SOME TESTS OF END-MATCHED LUMBER

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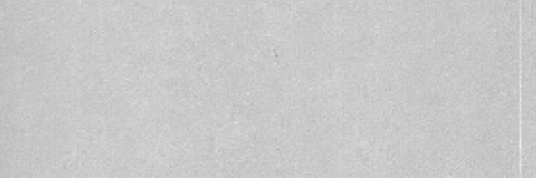

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

SOME TESTS OF END-MATCHED LUMBER[1, 2]

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End matching of hardwood flooring has been standard practice for a long time. The application of the end-matching process to certain items of softwood manufacture, however, has come into extensive use only recently. The development has been in the southern pine region where not only finish flooring, ceiling, and partition items, but lumber for such construction purposes as wall and roof sheathing, subfloors, concrete forms and, to a limited extent, drop siding have been end-matched. End matching has also been adopted by the manufacturers of flooring in some other softwood producing regions. In the southern pine region side-matched and to some extent square-edged construction material has been end-matched. When its advantages become more widely known, end matching may be expected to extend to other softwood regions and possibly to other items of manufacture, provided end-matched stock is well received by lumber users and no undesirable effects result from its use.

Many advantages of end matching have been cited. Among the apparently more important are:

1. Conservation of timber resources as a result of the reduction of manufacturing waste. End matching is presumed to make a piece of any length usable; hence, no serviceable stock need be wasted in cutting to standard lengths, boards that are a few inches short of the next greater standard length.

2. Performance at the manufacturing plant with machines operated by unskilled labor of cut-off and squaring operations formerly done on the construction job as hand work by skilled labor. This would reduce building labor costs and in addition bring to the construction job material that is practically 100 percent usable.

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[1] The tests described in this article were undertaken at the request of the National Committee on Wood Utilization to supplement its report entitled "End-Matched Softwood Lumber and Its Uses."

[2] Published in Southern Lumberman, December 22, 1928.

[3] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Service value as well as these and other advantages obviously deserve consideration in connection with the production, marketing, and use of end-matched products. Realization to the full of the waste reducing possibilities of end matching obviously requires using shorter lengths than have been customary as well as abandoning the practice of cutting logs and lumber to standard lengths. Furthermore, the experience of some builders and contractors in the use of end-matched material has suggested the convenience of making each piece of construction lumber a "one-man piece" by setting an upper limit of length at about 10 feet. Manufacturers are considering cutting all longer stock into lengths of about 10 feet or shorter and handling all end-matched stock in bundles about 10 feet long, which would have the additional advantage of simplifying the tallying of mixed random lengths.

End matching furnishes the builder random-length lumber that is ready for installation with very much less waste and with less labor cost than material of so-called standard lengths. On the other hand, the average length of material is considerably reduced and the use of end-matched stock necessitates joints being placed without regard to supports. Consideration of such changes raises a number of questions as to their effects on structures in which the lumber is used. The tests described in this article were therefore made at the U. S. Forest Products Laboratory to afford information on two of the more important of these questions which are outlined as follows:

1. When boards long enough to cross a number of joists, studs, or rafters are nailed to these supports to form a continuous covering the supports are "leveled" or "smoothed" unless they are all straight or are all equally bowed in the same direction. (This effect is recognized by the carpenter who defers the nailing or bridging until the sub-floor, and sometimes the finish floor, is laid.) Furthermore, the defection or bending under a concentrated load is lessened since the load is not carried by any one or two supports but is distributed to a number of them. Tests to find out how these effects are influenced by the length of the boards are presented under "Deflection Tests."

2. Many residence buildings are erected without subfloors, the finish floors being laid directly on the joists. Also, the finish floor in many residence and other buildings is laid on furring strips placed on the subfloor.

Subfloors and roof sheathing, and to a lesser extent wall sheathing and boards for concrete forms, are subject to concentrated loads and shocks during erection of the building. Floors are similarly exposed during occupancy of the building. Since such loads and shocks may be applied anywhere, the strength of end-matched joints that come between joists or other supports is of considerable importance. Tests of the strength of end-matched joints are reported under "Strength Tests."

Description of Tests

Deflection Tests

The deflection tests were made on a panel representing a portion of a floor as illustrated by Figure 1. Two series of tests, designated as "Series 1" and

and "Series 2," were made, each series consisting of a number of steps.

In Series 1 these steps were as follows:

Step 1. The joists were set up, no attention being paid to whether the "bow" was up or down. (Joists Nos. 2, 3, and 7 were placed with bow up and the remaining four with bow down.) The heights of upper surfaces of the joists at each reading point, or intersection of lines A, B, and C (fig. 1) with joist center lines, were then determined. These heights were obtained by means of an engineer's transit reading on graduated rods set at the intersections.

Step 2. The covering boards were nailed in place with tongue to tongue and groove to groove to simulate unmatched stock. Two 8d common nails were driven directly through each board at each crossing of a joist. No blind-nailing was done. Weights were placed one at a time at point 4B (intersection of line B with center line of joist No. 4) until a load sufficient to produce considerable deflection, but insufficient to cause any damage or permanent distortion, was attained. The weights were then removed one at a time. After the addition and just before the removal of each weight the heights of each reading point was observed.

Step 3. The boards were removed and were nailed as before except that they were placed with groove to tongue. Cracks of an average width of approximately 1/16 inch were made between boards by drawing each board into contact with a steel strip placed against the edge of the preceding board. The loading and the reading of heights or levels were then repeated.

Step 4. Boards were cross cut by means of a key hole saw starting from a small hole bored near the edge of the board to make plain butt joints at points marked "1" in Figure 1, and the loading and the reading of levels were again repeated.

The program of loading and of reading levels was similarly carried out after additional cuttings of the boards as follows:

Step 5. Cross cuts at points 1 and 2.

Step 6. Cross cuts at points 1, 2, and 3.

