

IN-PLACE EVALUATION OF FIRE-RETARDANT-TREATED PLYWOOD

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ABSTRACT

This paper reviews research on nondestructive testing techniques for in-place assessment of the performance of fire-retardant-treated (FRT) plywood. Two techniques are described in particular: the bending proof load test and the probe or screw withdrawal test. These techniques are currently being used by professionals who inspect roof systems that use FRT plywood.

INTRODUCTION

Engineered wood roof systems using FRT plywood are often used in multiple family dwellings and for light to medium commercial construction. Recently, some FRT plywood used for roof sheathing has exhibited ongoing, in-service strength reductions. In these cases, the plywood has become brittle, has crumbled easily, and has darkened. The length of service before these problems occurred has varied from 1 to 8 years. Consequently, considerable concern has been expressed about the in-place strength of all FRT plywood. Moreover, building inspectors have been frustrated by the lack of low-cost nondestructive testing (NDT) tools for assessing the residual strength of in-place FRT plywood.

This paper reviews recent research on FRT plywood and describes two NDT techniques presently used by building inspectors.

RECENT RESEARCH

Tables 1 and 2 summarize recent published research on the development of NDT techniques for in-place assessment of FRT plywood. Note that a variety of techniques have been investigated. Several techniques have shown considerable promise.

American Plywood Association

The most comprehensive effort towards the development of NDT techniques was sponsored by the American Plywood Association (APA) (1989a,b) (Table 1). The APA funded efforts to investigate the feasibility of using visible and infrared light, chemical analysis, and stress wave techniques. The efforts of research cooperators revealed that several specific wavelengths of infrared light, holocellulose content, and absorption properties of stress waves were all sensitive to thermal degradation of FRT plywood. However, several problems associated with these NDT methods have limited their application. For example, correlations would be required for each chemi-

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Table 1—Cooperative research on nondestructive evaluation of FRT plywood sponsored by American Plywood Association

Cooperator	NDT technique	NDT parameter	Results	Comments
University of New Hampshire	Visible light	Color	Visible color measurement considered questionable.	-
	Near infrared spectroscopy	Spectral analysis of 800–1,400 nm and 1,100–2,500 nm bands	Several wavelengths appeared sensitive to thermal exposure of FRT plywood.	Test modest in cost. Response directly related to chemistry of wood. Separate correlations required for each chemical formulation. Trained chemist required for interpreting results.
North Carolina State University	Chemical analysis	Holocellulose and alpha cellulose content, degree of polymerization	All parameters showed dramatic changes in response to degradation. Holocellulose content was a good indicator of general condition of plywood.	Test costly. Correlations required for each chemical formulation. Tests can be run at a limited number of laboratories and require a trained chemist for interpreting results.
University of California, Forest Products Laboratory	Stress wave acousto-ultrasonics	Energy absorption (signal strength)	Good correlation with residual strength.	-
Engineering Data Management, Inc., Fort Collins, CO	Stress wave	Energy absorption	Good correlation with residual strength.	-
APA Staff	Stress wave	Speed of sound transmission	Poor correlation with residual strength.	Stress wave techniques generally promising. Considerable effort required for furthering techniques, particularly in regard to boundary conditions and their effect on wave behavior.

cal formulation if infrared light techniques were used, and results of chemical analysis techniques would require interpretation by a trained chemist. Stress wave techniques have shown considerable promise in other applications, such as assessing the residual strength of biologically degraded wood members, but the parameter most sensitive to thermal degradation of FRT plywood is also influenced significantly by the manner in which the plywood sheet is attached to other members of the structure.

Forest Products Laboratory

The USDA Forest Service, Forest Products Laboratory (FPL), has devoted considerable effort to developing in-place evaluation techniques as well as to identifying the causes of FRT plywood degradation. This effort has served to verify results obtained by APA-sponsored studies and has resulted in the use of an in-place assessment technique by building inspectors. Research has focused on several general areas (Table 2). In an extensive study aimed at examining the relationship between thermal-degradation-induced chemical changes and mechanical properties of FRT wood, we found strong relationships between acid-soluble lignin content and specific sugar components and mechanical properties. In addition, we found a strong relationship between energy absorption as measured by stress wave techniques and residual strength of FRT wood.

CURRENT NONDESTRUCTIVE TESTING TECHNIQUES

Two NDT techniques evolved from research by the APA and the FPL: the bending proof load test and the probe or screw withdrawal test (Table 3).

Bending Proof Load Test

The APA research resulted in the development of a commercially available device that applies a bending proof load to suspect plywood sections of roof systems. This technique is based on the belief that a panel section should be able to support the load required to meet minimum performance standards. If the load can be supported, then the panel is deemed acceptable and it is not replaced.

Probe or Screw Withdrawal Test

The FPL research focused on the development of a simple screw or probe extraction test for estimating residual bending strength. Such a test was originally developed by Talbott (1982) to estimate the residual strength of wood subjected to brown-rot decay fungi. Talbott hypothesized that a correlative relationship should exist between withdrawal resistance and residual strength. He conducted an experiment using several small Douglas-fir beams in various stages of degradation as a result of exposure to decay fungi. Probe withdrawal resistance was measured on the neutral axis of the beams prior to testing to failure in bending. Bending strength and corresponding probe resistance values were then compared. Talbott's results revealed that withdrawal resistance is in fact related to residual strength (Fig. 1).

