Evaluating wood failure in plywood shear by optical image analysis

Technical Note

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Abstract

This exploratory study evaluates the potential of using an automatic image analysis method to measure percent wood failure in plywood shear specimens. The results suggest that this method may be as accurate as the visual method in tracking long-term gluebond quality. With further refinement, the method could lead to automated equipment replacing the subjective visual method now used throughout the industry.

In both industrial quality control applications and in research, the integrity of the plywood gluebond is frequently evaluated by measuring strength in shear and percent wood failure. While shear strength can be measured with considerable accuracy, percent wood failure is subjectively estimated by visual inspection of the failure surfaces. It is generally held that these measurements can contain considerable inaccuracies due to different interpretations between evaluators, evaluator fatigue and boredom, and inability of the human eye to quantify small differences between specimens.

Instruments using optical, video, electronic, and computer components have recently been developed to automatically and rapidly make quantitative measurements from images with minimal operator interaction. The instruments are ideally suited to measurement of area and area proportion.

The purpose of this exploratory experiment was to evaluate the potential of using an automatic image analysis method to measure percent wood failure in plywood shear.

Method

A general description of the automatic image analyzer used in this study has been provided by McMillin.[1] Briefly, the operator obtains a video image of the specimen at an appropriate magnification and initiates a software program to calibrate the system. Threshold controls are then adjusted to the desired detection level, and a series of keyboard commands are used to instruct the computer regarding the type of measurement to be made and the form of the analysis. The operator then issues a single command to measure the detected feature in a preselected field of view.

Figure 1A shows the video image of the failure surface of a southern pine plywood shear specimen, the field of analysis being defined by the dark vertical and horizontal lines. Wood appears as light colored areas while the phenolic adhesive appears as the dark areas. Plywood bonded with urea resin may lack sufficient contrast between wood and adhesive to property threshold although a dye could be incorporated to enhance contrast.

Figure 1B shows the video image when the threshold level was adjusted to detect light portions of the image representing wood failure. The ratio of the white area to total field area is proportion of wood failure, and it was measured in this example as 72.7 percent. The surface was judged 70 percent wood failure by independent visual evaluation.

Three hundred and twenty southern pine plywood sheathing shear samples bonded with phenolic adhesive were tested to failure and then visually evaluated for percent wood failure by the American Plywood Association. In this limited test, all specimens were tested dry. No consideration was given to specimens tested after a vacuum-pressure-soak treatment or after a boil-dry-boil cycle. These treatments may alter the contrast between wood and resin and affect thresholding.

[1]McMillin, C.W. 1982. Application of automatic image analysis to wood science. Wood Sci. 14(3):97-105.

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Forest Prod. J. 34(7/8):67-69.

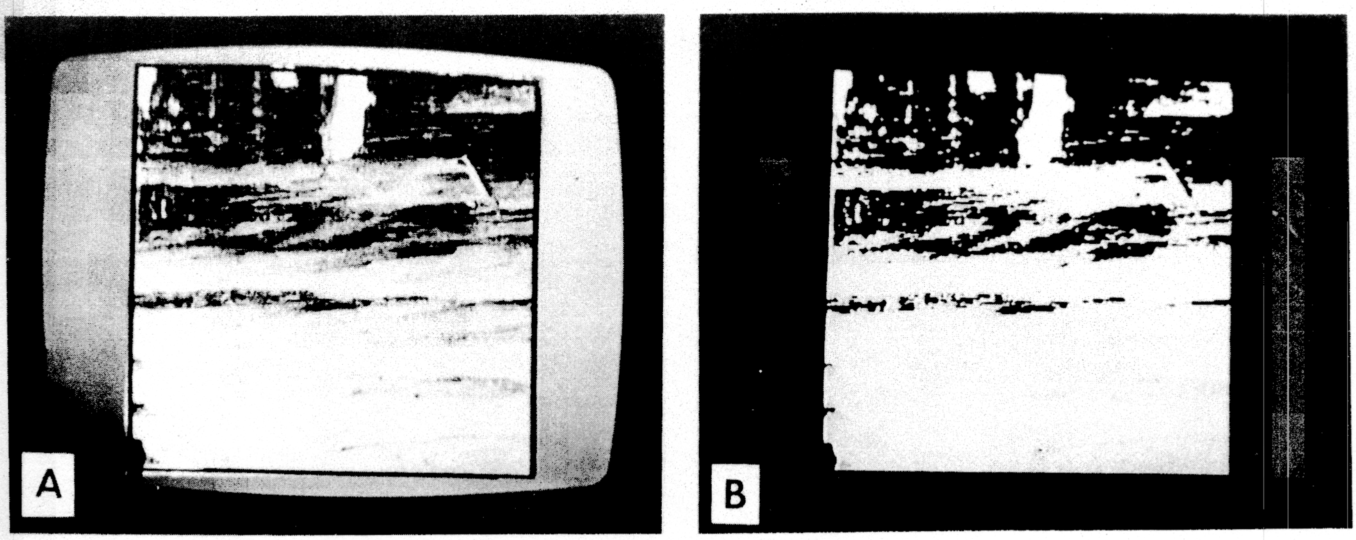

Figure 1. — Analysis for percent wood failure in plywood shear specimen: A) Video image of failure surface; B) Video image of detected wood failure.

