FLOOR PANELS WITH STRESSED PLYWOOD COVERINGS

Information Reviewed and Reaffirmed

June 1955

INFORMATION REVIEWED AND REAFFIRMED 1960

No. 1026

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin

In Cooperation with the University of Wisconsin
FLOOR PANELS WITH STRESSED PLYWOOD COVERINGS

By
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Increasing interest in houses built of factory-fabricated units led to this series of tests on wood floor panels in which the principle of stressed covering is embodied. The tests were conducted at the Forest Products Laboratory, Madison, Wis., and their scope was sufficient to determine the efficiency of units of this type and to establish a basis of design. The panels tested consisted of relatively shallow joists to the top of which plywood suitable for a subfloor was nailed and glued, and to the bottom of which thinner plywood, to serve as a ceiling in lieu of plaster, was also nailed and glued.

The Stressed Covering

In the ordinary floor system of relatively deep joists overlaid with a subfloor of nailed boards that carry the finished floor the subflooring serves to distribute the floor load to the various joists making possible the laying of a relatively thin finish floor. When laid diagonally it also stiffens the building. Aside from these structural functions it serves as a working surface during construction, assists in deadening sound, prevents dust from rising from the basement to the first floor, and adds to the insulation of the room. It contributes nothing, however, to the bending strength of the joists.

Ceilings hung on the floor joists are parasites as far as bending strength of the entire floor system is concerned.

Stressed coverings, on the other hand, are those which contribute to the flexural strength of the floor system. They must be rigidly attached to the upper and lower surfaces of the joists, as with glue, so that by virtue of the resistance to shear of the surfaces between the joists and the coverings, the upper covering is thrown into compression and the lower one into tension. Plywood serves admirably for such coverings. That on top should be sufficiently thick to perform the usual functions of the subfloor, while that on the bottom, which serves as a ceiling, need not be so thick.

A floor panel consisting of plywood glued to the upper and lower surfaces of several joists laid parallel to each other is in effect a box girder. The purpose of the tests described here was to determine the rigidity and strength of such girders.

**Design of Floor Panels**

The test panels were 14 feet long and either 2 or 4 feet wide. The joists, which were southern yellow pine, were 5-3/8 inches deep, net dimension. Douglas-fir plywood was nailed and glued to the top and bottom surfaces of the joists to form box girders. Casein glue was spread on these surfaces, but no pressure was applied during the setting of the glue except that provided by 6d common nails spaced 6 inches on top and 6d finishing nails spaced 3 inches on the bottom. The joist thicknesses and spacing, plywood thicknesses and direction of face grain, and the panel widths are given in table 1.

A single panel, 2 feet wide, with plywood attached only to the upper surface of the joists was tested to demonstrate the inadequacy of such construction.

**Method of Test**

The panels were tested over a span of 13-1/2 feet with load applied at the third points as illustrated in figure 1. The loading device descended at the rate of 0.4 inch per minute and deflections were read to the nearest 0.01 inch for each increment of 200 pounds of load for the 2-foot panels and 400 pounds for the 4-foot panels.

Control specimens cut from the joists were tested in accordance with standard procedure to determine their strength properties.

**Discussion of Test Results**

In addition to a further description of the test panels and their dimensions, table 1 gives the calculated moments of inertia of the test panels, their strength characteristics as determined by test, and deflections calculated on the basis of a 40-pound per square foot live load and 7-pound per square foot dead load of the panels and finish floor.

In calculating the moment of inertia of a panel section those plies whose grain ran perpendicular to the length of the panel were neglected. It is to be observed in this connection that in 5-ply, 5/8-inch plywood, for example, each ply is not necessarily 1/8 inch in thickness. It is present practice to use various combinations of veneer thicknesses to produce...
given thicknesses of plywood. Furthermore, when the plywood sheet is removed from the press it is usually over the finished thickness to permit sanding of the face plies. All plywood used in these tests was sanded on both sides.

Panels A, B, C, and D (figure 2 and table 1) were 2 feet wide, with 5-ply 5/8-inch plywood on top and 3-ply 1/4-inch plywood on the bottom. As indicated in table 1, the grain of the face plies of the plywood on the top of panel A ran parallel to the length of the panel. In all other panels except panel J it ran perpendicular to the length. The grain of the face plies of the bottom plywood was laid parallel to the length of all panels except panel J which had no plywood on the bottom.

Panels A, B, C, and D each had three joists, the outside ones 13/16 inch thick, the center one 1-5/8 inches thick. A and B were tested individually, C and D together. Their maximum strength ranged from 300 to 500 pounds per square foot when adjusted to the basis of a uniformly distributed load. For a 13-1/2-foot span they averaged 32 percent better in stiffness under a 40-pound per square foot live load and a 7-pound per square foot dead load than the requirement limiting the deflection to 1/360 of the span (0.45-inch deflection). Attention is directed to the fact that panels C and D were tested together and the moment of inertia, maximum load, and similar information in table 1 are for the two panels.

Panel E represents an attempt to reduce the amount of material in the joists. This panel was 4 feet wide and had three joists each 1-5/8 inches thick, or 25 percent less material in the joists than in the first four panels for an equivalent width. Panel F was identical with panel E except that 1-by 4-inch spacer bars were inserted in each end to reduce the buckling of the bottom plywood illustrated in figure 3. Both of the panels were sufficiently strong and average about 23 percent stiffer than the requirement already mentioned. The drop from 32 percent to 23 percent excess in stiffness is a direct reflection of the reduction in moment of inertia of the joists.