Step 7. Cross cuts at points 1, 2, 3, and 4.

Step 8. Cross cuts at points 1, 2, 3, 4, and 5.

Step 9. Cross cuts at points 1, 2, 3, 4, 5, and 6.

Step 10. Cross cuts at points 1, 2, 3, 4, 5, and 6, and the tongue in each longitudinal joint ripped.

Step 11. Boards removed and readings taken on joists.

The same set of boards were used throughout Steps 2 to 10 and remained in place through Steps 3 to 10, inclusive.

Series 2.

All joists were placed with their bows up. A new set of boards was placed at Step 2 and used throughtout Steps 2 to lo, inclusive. In laying the boards at Step 3, face cracks of an average width of about 1/8 inch were made between boards by drawing each board into contact with a wooden strip placed against the edge of the preceding board. Steps 1 to 11 were carried out in the same manner as in Series 1. The program of placing loads and taking level readings was then carried out for each of the following additional steps:

Step 12. A new set of covering boards with end-matched joints at points 1, 2, and 3 were put in place.

Step 13. End-matched joints at points 1, 2, and 3; cross cut at point 4.

Step 14. End-matched joints at points 1, 2, and 3; cross cuts at points 4 and 5.

Step 15. End-matched joints at points 1, 2, and 3; cross cuts at points 4, 5, and 6.

Step 16. End-matched joints at points 1, 2, and 3; corss cuts at points 4, 5, and 6; and the tongue in each longitudinal joint ripped.

Strength Tests

Tests were made of the strength of end-matched joints in panels of the construction and dimensions shown in Figure 2. Seven southern pine mills furnished end-matched stock of the lengths required for joints at the points indicated in the sketch. Tests were made on five classes of stock, namely, 3- and 4-inch flat-grain, 3- and 4-inch edge-grain flooring, and 6-inch center-matched boards. Each of the mills furnished material for one panel of each of these classes. Six panels of 6-inch center-matched and seven panels of each of the other four classes of stock were tested. The moisture content of the stock, which was determined from two discs cut from each panel as indicated in Figure 3, varied for the 6-inch stock from 6.9 to 10.1 percent and averaged 8.3 percent. Average, maximum, and minimum moisture content values of the 3- and 4-inch flooring were 7.4 percent, 10.3 percent, and 4.7 percent, respectively.

In making the tests loads were applied at each of the fourteen numbered points indicated in Figure 2. The order of tests on each panel was that of the numbers at the points. This order was such that each test was practically uninfluenced by the previous tests on the same panel.

Arrangement of the testing machine and apparatus is shown and described in Plate 1. In the tests the straining beam "d" was forced downward causing post "o" to be pressed against the panel at the point under test. In the tests of the 3- and

4-inch stock this action was continued until splitting of the flooring was observed at or near the load point, and the test was discontinued soon thereafter. Tests of some of the panels of 6-inch stock were continued until the load reached its maximum value. Simultaneous readings of loads and deflections were taken at short intervals. The deflection measured was that of the loaded point below the two adjacent joists.

The casters with which heavy pieces of furniture are ordinarily equipped concentrate the weight of such pieces on a very small area. To simulate this condition, load was applied in these tests through a post that was 1 inch square at its bearing on the floor.

Results of Tests

Deflection Tests

The results of the deflection tests are presented in Figure 3. In graph No. 1 of this figure is shown the deflection of the center of the loaded joist (point 4B) under a load of 500 pounds. Graph No. 2 shows the deflections of the center of the loaded joist (point 4) below the line joining the centers of the joists (points 3 and 5) on either side of it. These deflections are measures of the extent to which the covering boards stiffen the panel and cause the joists to act together in carrying concentrated loads. Graph No. 3 presents a measure of the tendency of the boards to draw the joists to a common level.

Small values of the several quantities plotted or low points on the graphs in Figure 3 indicate efficient action of the covering boards. Theoretical considerations indicate that the quantities graphed should decrease considerably from Step 1 to Step 2, and slightly from Step 2 to Step 3, then increase slightly at each step to and including Step 9 with larger increases to Steps 10 and 11. A large decrease from Step 11 to Step 12 of Series 2 followed by slight increases at each succeeding step would also be expected. The full line graphs of Figure 3 represent the actual test results. Where the expected trends differ from the results of the tests they are indicated by dotted lines.

Strength Tests

Flooring.--Figure 4 illustrates some typical load-deflection diagrams obtained from the strength tests. The yield point is reached when the points representing load and deflection begin to bend away from a straight line. In Figure 4 there is also noted the "damage load" of load at which splitting or breakage sufficient to disfigure the floor was first observed. In some instances, as in Figure 4, C, the yield and damage load points are identical; in some, as in Figure 4, D, they are very close together; and in others, as in Figure 4, A and 4, B, they are widely separated. Thus there is in some instances a sudden splitting without warning and in others visible failure is preceded by a gradual yielding. The determinations of damage load, which was intended to be recorded at the first occurrence of splitting sufficient to disfigure the floor and necessitate the replacement of the piece, are subject to considerable uncertainty. Since some splitting no doubt escaped detection and since splits developed very slowly in many instances where visible splitting was preceded by cupping of the surface near the load, it was difficult to estimate just when splitting first occurred. Consequently, no recorded value of damage load is less than the load at which splitting actually occurred.

The points at which loads were applied in the tests (fig. 2) represent a variety of positions of loads with respect to supporting joists and with respect to end and side tongues and grooves. For the purpose of discussion and analysis these several positions are classified into three groups as follows:

A. Points 4, 6,13, and 14 which are not at end joists and which represent flooring laid with all joints on supports. These points, being near the edges of the boards and centered between joists, are the weakest in such a floor.