The samples were obtained in groups of 20 over a 16-week period and represent the normal inspection procedure followed by the APA. The specimens were then evaluated for percent wood failure using the automatic image analysis method just described. Each of the two failure surfaces was measured separately and the results were averaged. A second 52-specimen sample provided by the APA contained a broader range of wood failure (45% to 90%) and was also evaluated by the computer method.

Results

Figure 2 shows the relationship between percent wood failure obtained by the visual and computer methods over a wide range of values. The points plotted are average values; the number of observations is shown in parentheses beside each point. Regression analysis of the complete data set yielded the following equation:

$$Computer = 1.2909\ (Visual) - 24.2322$$

The correlation coefficient was 0.89, and the relationship was significant at the 0.05 level. The result indicates that the computer method could be used over a wide range of values with reasonable accuracy.

Table 1 shows mean percent wood failure by the visual and the computer method for the 320 samples taken over a 16-week period. (Each value consists of 20 observations.) By the t-test, underlined pairs of values are not significantly different at the 0.05 level. Of the seven data pairs that were significantly different, the absolute percentage point difference was only 7 or less with four pairs being 4 percentage points or less.

In practice, percent wood failure is usually tracked by a running cumulative average with each value consisting of the average values for 5 successive weeks. At the end of the 5th week, the 1st week is deleted, the 2nd through 6th weeks are included, and so on. The weekly values in Table 1 were thus averaged and the results presented in Table 2.

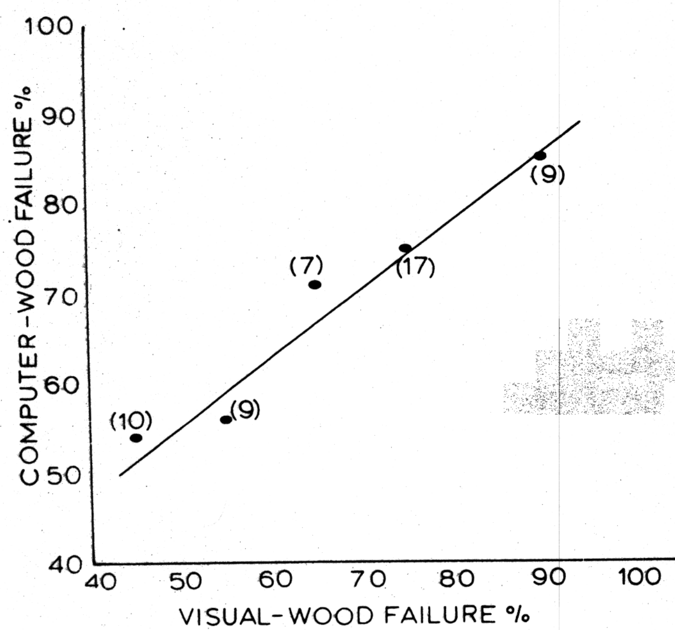

Figure 2. — Relationship between percent wood failure obtained by the visual and computer methods over a wide range of values. Points plotted are average while the value's number of observations is shown in parentheses beside each point.

With the exception of the first two data pairs in Table 2, there was no significant difference between the visual and the computer methods of evaluating wood failure. The result suggests that, given a sufficient number of observations, the computer method may be as accurate as the visual method in tracking long-term gluebond quality.

It should be noted that the computer method used here does require the operator to make a subjective determination of the proper threshold level needed to

TABLE 1. — *Mean percent wood failure by visual and computer methods for 320 samples taken over a 16-week period. Each value consists of 20 observations.*[a]

Week	Visual	Computer
	(%)	
1	94	88
2	96	89
3	92	86
4	92	87
5	90	87
6	92	90
7	96	94
8	87	87
9	89	88
10	93	90
11	99	97
12	80	84
13	87	91
14	96	94
15	96	95
16	96	96

[a]Underlined values are not significantly different at 0.05 level.

TABLE 2. — *Cumulative running average wood failure by visual and computer methods.*[a]

Visual	Computer
(%)	
93	87
92	88
92	89
91	89
91	89
91	90
93	91
90	89
90	90
91	91
92	92
91	92

[a]Underlined values are not significantly different at the 0.05 level.

detect wood from adhesive. While not tested, the degree of subjectivity and training required to make the evaluation is clearly less than by the visual method. In a brief nonstatistical test, two nonexperienced operators using the computer method obtained very similar results on a variety of samples, while two different experienced estimators using the visual method frequently arrived at widely divergent estimates. Refinement of the computer method could lead to an automatic way to set the threshold and further reduce subjective judgments associated with the measurement. Other methods of determining optical tonal properties are also available that do not rely on thresholding.