Figure 3, as already mentioned, shows the buckling of the lower plywood of panel E at maximum load. Incidentally, this buckling was very slight at safe loads. The tensile forces passing out from the joist to the thin lower plywood have components which tend to draw the lower edges of the joists together and buckle the plywood. In fact in panel E this force was so great at maximum load that the glue line between the upper plywood and the outside joists were broken. Even with spacer blocks at the ends, these buckling forces were sufficiently great to buckle the lower plywood at the center of the length of the panel. At maximum load the concavity of the lower surface in this region was decidedly noticeable.

In panel G the upper plywood was reduced from 5/8 inch to 1/2 inch with the lower plywood 1/4 inch as before. The stiffness was reduced about 18 percent below that of panels E and F but it is still about 5 percent above the stiffness requirement already mentioned.
In panel H, 1/2-inch plywood was again used on top but with 3/8-inch plywood on the bottom. The stiffness was brought well within the required limits but not quite equal to that of panels E and F. The breaking strength, however, was greater than for either E or F. It so happens that the core thickness of the 3/8-inch plywood was almost 60 percent greater than that of the face plies, while in the 1/4-inch plywood the core was about 25 percent thicker than the face plies. Therefore, the net result of taking 1/8 inch in thickness off of the top plywood and putting it on the bottom was a slight loss in moment of inertia which is reflected in the stiffness.

As a final step panel I was made with four joists each 13/16 inch thick, a reduction in joist area of 1/3 below that of panel H. The top plywood was 1/2 inch thick and that on the bottom 3/8 inch thick as for panel H. The breaking strength of this panel is considered satisfactory but it is just on the border line of acceptability as regards stiffness. The reduction in stiffness below that of panel H is a reflection of the loss in moment of inertia occasioned by the reduction of material in the joists.

In order to demonstrate the inefficiency of a section with plywood on the top surfaces of the joists only, panel J, figure 2, was made identical with panel A except for the omission of the lower plywood. While its strength characteristics may be considered satisfactory, its stiffness was only about two-thirds of that of panel A.

Conclusions

It appears from these tests that floor panels made with stressed top and bottom coverings, such as with plywood glued to joists to form a box girder, can be made with satisfactory strength and stiffness.

For a panel length of 14 feet a joist height of 5-3/8 inches appears suitable, which means an appreciable reduction in the thickness of the floor system aside from any consideration of less material and labor costs.

In order to obtain sufficient stiffness in panels over 14 feet in length a joist depth greater than 5-3/8 inches or thicker plywood than that used in the tests would be required, although the former would furnish the added stiffness with less material.

The stiffness of floor panels made in the fashion described can be calculated with reasonable accuracy by neglecting the plies of the coverings that run at right angles to the length and by using 5/6 of the modulus of elasticity for the wood of which the plywood is made based on corresponding moisture content values.

In calculating the maximum strength of girder type floor panels, it should be observed that the average extreme fiber stress in table 1 is slightly less than one-half the modulus of rupture for clear Douglas-fir wood at a corresponding moisture content.
Table 1.--Dimensions and performance characteristics of 14-foot floor panels with stressed plywood coverings.

(Panels tested over a span of 13 feet 6 inches, under symmetrical two-point loading with a distance between loads equal to one-third the span.)

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<td>Inches</td>
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<td>229,700,000</td>
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<td>326</td>
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1 Parallel and perpendicular refer to direction of grain with respect to the length of the panel.

2 In calculating the moment of inertia of the panel sections the plies of the coverings that ran at right angles to the length were neglected. The calculations are based on actual dimensions of the joint and ply thicknesses.

3 The moments of inertia of the joists are about their own neutral axis.

4 EI is the product of the modulus of elasticity and moment of inertia.

5 The modulus of elasticity in this column is the EI from test divided by the calculated moment of inertia.

6 Based on 40 pounds per square foot live load and 7 pounds per square foot dead load for panel and finish floor, a span of 13 feet 6 inches, a modulus of elasticity of 1,600,000 pounds per square inch, and the calculated moment of inertia given in the table. A deflection limited to 1/360 of the span would be 0.45 inch.

7 Panels C and D, each 24 inches wide with 3 joists, were tested together.

8 Spacer blocks in ends.
Testing a glued-up floor panel of joists and plywood constructed on a principle borrowed from modern airplane design.
The following lists of publications based on research at the Forest Products Laboratory (Madison 5, Wis.) are obtainable on request:

- Boxing and Crating
- Building Construction Subjects
- Chemistry of Wood and Derived Products
- Fungus Defects in Forest Products
- Furniture Manufacturers, Woodworkers, and Teachers of Wood Shop Practice
- Glue and Plywood
- Logging, Manufacture, and Utilization of Timber, Lumber, and Other Wood Products
- Mechanical Properties and Structural Uses of Wood and Wood Products
- Pulp and Paper
- Seasoning of Wood
- Structure and Identification of Wood
- Wood Finishing Subjects
- Wood Preservation

Since Forest Products Laboratory publications are so varied in subject no single big list is issued. Instead a list is made up for each Laboratory division as shown above. Twice a year, a list is made up showing new reports for the previous 6 months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. There is no charge for single copies of any of the reports.

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