NAIL-GLUED SUBFLOOR ATTACHMENT

by

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ABSTRACT

Under sponsorship of the National Association of Home Builders, an evaluation of the efficiency of a glued and nailed method of subfloor attachment was made. Standard floor panels with 16-inch and 24-inch spacing of joists were tested according to methods outlined in A.S.T.M. Designation E72-55. The panels were first tested with subfloors nailed to the joists. The subfloors were subsequently removed. Later the floors were reassembled with the original materials and with the subfloors nail-glued to the joists. The floors were then subjected to the same tests as before.

Results of the tests showed that nail-gluing may be used efficiently to fasten plywood subfloors to joists. Nail-gluing improves the quality of a plywood floor without the use of additional material. This improved quality results from more uniform deflection of adjacent plywood edges and from the increased ability of the floor to resist deformation under bending loads.
INTRODUCTION

In a research project sponsored by the National Association of Home Builders, the feasibility of using glue as a fastener for plywood subfloors was studied.

Purpose of the study was to determine whether the use of adhesives would increase the quality of the structure without increasing the thickness of the plywood subfloor, or whether a thinner plywood would still produce a quality equal to present conventional construction.

Work has previously been done at the Forest Products Laboratory\(^1\) on the strength of glued plywood floor constructions; however, no comparison of the glue method of attachment has been made with standard methods of attachment.

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CONSTRUCTION OF FLOOR PANELS

In order to directly compare the glued method of attachment with recommended methods, it was decided to first construct floor sections conventionally. After these floor sections were tested, they were disassembled, reconstructed by nail-gluing the plywood subfloors to the joists, and tested again.

The FHA Minimum Property Requirements For Properties of One Or Two Living Units Located In The Central States was used as a guide in constructing the floor panels. It was assumed that less than 25/32-inch, wood or other finish flooring would be applied to similar panels in service; however, no finish flooring or underlayment was applied to the test panels.

Since the standard A.S.T.M. methods for testing floor constructions specify a length of 12 ft. 6 in., this was the length chosen for the panels made. Panel 1 was made with a frame of four Douglas-fir 2" x 8" joists 12 ft. 6 in. long. The joist material was not grade-marked, but it was bought as No. 1. Moisture content of the joists was about 14 per cent. The joists were spaced 16 inches on center. A 2" x 8" header was nailed across the ends of the joists with two 20d nails per crossing. Nominal 1" x 3" cross bridging was attached to the joists in the center of the span length. Pilot holes were drilled in the bridging so that it could be applied with two 8d nails at the end of each piece. Blocking composed of 2" x 4" pieces was nailed flatwise between the joists, 4 feet on center. Douglas-fir ½" unsanded plywood (sheathing grade "C-D") was nailed with the face grain perpendicular to the joists.

to cover the entire floor area. The plywood was laid flush with the exterior of the headers. The plywood was 5' 4" long so as to extend beyond the outside joists one-half the joist spacing. The plywood was attached with 8d nails spaced 6 inches on center at the edges and 10 inches on center at the interior bearings. Panel 2 was built with the same nailing, bridging, and blocking as Panel 1. The joists for this panel were 2" x 10" members, spaced 24 inches on center. The headers were likewise 2" x 10" members. The plywood used was 3/4" Douglas-fir unsanded plywood (sheathing grade "C-D") in lengths of 6 feet. The framing for Panel 2 is shown in figure 1.

![Figure 1. Framing for Floor Panel 2.](image)

After the conventionally built panels were tested, they were taken apart and rebuilt by nail-gluing. Casein glue (Fed. Spec. C-G-456) was used. Pressure was obtained from nails spaced 4 inches on center. For Panel 1, 6d box nails were used. For Panel 2, 6d common nails were used.
MATERIAL COST OF NAIL-GLUING

The cost of nails used in both types of attachment was virtually the same. In Panel 1, 1.35 lb. of 6d box nails were used in gluing as compared to 1.76 lb. of 8d common nails for the nailed attachment. In Panel 2, 1.69 lb. of 6d common nails were used in gluing as compared to 1.64 lb. of 8d common nails for the nailed attachment.

The added cost of the materials for fabricating the nail-glued panel lies in the cost of the glue. About 30¢ worth of casein glue was used for each of the floor panels (cost of glue was 35¢ per pound.) This was about \( \frac{1}{2} \)¢ per square foot of floor. No study was made of the increased time required for applying the glue.

METHODS OF TESTING

Each of the panels was tested with transverse, concentrated, and impact loads. The set-up for the transverse loads is shown in figure 2.

Figure 2. Panel 1 under transverse load.

Uniformly distributed layers of concrete block loads were used in lieu of machine-applied quarter-point loading. The end rows of blocks
on the first layer were placed directly over the supports. These blocks merely provided for secure bearing of the panels on the supports and were not part of the load. Maximum deflection and set readings were taken at the neutral axis of the outer joists after application of each of the three layers. These readings corresponded to loadings of 38 psf, 76 psf, and 115 psf.

Figure 3 shows the apparatus used for applying concentrated loads.

Figure 3. Loading platform for applying concrete block concentrated loads.