In laying random length end-matched flooring, joints may occur in any position relative to the joists. The remaining test points represent two such positions and a variety of placements of load relative to the joints and may be considered in two additional groups:

B. Those in which the piece carrying the load crosses and is nailed to at least two joists (points 1, 2, 7, 8, 10, and 11).

C. Those in which the piece carrying the load bears on one joist only (points 5 and 12) and those in which the loaded piece is entirely between joists (points 3 and 9).

Although the number of tests was not sufficient to permit an accurate comparison of flat-grain with edge-grain stock or of 3-inch with 4-inch, examination of the data indicates no significant difference between these two widths or between flat- and rift-sawed stock. Consequently, values for the four classes of flooring tested are not separately reported, the classification being on the basis of groups A, B, and C as defined previously.

Results for each group of points are found to vary widely and the distribution of individual values as well as the averages need to be considered. The data are presented in a form to show not only averages but maximum and minimum values and the frequency of occurrence of values below specified limits. These data given in Tables 1 and 2, and are shown graphically in Figure 5.

Other tests on timber have shown that loads equal to elastic limit or yield point values will cause failure if they remain in place for a long time. Hence the loads at yield point as found in the present tests may be taken as the limit of the loads that can remain in place on a floor without causing breakage.

The damage load, if accurately determined, measures the resistance of the loaded points to damage by temporary loads. Because of the uncertainty of the recorded values of damage load as previously discussed, the mean between this load and the load yield point is probably a better measure of the temporary resistance. This value is tabulated in Table 1 in the third double column under each of the headings Group A, Group B, and Group C.

"Work to yield point" as given in Table 2 is the amount of work or energy that was absorbed up to the yield point. The values are probably quite closely proportional to the amount of shock that could be absorbed without producing stress exceeding the yield point. Tests on wooden beams have shown that both load and deflection at the yield point are somewhat higher for shocks or suddenly applied loads than for slowly applied loads. Consequently, the energy absorbed by a beam stressed to the yield point is 2 or more times as great when the load is applied suddenly, or as a shock, as when it is gradually applied. No tests have been made to determine a proportionality factor between gradually and suddenly applied loads with respect to their effects on floors. Consequently, the values of work to yield point as given in Table 1 are not directly usable for estimating the magnitude of the shocks which the floor can absorb without damage. However, the results of the beam tests mentioned together with other observations indicate that the shocks that can be absorbed without damage considerably exceed in magnitude the values of work to yield point as obtained from the present tests and given in Table 2. These values do afford good comparisons with respect to shock-absorbing capacity and their principal usefulness is for comparing the different groups of points on this basis.

Six-inch stock.--The 6-inch stock tested represents material for construction uses in which appearance is of little importance. Consequently, breaking loads are of more importance than the yield point or damage loads. The maximum loads as determined in tests of the 6-inch material are listed in Table 3. These are the loads which were required to actually push the load post through the floor.

When loading was at Group A points, failures were by splitting of the tongue or groove alongside the load followed by failure in bending of the board carrying the load. Many of the failures at Group A points involved splitting of the board, only the portion under the load post being broken as a beam. With loading at Group B points failures consisted of splitting of end and side tongues and grooves followed by the loaded board breaking in bending over the joists. Many of these failures likewise involved splitting of the board and breakage of part of it as a beam. Most of the failures at Group C points were by splitting and breakage of tongues and grooves followed by pushing the loaded piece down. None of the failures were influenced by defects.

Discussion

Construction Lumber

Deflection tests.--Figure 3 indicates that comparatively little of the "leveling" and stiffening effects of long lumber is lost by the substitution of short material to the extent to which this was done in the steps up to and including

Step 9 of Series 1 and 2. End-matched joints were used in Step 12 at the same points (Nos. 1, 2, and 3) as plain butt joints in Step 6. Comparisons show a slight superiority of the end-matched joints with respect to each of the three quantities graphed. This superiority continued when plain butt joints were added at points 4, 5, and 6 (Steps 7, 8, and 9, and 13, 14, and 15) and as the tongues in longitudinal joints were ripped (Steps 10 and 16).

Placing boards with tongue to tongue and groove to groove as in Step 2 is practically equivalent to using square-edged boards with cracks of about 1/4 inch between them. In step 3 boards were laid regular side-matched stock, that is, with groove to tongue. Comparisons indicate no more improvement of Step 3 over Step 2 than would be expected merely from the closer spacing of the boards. In other words, side-matched stock in long lengths is little, if any, better with respect to the effects studied in these tests than square-edged boards in the same lengths. On the other hand, the changes in the graphs from Step 9 to Step 10 show that in short lengths the side-matched stock is considerably superior since the side-matched stock in Step 9 gave much better results than when it had been reduced to the equivalent of square-edge by ripping the tongues at Step 10. The small effect of the change (ripping the tongues) from Step 15 to Step 16 (end-matched joints at points 1, 2, and 3, and plain butt joints at points 4, 5, and 6) as compared to the effect of the change from Step 9 to Step 10 (butt joints at points 1 to 6, inclusive) indicates that, if square-edge stock were laid with end joints at random, end-matching would be a distinct advantage.

In order to interpret these tests and conclusions in terms of actual construction with end-matched lumber the lengths represented by the tests must be compared with the lengths produced in the manufacture of end-matched stock.

