the middle of a 24″ span was less along the entire 4-ft width than the deflection of a similarly loaded ⅝″ plywood panel with face veneer of equal quality.

Shear moduli values of sandwich panels are larger than corresponding properties of plywood panels of same EMC. Edgewise shear moduli of sandwich panels were approximately 30% larger than corresponding values of plywood. This undoubtedly can be attributed to the effect of the particle-

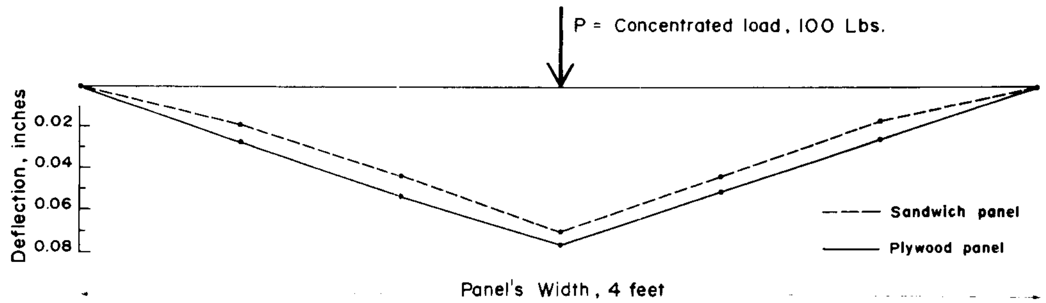

FIG. 3. Deflections along the 4-ft width of a ⅝-inch thick sandwich panel (⅜-inch particleboard—underlayment as core faced on each side with ⅛-inch southern pine clear veneer) and of a ⅝-inch plywood panel (clear southern pine), each loaded with a concentrated load of 100 lbs at the panel's center and supported by two full width supports 24 inches apart.

board core, which has an edgewise shear modulus approximately 60% larger than that of plywood of the same thickness.

A limited number of shear strength tests conducted with ⅝" plywood and with ⅝" sandwich specimens indicate both edgewise and flatwise (interply) shear strength of the sandwich specimens to be larger than those of the plywood, at the same moisture condition.

It is the considered opinion of the investigators that a sandwich panel ⅝", or even 0.575", thick is both structurally superior to and economically more attractive than a ½" plywood panel for wall and roof sheathing.

The limited results presented are merely indicative of the potential of such sandwich panels for increasingly efficient wood utilization. Numerous experimental tests are required for complete evaluation of the physical and structural behavior of such panels. There also are several technical details yet to be worked out before successful industrial production of such panels becomes feasible. Researchers at the Auburn University Agricultural Experiment Station are at work seeking additional information. However, it is quite possible that the highly motivated and technically competent managers and floor superintendents of southern pine plywood and particleboard mills may develop, as in the past, a useful product before the wood scientists complete their research.

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