Concrete blocks were balanced on the loading platform so as to apply their load to a 1" diameter disc bearing on the plywood subfloor. The side members of the platform were hinged to a frame support; however, since the load was placed directly over the disc bearing on the plywood very little of the weight was transmitted to the hinge reaction.

Loads were applied close to the center of the panels and a little more than four feet from the end of the panels. The central load was positioned midway between the joists and midway between the blocking.
The other load was positioned midway between the joists and about one inch away from the bearing over the blocking. The joists were supported under each row of blocking. Thirteen blocks, weighing 44 lb. each were used for each test. Deflection readings were taken after each block application. Set readings were taken after the sixth and thirteenth block had been applied.

Figure 4 shows the sandbag, set gage, and deflectometer used in the impact tests. This test was conducted as specified in A.S.T.M. Designation E72-55. The bag was dropped from heights of 1, 2, 3, 4, 5 and 6 feet.

Figure 4. Apparatus for conducting impact tests on floor panels.
RESULTS

The performance of the panels at pertinent test loads are reported in Table 1 and Table 2. Design load was taken to be 45 psf. The point-by-point graphical reports as specified by A.S.T.M. Designation E72-55 are included in the appendix.

Table 1. Performance of Floor Panel 1.

<table>
<thead>
<tr>
<th>Test</th>
<th>Deflection at Design Load Unglued/Glued</th>
<th>Deflection at 2 1/2 times Design Load Unglued/Glued</th>
<th>Set at Design Load Unglued/Glued</th>
<th>Set at 2 1/2 times Design Load Unglued/Glued</th>
<th>Ratio of Unglued to Glued Deflection at Design Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrated Load</td>
<td>.110/.116</td>
<td>.290/.279</td>
<td>.007/.009</td>
<td>.042/.038</td>
<td>0.95</td>
</tr>
<tr>
<td>Center of Plywood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge of Plywood</td>
<td>.056/.031</td>
<td>.138/.073</td>
<td>.005/.005</td>
<td>.018/.010</td>
<td>1.89</td>
</tr>
<tr>
<td>Uniform Load</td>
<td>.360/.262</td>
<td>.804/.586</td>
<td>.016/.012</td>
<td>.044/.022</td>
<td>1.37</td>
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<td></td>
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<td></td>
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<tr>
<td>Deflection at 6' Drop</td>
<td>1.14</td>
<td>.970</td>
<td>.015</td>
<td>.025</td>
<td>1.18</td>
</tr>
<tr>
<td>Test</td>
<td>Deflection at Design Load</td>
<td>Deflection at (2\frac{1}{2}) times Design Load</td>
<td>Set at Design Load</td>
<td>Set at (2\frac{1}{2}) times Design Load</td>
<td>Ratio of Unglued to Glued Deflection at Design Load</td>
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<td>-------------------------------------------</td>
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</tr>
<tr>
<td>Concentrated Load Center of Plywood</td>
<td>.109, .117</td>
<td>.245, .262</td>
<td>.009, .008</td>
<td>.034, .025</td>
<td>.93</td>
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<tr>
<td>Edge of Plywood</td>
<td>.036, .020</td>
<td>.096, .039</td>
<td>.004, .006</td>
<td>.020, .031</td>
<td>1.80</td>
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<td>Uniform Load</td>
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<td>.456, .370</td>
<td>.010, .004</td>
<td>.034, .027</td>
<td>1.23</td>
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<td>Impact Test</td>
<td>.580</td>
<td>.482</td>
<td>.015, .010</td>
<td></td>
<td>1.20</td>
</tr>
</tbody>
</table>
ANALYSIS OF RESULTS

The quality of a floor is increased by gluing. Edge deflection of the plywood is reduced by about 44 per cent. When the concentrated load was applied close to the edge of plywood sections, the nailed attachment produced a deflection at design load of 1.89 times the corresponding deflection of the glued attachment in Panel 1. In Panel 2, the nailed attachment deflection was 1.80 times the glued attachment deflection.

Since the uniform loading and impact tests were performed with the entire panels simply supported over the 12-foot spans, these tests measured the performance of the composite panel as a beam. In designing floors to span given lengths, the joists alone are considered as taking the bending load. The limiting criterion for the span of the joists is frequently the central deflection under a uniformly distributed design load.

By referring to the results of the tests in table 1 and table 2, it is seen that under uniformly distributed loading, the panels with glued subfloors had less deflection at design loads than the corresponding floors with subfloors attached conventionally. The increase in performance found by test was close to that predicted by theory for Panel 1. The increase in performance for Panel 2 was less than that predicted by theory. When the subfloor is not glued, the moment of inertia is considered to be that of the joists alone. When the subfloor is glued to the joists, the moment of inertia may be calculated for the composite section of joists and subfloor. This calculation can be made
according to suggestions in a Forest Products Laboratory report. For Panel 1, the moment of inertia of a 2" x 8" joist is 57.1. The value for a "T" section composed of one joist and a 16-inch width of 1/2-inch plywood is 97.5. Since deflection varies inversely with moment of inertia, the ratio of nailed attachment to glued attachment deflection would be expected to be $\frac{97.5}{57.1} = 1.71$. This figure must be modified somewhat because a nailed connection can take some shear; therefore, even the nailed subfloor adds to bending strength of the joists. In the publication on floors with stressed coverings which was previously mentioned, the Forest Products Laboratory recommends that, for floor panels with stressed plywood coverings, 5/6 of the modulus of elasticity for the wood of which the plywood is made should be used. The use of the lowered modulus of elasticity value would have the effect of changing the expected deflection ratio to $\frac{5/6 \times 1.71}{57.1} = 1.43$. The difference between this ratio and the 1.37 ratio found in the tests may be explained by experimental error.