The method used for computing the average lengths of boards represented by the test panels at the various steps may be illustrated by an example. Suppose that a large surface is covered with boards of random lengths but that all that can be seen of this sufface is a section 24 boards wide and 10 feet long, involving 240 lineal feet of boards. If the section is assumed to be an average one and 20 joints are found in it, the average length of board would be estimated as $\frac{240}{20}$ or 12 feet, since there would be one end joint for each board. Application of this method to the panels tested which were 26 boards wide and 8 feet long gives the following:

Step	Number of joints in panel	Average length of board represented
2 and 3	0	"very great"
4	14	14'-10"
5	26	8'-0"
6 and 12	40	5'-2"
7 and 13	52	4'-0"
8 and 14	66	3'-2"
9, 10, 15, and 16	78	2'-8"

An estimate of the lengths of end-matched 6-inch stock may be had from Table 4 which represent three cars (73,000 feet b.m. total) of No. 2 Common 6-inch center-matched stock shipped by a southern pine mill to a contractor for use in concrete forms. Table 5, which is based on shipments from the same mill, is similar tally for 10 cars including 250,000 feet b.m.[4]

From the data on lengths of end-matched lumber[5] shipped it is seen that the tests at Steps 6 to 10 and 12 to 16 represent average lengths considerably below that which is likely to be produced; even if a maximum length of about 10 feet is adopted. The joints in the panels tested, however, were uniformly and systematically placed. Obviously, this could not conveniently be done in the actual use of end-matched lumber. Yet if reasonable attention and judgment with respect to distribution of joints were exercised in placing end-matched lumber of lengths as now produced, or as they would be produced if the maximum length were reduced to 10 feet, the average length in any considerable area would seldom be less than the least average length represented in the tests. The lower the average length of the material available, however, the greater will be the care required to get a good distribution of joints.

The tests apparently indicate that there is little danger of any significant loss of the leveling and stiffening effects of covering lumber because of any reduction in average length which is likely to accompany the development of end-matching. Some factors which have not been discussed need consideration before accepting such a conclusion.

The carpenter applying sheathing lumber may consider that comparatively short spaces between wall openings should be covered with full-length pieces. In carrying out such a practice the proportion of short pieces to be used up in larger areas of the surface will be increased.

The tests were made on lumber with closer fitting side tongues and of more uniform width than the construction lumber being end-matched. Furthermore, the covering lumber was not subjected to appreciable changes in moisture content whereas such lumber undergoes large fluctuations in moisture content during construction. Variations of considerable magnitude likewise occur in connection with plastering and even after the building is occupied. Such fluctuations cause repeated alternations of shrinking and swelling, and these reduce the holding value of nails, and reduce the margin of superiority of side-matched over square-edge stock.

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[4] The manufacturer who supplied the data of Tables 4 and 5 states that the average length of 1 x 6 No. 2 Common shipped from their mill before the adoption of end-matching was slightly over 14 feet. This stock was not, however, 100 percent usable as shipped and the average length installed in buildings or other construction was no doubt considerably less.

[5] The shorter length stock has been marketed to some extent in an assortment consisting of 2- to 7-foot bundles, leaving the longer stock to be sold separately. The average length of 2- to 7-foot bundles as listed in Table 5 is slightly under 4 feet 6 inches.

Strength tests.--Table 3 shows clearly the higher strength of boards continuous between joists (Group A) as compared to those jointed between joists. Loads also average somewhat higher for Group B than for Group C points although the minimum value is lower for Group B.

Load was applied in these tests to an area 1 inch square and close to the edge of the board. Most of the failures at Group A and B points were by splitting alongside the load post, which left only a narrow strip of the loaded board to be broken in bending over the adjacent joist. Failures at Group C points were mostly due to splitting of side and end tongues and grooves, which is all that is required to permit the loaded piece to be pushed down. Ordinarily, the loads and shocks to which such joints are subjected during construction do not come on so small an area. Consequently, the bending strength of the entire width of the board at points such as those of Groups A and B will usually be available to support the load after all tongues and grooves are broken and considerably higher loads than recorded in Table 3 will be required to cause complete failure by loading at these points. Similar increase would not occur with respect to Group C points because after the tongues and grooves are broken very little resistance is left. Furthermore, successive shocks and blows after the lumber is in place may break the tongues and grooves around a suspended piece (points 3 and 9) or a piece with rests on but a single support (points 5 and 12) but leave it in place with little to indicate a weakness. Tongues and grooves may likewise be split in handling the lumber before it is put in place or may be seriously weakened by seasoning checks. Such a piece constitutes a danger to men working or handling heavy materials on a subfloor or on roof sheathing.

Flooring

Tables 1 and 2 and Figure 5 afford a comparison of the strength of floors made of random length end-matched stock with the loads which floors may be required to support.

The heaviest concentrated loads on residence floors are probably bookcases and pianos. Definite information on the weights of bookcases is not available but the weight on a bookcase leg probably is seldom as great as may be on the leg of a heavy piano. Furthermore, a bookcase ordinarily has four or more legs, and if one of them is on a weak place in the floor the yielding of the floor will transfer the weight to the other legs. A grand piano has only three legs and consequently a floor supporting it must be strong enough to support any one of the legs. A prominent piano manufacturer has supplied data showing that the greatest weight on a single leg of any instrument of this make is about 390 pounds on the right front leg of the largest grand piano. The next heaviest load on a leg of a grand piano of this manufacture is about 350 pounds. Several player grands have weight on a single leg exceeding 300 pounds. The data from the tests show that loads at yield point were all above 450 pounds for Group A points and indicate that the yield point loads were below 390 pounds for 31 percent of the Group C points and for 23 percent of the Group B points with a minimum value of 250 pounds in each of these groups.

End-matched southern pine flooring has been sold in two length assortments, (a) bundles 2 to 7 feet long, minimum length of piece about 18 inches and (b) bundles 5 to 16 feet long.

Tables 6 and 7 are tallies of five carloads of each of these assortments. With assortment (a) there would be an average of 1,165 joints, and for assortment (b) an average of 476 end joints for each 1,000 square feet of floor area. Table 8 is derived from the data on loads at yield point from Table 1 combined with the information on lengths of stock in the two assortments as given in Tables 6 and 7.