To examine the validity of Talbott's test for the case of FRT plywood, we conducted an experiment with nearly 200 plywood specimens in various stages of degradation. The specimens were obtained from commercial material removed from defective roofs and from laboratory material exposed to elevated temperatures. A more thorough description of the laboratory-degraded material was reported previously (Winandy and others 1991). Both screw withdrawal and bending tests were performed on these specimens according to standard American Standards for Testing and Materials (ASTM) procedures. Screw withdrawal and corresponding bending strength values for the specimens are shown in Figure 2. Note the relationship between the two values. Our regression analysis yielded a correlation coefficient of 0.80.

Table 2—Research on nondestructive evaluation of FRT plywood conducted by Forest Products Laboratory

Study	NDT technique	NDT parameter	Results	Comments
LeVan and others (1990)	Chemical analysis	Klason lignin, acid-soluble lignin, glucose, xylose, galactose, arabinose, and mannose content	Xylose, galactose, and arabinose content were sensitive to degradation in mechanical properties.	Same as for APA-sponsored chemical analysis research. See Table 1.
Ross and others (1990)	Stress wave	Energy absorption, speed of sound transmission	Speed of sound transmission was insensitive to degradation. Energy absorption was sensitive and correlated well with residual bending strength.	Same as for APA-sponsored stress wave research. See Table 1.
-	Probe or screw withdrawal	Force required to extract probe or wood screw from plywood	Useful correlative relationships were found.	Accepted and used by several inspectors. Equipment commercially available.

Table 3—Current nondestructive testing techniques

Study	NDT technique	NDT parameter	Equipment supplier ^a
APA (1989b)	Bending proof load	Load-deflection of roof panel subjected to bending load. If panel supports 400-lb (1.7-kN) proof load, it meets minimum performance requirements for span.	Architectural Support Group, Inc. Two Centre Park Drive Suite 203 Columbia, MD 21045 (301) 995-0061
FPL	Probe or screw withdrawal	Force required to extract probe or screw from plywood. Modified ASTM D1761 procedure.	Sensor Developments, Inc. P.O. Box 290 Lake Orion, MI 48035 (313) 391-3000 Accutex, Inc. 1734 Front St. P.O. Box 266 Cuyahoga Falls, OH 44222 (216) 923-5100

^aThe use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

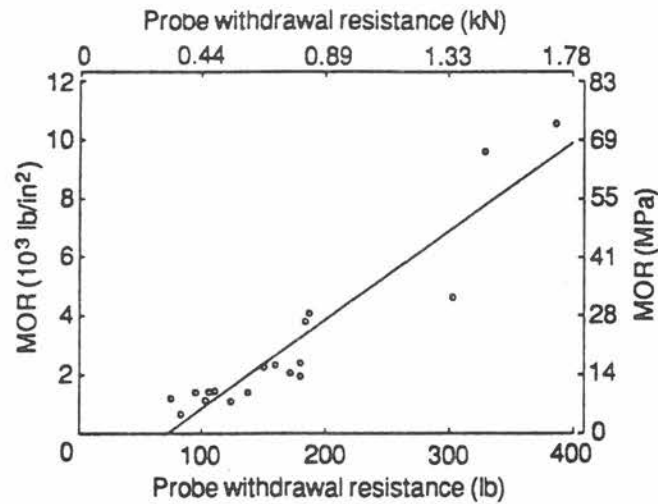


Figure 1—Relationship of residual strength (modulus of rupture) to probe withdrawal resistance in Talbott study.

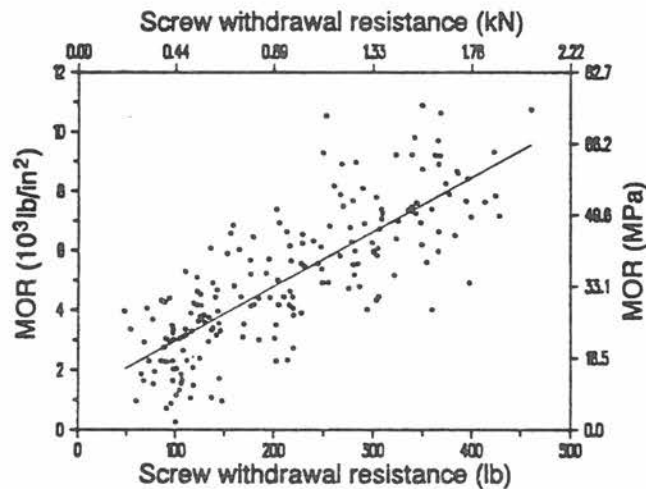


Figure 2—Relationship of bending strength (modulus of rupture) to screw withdrawal resistance in FPL study.

Field Comparison of NDT Techniques

A series of experiments were conducted to determine if both NDT techniques provide comparable information on the performance of in-service FRT plywood. Seventy-three roof panels of FRT and untreated plywood were evaluated using both methods. At least 20 screw withdrawal tests were performed on each panel. Average screw withdrawal values were then compared to a maximum bending load value. Regression analysis of the results revealed that a useful relationship does exist between bending strength and screw withdrawal resistance. For the 73 observations, the

correlation coefficient was 0.88, and the standard error of Y estimate was 150.2. These results indicated that both methods provide comparable information about panel performance.

CONCLUDING REMARKS

Two nondestructive test methods for evaluating the residual strength of fire-retardant-treated plywood have been accepted by building inspectors. One technique applies a bending proof load to a section of material. The other technique measures the force necessary to extract a probe embedded into a member. As a result of their simplicity and ease of use, both techniques provide adequate results and timely information on panel performance.

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