Similar calculations for Panel 2 show the expected deflection ratio to be about 1.90. The difference between this ratio and the ratio of 1.23 found by test is not explainable by experimental error. The stiffness of the floor with the glued connection may have been lowered considerably because of damage sustained by the plywood and joists in removing the plywood when it was nailed to the joists. There was a tendency for the plywood to split and tear along the edges where it was nailed. Since the joists were supported at short intervals in the concentrated

load test, this test was essentially a test of the skin material covering the joists. When the design load was placed in the center of the plywood between joists, there was little difference in the deflection experienced by the panels with glued and nailed sub-floor attachment. This indicates that the recommended thickness of subfloor plywood for various joists spacings should not be changed even though glue is used for attachment.
CONCLUSIONS

The results as analyzed above lead to the following conclusions with regard to methods of subfloor attachment:

1. When a glued and nailed type of attachment is used, the differential deflection of adjacent plywood edges is minimized. This increases the quality of the plywood subfloor without the use of additional material. The advantage of glued construction as shown here is especially significant when tile, carpet, linoleum or other non-structural flooring is to be applied over the subfloor.

2. When \( \frac{1}{2} \)-inch plywood subflooring is used with the face grain laid perpendicular to joists spaced 16 inches on center, the assembly may be designed according to the principles of stressed skin construction. This may result in a saving of joist material for some floor spans.

3. When \( \frac{3}{4} \)-inch plywood subflooring is used with the face grain laid perpendicular to joists spaced 24 inches on center, the assembly should not be designed according to stressed skin principles without further investigation.

4. Plywood deflection between joists is not changed significantly by the glued method of attachment; therefore, the recommended thickness of subfloor plywood for various joist spacing should not be changed when this method of attachment is used.
Performance Graph For Floor Panel 1
Under Transverse Load Test

Deflection in Inches

Transverse Load in Pounds Per Square Foot

0 0.16 0.32 0.48 0.64 0.80 0.96
0 12 24 36 48 60 72 84 96 108 120
Performance Graph for Floor Panel 1
Under Transverse Load Test
(Subfloor glued to joists)
Performance Graph for
Floor Panel 2
Under Transverse Load Test
Performance Graph for
Floor Panel 2 (Glued)
Under Transverse Load Test
Performance Graph for Floor Panel 1

Concentrated Load Applied at Center of Floor

Deflection in Inches

Load in Pounds
Performance Graph for Floor Panel 1 (Glued)
Concentrated Load Applied at Center of Floor

![Performance Graph for Floor Panel 1 (Glued)](image-url)

- **Load in Pounds**: 0 to 600
- **Deflection in Inches**: 0 to 0.30

The graph shows the relationship between load applied at the center of the floor panel and the resulting deflection in inches.
Performance Graph for Floor Panel 2

Concentrated Load Applied Between Center and Outer Joists and in Center of 4' Span of Plywood Sheet

Deflection in Inches

Load in Pounds
Performance Graph for Floor Panel 2 (Glued)

Concentrated Load Applied between Center and Outer Joists and in Center of 4' Span of Plywood Sheet

Deflection in Inches

Load in Pounds
Performance Graph for Floor Panel 1
Concentrated Load Applied between Center Joists and 1" from Edge of Plywood Sheet 4' from Floor End
Performance Graph for Floor Panel 1 (Glued)

Concentrated Load Applied Between Center Joists and 1" from Edge of Plywood Sheet, 4' from Floor End
Performance Graph for Floor Panel 2

Concentrated Load Applied Between Center and Outer Joists and 1" from Edge of

Plywood Sheet 4' from Floor End

Deflection in Inches

Load in Pounds

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<thead>
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<th>Load in Pounds</th>
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<tbody>
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<table>
<thead>
<tr>
<th>Deflection in Inches</th>
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<tbody>
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<td>0.10</td>
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<td>0.12</td>
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</table>
Performance Graph for Floor Panel 2 (Glued)
Concentrated Load Applied Between Center and Outer
Joists and 1" from Edge of Plywood Sheet 4' from
Floor End
Impact Test on Panel 1

Impact Test Graph

Deflection in Inches

Height of Drop in Feet

0 0.2 0.4 0.6 0.8 1.0 1.2

0 1 2 3 4 5 6

Graph showing the relationship between height of drop and deflection in inches.
Impact Test on Floor Panel 1 Glued

![Graph showing deflection in inches against height of drop in feet.](image-url)
Impact Test on Floor Panel 2
Impact Test on Floor Panel 2 (Glued)