The estimates for assortment (a) in Table 8 are based on the assumption that pieces shorter than 30 inches are placed without any care being exercised to give them bearing on two joists. If such pieces are placed to cross two joists and are nailed to the joists the number in the (a) column would be reduced slightly. Numbers in both columns would be about 30 percent less for 4-inch flooring because of the smaller number of joints. The numbers in Table 8 are the number of joints that would be incapable of supporting the designated loads for a long time. Table 8 applies to the average floor of the specified area made from stock of the two length assortments. Obviously some floors are likely to have more and others fewer of the weak joints. Breakage of the floor is a matter of chance depending on whether weights of heavy pieces of furniture or other heavy loads are concentrated on small areas adjacent to the weak joints. The presence of relatively large numbers of joints that are subject to being broken sufficiently to disfigure the floor and to necessitate repair renders the use of end-matched flooring laid directly on joists spaced 16 inches, or on furring strips similarly spaced and laid on top of the subfloor, of doubtful advisability.

These tests were on nominal 1-inch flooring with joists spaced 16 inches. If thicker flooring, such as nominal 1-1/4-inch, is used the minimum load values would be considerably increased and the frequency of yield point loads below 400 pounds would be very greatly reduced. Closer spacing of supports would also increase the minimum values and decrease the frequency of low values.

The relatively low shock resistance of Group C joints compared to Group A and Group B joints as indicated by Table 2, and the fact that the strength of Group C joints depends entirely on the strength of the tongues and grooves, emphasizes the undesirability of joints of the type of Group C (pieces completely suspended and pieces having bearing on but one joist), and indicating that each piece of flooring should cross and be nailed to at least two joists.

Resume

It is evident from the tests that random length end-matched lumber may be used in lieu of so-called standard length lumber jointed on supports for such purposes as subflooring, wall sheathing, roof sheathing, and concrete forms without appreciable loss of efficiency in distributing concentrated loads, stiffening the construction, and improving the alignment of joists, studs, or rafters, provided no more short pieces are included than are necessary for the elimination of loose knots, knot holes, or other defects which extend through the board.

The segregation and separate marketing of short lengths, which has been practiced to some extent, seems undesirable because of the low average length of boards in lots composed exclusively of short pieces. Furthermore, it is doubtful if the actual service value with respect to the effects tested of the remaining stock is appreciably higher than that of stock consisting of a full assortment of lengths.

The tests indicate that pieces which are suspended between joists or rafters, or pieces which cross and are nailed to but one such support, are a source of danger to men working on roof sheathing or an a subfloor. Such pieces, furthermore, when used in wall or roof sheathing, afford an insecure base for the attachment of shingles or other covering. This is more particularly true of roofs if rafter spacing is wider than 16 inches as is frequently the case.

No tests were made to establish comparisons between walls sheathed with short and random length end-matched lumber and walls sheathed with standard length stock with respect to their resistance to diagonal distortion. Such tests will probably be included in a series now being made on wall panels of different constructions.

Tests have not been made to compare concrete cast against forms made of end-matched lumber with concrete cast against forms made of standard length lumber jointed on supports. Forms made of end-matched stock would permit the formation of a greater number of comparatively small lumps and irregularities, the undesirability of which would depend upon the character of surface desired. Such comparisons between end-matched and standard length lumber can be more readily obtained from actual service tests and observations than from laboratory experiments.

The tests show that an appreciable percentage of unsupported end-matched joints in southern pine flooring are subject to failure of sufficient extent to produce disfigurement of the floor under concentrated loads no greater than are fairly common in the living rooms of a residence building. This indicates that the use in these rooms of such end-matched flooring laid directly on joists or on furring strips nailed to the subfloor is of questionable advisability. The flooring tested was quite free from cross grain at the ends. If in the production of end-matched flooring knots are trimmed close enough to leave cross grain at the end of the piece, the strength of end-matched joints will be reduced. None of the test loads are low enough to indicate appreciable danger of damage to end-matched floor laid directly on the joists when used in bedrooms under ordinary service conditions.

In placing end-matched lumber as roof sheathing, subflooring, or finish flooring without subfloor, end joints in adjacent boards should not be permitted in the same space between joists or rafters and each piece should cross and be securely nailed to at least two joists or rafters. If the finish floor is laid on furring strips on a subfloor, a piece of furring strip should be nailed in place under each joint.

Table 1.—Frequency distribution of values of loads in strength tests of 3 and 4-inch flat and edge-grain flooring.

Number and per cent of tests yielding results at or below values listed in first column

Group A—Points 4, 6, 13, 14

Load	Yield point		Damage load		(Yield point + damage load) ÷ 2	
	Number	Per cent	Number	Per cent	Number	Per cent
Pounds						
200	...	....	...	....	...	....
300	...	....	...	....	...	....
400	...	....	...	....	...	....
500	4	3.6	...	....	...	....
600	5	4.5	2	1.8	2	1.8
700	23	20.5	8	7.1	9	8.0
800	40	35.7	24	21.4	30	26.8
900	61	54.5	39	34.8	44	39.3
1,000	79	70.5	51	45.5	60	53.5
1,100	95	84.7	67	59.7	78	69.5
1,200	106	94.5	85	75.8	95	84.6
1,300	108	96.3	94	83.9	103	92.0
1,400	110	98.2	98	87.5	106	94.5
1,500	112	100.0	105	93.7	111	99.1
1,600	...	....	108	96.3	112	100.0
1,700	...	....	112	100.0	...	....
1,800	...	....	...	....	...	....
Average	912		1,063		988	
Maximum	1,500		1,700		1,545	
Minimum	450		550		525	

Group B—Points 1, 2, 7, 8, 10, 11

Load	Yield point		Damage load		(Yield point + damage load) ÷ 2	
	Number	Per cent	Number	Per cent	Number	Per cent
Pounds						
200	...	....	...	....	...	....
300	8	4.8	...	....	...	....
400	43	25.6	11	6.5	19	11.3
500	91	54.0	49	29.1	60	35.7
600	128	76.1	80	47.5	99	58.8
700	153	91.0	113	67.2	132	78.5
800	165	98.2	136	80.9	151	89.8
900	167	99.4	152	90.5	161	95.8
1,000	167	99.4	158	94.0	166	98.8
1,100	168	100.0	164	97.5	167	99.4
1,200	...	....	166	98.8	168	100.0
1,300	...	....	168	100.0	...	....
1,400	...	....	...	....	...	....
1,500	...	....	...	....	...	....
1,600	...	....	...	....	...	....
1,700	...	....	...	....	...	....
1,800	...	....	...	....	...	....
Average	529		656		593	
Maximum	1,050		1,250		1,150	
Minimum	250		350		340	

Group C—Points 3, 5, 9, 12

Load	Yield point		Damage load		(Yield point + damage load) ÷ 2	
	Number	Per cent	Number	Per cent	Number	Per cent
Pounds						
200	...	....	...	....	...	....
300	14	12.5	...	....	1	.9
400	38	33.9	12	10.8	19	16.9
500	75	66.9	47	41.9	51	45.5
600	100	89.1	78	69.5	90	80.2
700	108	96.3	101	90.0	104	92.8
800	110	98.2	105	93.6	109	97.4
900	112	100.0	111	99.1	112	100.0
1,000	...	....	112	100.0	...	....
1,100	...	....	...	....	...	....
1,200	...	....	...	....	...	....
1,300	...	....	...	....	...	....
1,400	...	....	...	....	...	....
1,500	...	....	...	....	...	....
1,600	...	....	...	....	...	....
1,700	...	....	...	....	...	....
1,800	...	....	...	....	...	....
Average	480		567		524	
Maximum	850		1,000		875	
Minimum	250		350		300	

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Table 2.--Frequency distribution of values of work to yield point in strength tests of 3- and 4-inch flat and edge-grain.

Work to yield point	Number and percent of tests yielding results at or below value listed in first column					
	Group A Points 4,6,13,14		Group B Points 1,2,7,8,10,11		Group C Points 3,5,9,12	
Inch-pounds	Number	Percent	Number	Percent	Number	Percent
7.5			3	1.8	9	8.0
15.0			34	20.2	40	35.7
22.5	3	2.7	102	60.7	71	63.4
30.0	6	5.4	137	81.4	98	87.4
37.5	8	7.1	151	90.0	105	94.6
45.0	20	17.8	159	94.6	111	99.1
52.5	32	27.6	165	98.2	112	100.0
60.0	43	38.4	167	99.4		
67.5	56	50.0	167	99.4		
75.0	72	64.3	167	99.4		
82.5	82	73.2	168	100.0		
90.0	90	80.4				
97.5	95	84.9				
105.0	103	91.9				
112.5	107	95.4				
120.0	108	96.3				
127.5	108	96.3				
135.0	108	96.3				
142.5	108	96.3				
150.0	108	96.3				
157.5	110	98.1				
165.0	112	100.0				
	Work to yield point		Work to yield point		Work to yield point	
Average	70.1		23.1		20.3	
Maximum	161.7		76.0		49.0	
Minimum	17.5		6.2		2.5	

Table 3.--Maximum loads in tests of 6-inch center-matched and end-matched stock.

Panel number	Group A Points				Group B Points						Group C Points			
	4	6	13	14	1	2	7	8	10	11	3	5	9	12
	Maximum loads -- pounds													
9	1590	1600	1175	1630	1165	840	1080	780	495	845	930	660	665	735
10	1650	1235	1600	1900	800	640	765	530	1170	1000		650	650	700
31	2125	2200	1775	2190	1445	1040	1090	940	850	1085	750	975	815	735
32	1950	1200			860					985	900	890		650
33											1085			
34														
Average	1830	1560	1520	1910	1070	840	945	750	840	980	915	795	710	730
Maximum	2125	2200	1775	2190	1445	1040	1090	940	1170	1085	1085	975	815	735
Minimum	1590	1200	1175	1630	800	640	765	530	495	845	750	650	650	650

	Group A	Group B	Group C
Average	1700	925	785
Maximum	2200	1445	1085
Minimum	1200	495	650

Average for points 1, 7, 11 (midway between joists) = 1020 pounds
Average for points 2, 8, 10 (close to joists) = 810 pounds
Average for points 3, 9 (suspended pieces) = 825 pounds
Average for points 5, 12 (pieces bearing on one joist) = 750 pounds

Table 4.--Tally of bundles in three cars of 6-inch No. 2 Common center-matched end-matched southern pine.

Length of bundles	Number of bundles	Number X length= lineal feet of bundle
Feet		
2	249	298
3	338	1014
4	467	1868
5	292	1460
6	221	1326
7	297	2079
8	352	2816
9	264	2376
10	236	2360
11	214	2354
12	364	4368
13	117	1521
14	180	2520
15	75	1125
16	556	8896
Totals	4222	36,581

Average length = 36,581 ÷ 4222 = 8' - 8"

Number of bundles 11 feet and longer 1506

Number of bundles if all stock 11 feet and longer were cut in two 5728

If all stock 11 feet and longer were cut in two the average length would be 36,581 ÷ 5728 = 6' - 5"

Table 5.--Tally of bundles in 10 cars of 6-inch No. 2 Common center-matched end-matched southern pine.

Length of bundles	Number of bundles	Number X length = lineal feet of bundle
Feet		
2	571	1142
3	821	2463
4	917	3668
5	726	3630
6	744	4464
7	604	4228
8	635	5080
9	843	7597
10	432	4320
11	552	6072
12	1076	12912
13	518	6734
14	1569	21966
15	166	2490
16	2429	38864
Totals	12,603	125,620

Average length = 125,620 ÷ 12,603 = 10' - 0"

Number of bundles 11 feet and longer	6,310
Number of bundles if all stock 11 feet and longer were cut in two	18,913

If all stock 11 feet and longer were cut in two average length would be 125,602 ÷ 18,913 = 6' - 8"

Table 6.--Tally of bundles in 5 cars of 1 inch by 3 inch end-matched southern pine flooring. Bundles 2 feet to 7 feet long.

Length of bundles	Number of bundles	Number X length = lineal feet of bundles
2	3,144	6,288
3	3,554	10,662
4	4,094	16,376
5	3,470	17,350
6	3,008	18,048
7	2,118	14,826
	19,388	83,550

Average length = $\frac{83550'}{19388}$ = 4' - 4"

Table 7.--Tally of bundles in 5 cars of 1 inch by 3 inch end-matched southern pine flooring. Bundles 5 feet to 16 feet long.

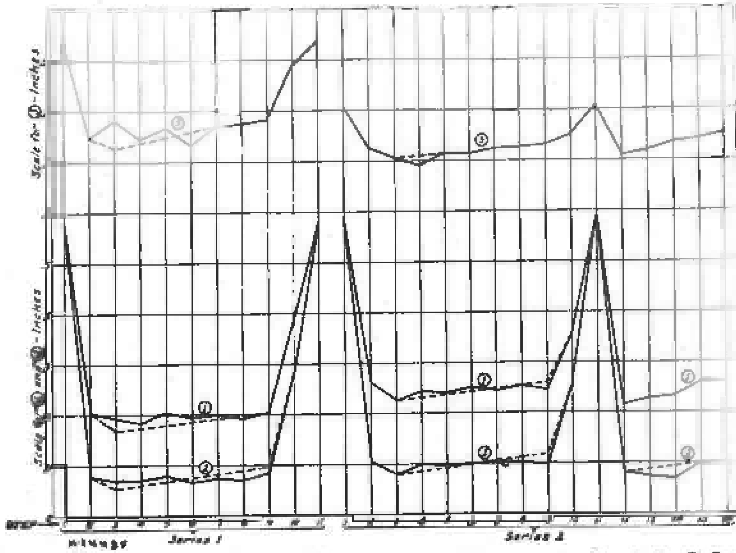
Length of bundles	Number of bundles	Number X length = lineal feet of bundle
5	668	3,340
6	559	3,354
7	440	3,080
8	791	6,328
9	752	6,768
10	511	5,110
11	508	5,588
12	528	6,336
13	586	7,618
14	631	8,834
15	302	4,530
16	986	15,776
	7,262	76,662

Average length = $\frac{76662'}{7262}$ = 10' - 7"

Table 8.--Estimated number of joints in room 192 square feet in area, 12 by 16 feet for example, that would be subject to failure at the designated load if the floor was laid from nominal 1 by 3 inch flooring of length assortments a and b on joists spaced 16 inches center to center.[1]

Load	a	b
390	41	16
350	24	9
300	12	4
250	5	2
200	2	1

[1] The average floor of this size would have 224 end joints if made of assortment a, and 90 if made of assortment b.



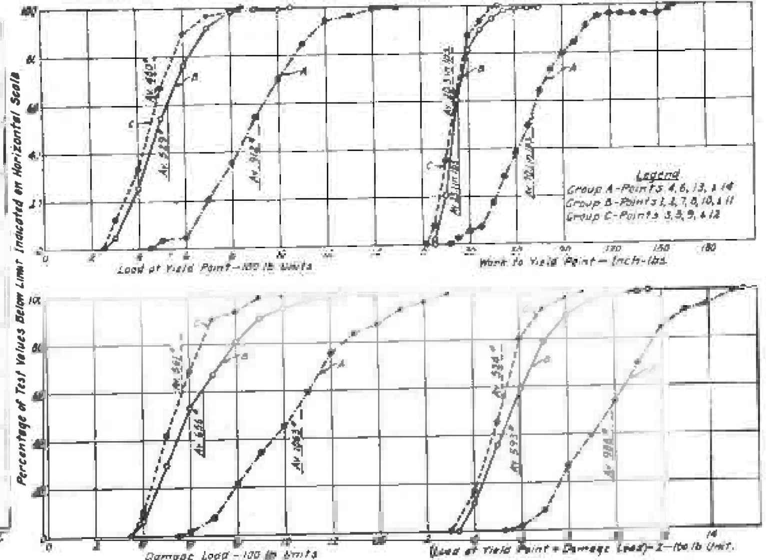


Fig. 3 (Left)—Results of deflection tests of floor panel. Graph 1—Deflection of center of loaded joist (500-pound load). Graph 2—Deflection of center of loaded joist below line joining centers of adjacent joists (500-pound load). Graph 3—Average (root-mean-square) deviation of joists' centers from their common level. Fig. 5—Results of tests on the strength of end-matched joints in flooring.

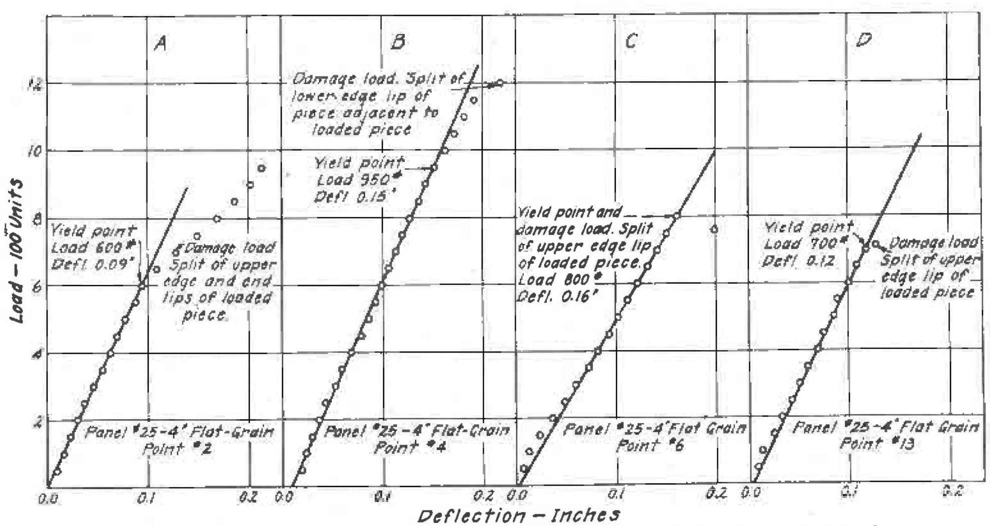


Fig. 4—Loaded deflection diagrams obtained in "strength tests" of end-matched lumber.

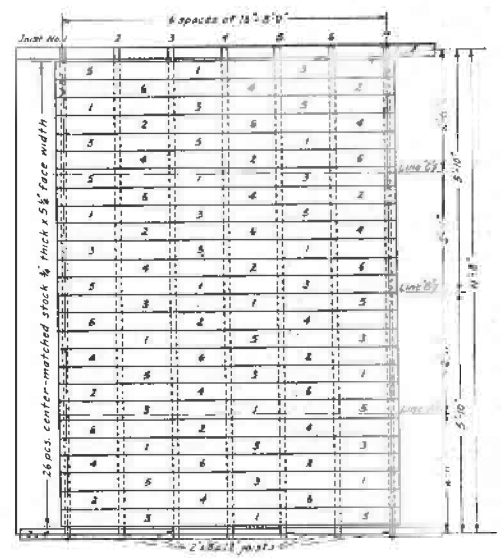


Fig. 1—Floor panel for deflection tests.

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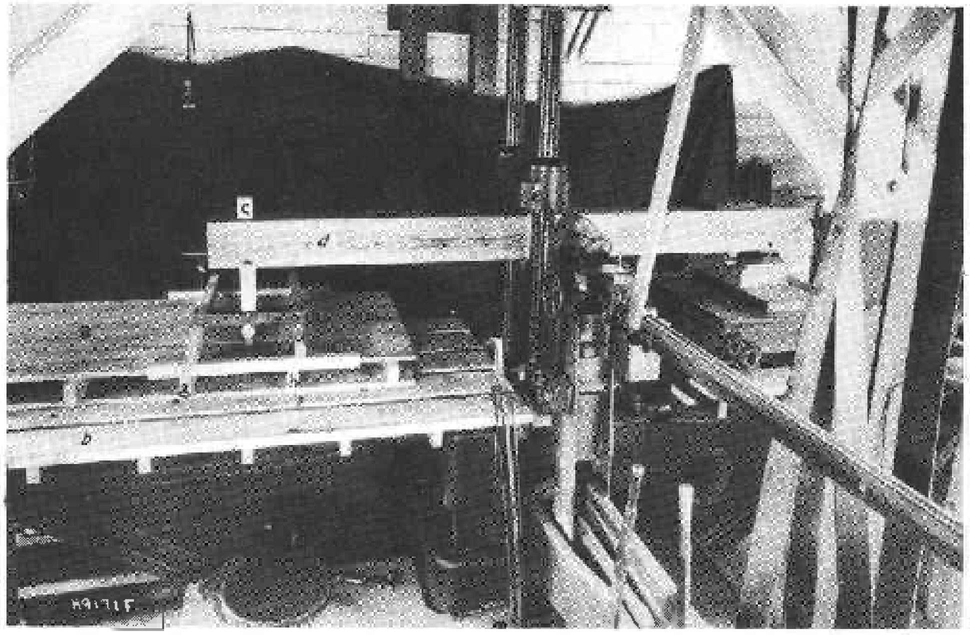

PLATE 1—PANEL TESTING APPARATUS

a. Test panel. b. Supporting structure resting on platform of 100,000-pound testing machine. c. Load post with end 1-inch square. d. Straining beam the left-hand end of which carries the load post and the right-hand end of which is supported on the platform scale on which the load was measued. e. Pulling head of testing machine. f. Instrument for reading deflection of loaded point below joists (g and h) on either side of it.

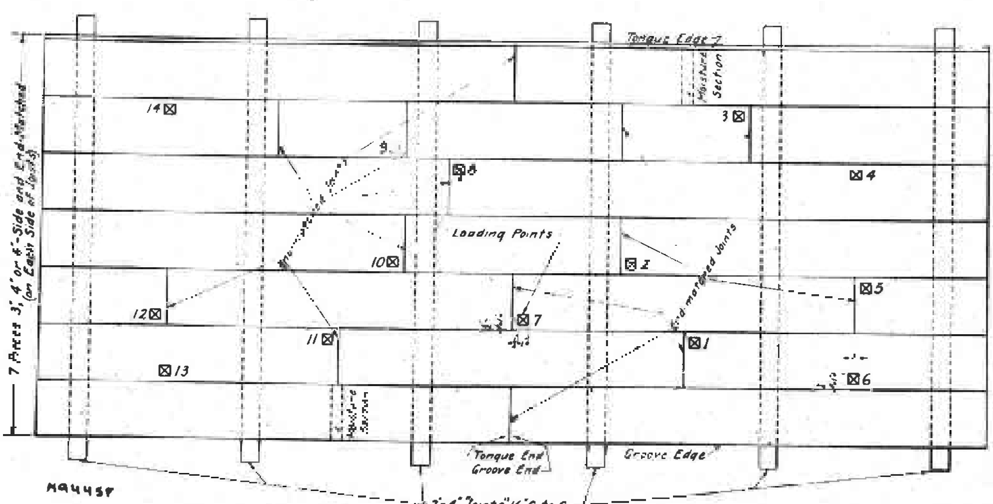

Fig. 2—Floor panel for tests of strength of end-matched joints.

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