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Forensic Engineering Analysis and Test Protocols of a Minimally Invasive Wood Test Device

by W.T. 'Dusty' Yaxley, P.E., C.S.P. (NAFE 270F)
William C. Bracken, P.E. (NAFE 605M)
Raymond Meyers (NAFE C298)

Field Summary

The use of minimally invasive technology for determining the quantity and relative competency of structural wood material not easily visible can be very useful for the Forensic Engineer. The Recorder Torsional Drill Probe provides an advancing drill bit capable of recording the torsional resistance and distance advanced, from the initial surface, on a graph mounted on the drill. The relative torsional resistance can be compared to known structural wood samples for an idea of the type and/or competency of the wood material encountered. This method can identify if the correct size, number, and relative condition of individual members are included within the wall. The resulting hole can be easily repaired on most finishes.

Test Theory

A sample made of various pieces of wood studs was prepared and covered with drywall. The sample wood studs contained termite damaged wood, rotted wood, hardness of various wood, and multiple studs. First the sample was tested with density devices to locate the hidden studs. The Recorded Torsional Drill Probe was then used to drill multiple holes to determine the relative resistance to the drill bit. Each hole was recorded on a separate graph paper for later analysis. Each graph was labeled for the location of the test drill area. Exemplar samples of common stud material were also tested for a relative test sample.

Field Operation

The operation of the Recorded Torsional Drill Probe consisted of inserting a small piece of graph paper in the top of the drill type machine called the Recorded Torsional Drill Probe. A marker records the relative resistance to torsional turning of the drill bit. The drill bit advances at a preset rate.

Wilbur T. Yaxley, P.E., C.S.P., 2946 Forest Circle, Seffner, FL 33584
William C. Bracken, P.E., 4899 West Waters Ave., Ste A, Tampa, FL 33634
Raymond Meyers, 630 Brookfield Loop, Lake Mary, FL 32746

The Recorded Torsional Drill Probe was located perpendicular to the wall where the structural support was to be tested. Usually the support material was covered with a finish material, commonly consisting of drywall and a finish on the inside surface. As the drill bit advances the relative torsional resistance encountered delineates such items as: growth rings, termite compromised, missing material, or deteriorated wood can easily be detected. Hard knots, nails and other impenetrable material stop the drill and the hole must be slightly relocated to miss the obstruction.

Small forward distances with very small resistant areas are often associated with termite tunnels. Significant changes in the resistance can be an indication of the growth rings of certain materials such as Southern Yellow Pine. If a more consistent resistance is encountered the material may be Spruce Pine Fir, commonly used for studs in a building. Larger areas of very little resistance indicate no wood present. Possibly because of a hole or missing support material. Rotted or deteriorated wood will often show some resistance but not be nearly what would be expected for competent wood. Suspicious areas can be opened with destructive methods to visually evaluate the material and the problems associated with the support material.

A logical method, number of holes and their location required a protocol. No written standard or protocol and recording of the results were found. A standard was desired to guide the forensic engineer to sample and record a structure's condition; a minimally destructive test method was desired.

Test Apparatus

The Recorded Torsional Drill Probe is a device that measures the relative density of wood through torsional resistance to an advancing drill probe. This resistance is simultaneously mapped onto a test strip from which a determination of density can be made. This device employs an accumulator drill, a drill probe and a result strip. The principal behind this device is that competent wood will provide resistance to the drill probe while deteriorated wood will provide little to no resistance. Therefore by employing this principle, the relative density of wood can be mapped and evaluated. Ancillary Equipment includes; a graduated measurement tape, a borescope used to visually confirm the existence of compromised material and data recording equipment.

Test Protocols & Procedures

In summary the test protocol consists of first identifying and dividing the test subject into systems, sections, components, test regions and finally test sites. Once the component to be tested is identified and the test region established holes are drilled with a Recorded Torsional Drill Probe. From the Recorded Torsional Drill Probe readings the relative integrity of the component can be

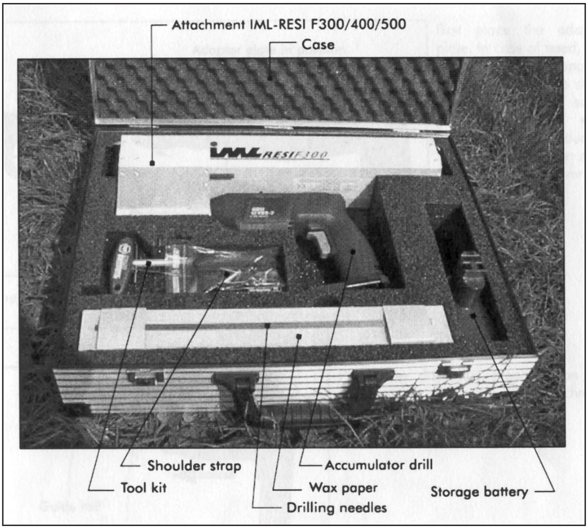

Figure 1
Typical Resistograph Apparatus

determined. It should be noted that this procedure is not intended to detect or identify isolated or small imperfections but that this type of procedure was developed so as to identify significant deterioration and/or section loss. It should also be noted that there is a limitation, as determined by the engineer, on the number of holes allowed within a single test region. Typically, less than 10% of the total test section is deemed appropriate.

The first step of the protocol is to organize and divide the test subject into five separate categories. The test system is identified first and represents the global extent of the project. The test system is used to further describe a collection of sub-systems and/or components to be further subdivided and ultimately examined. Once the test system is established test sections are identified. For the purpose of data collection a test section consists of any subdivision of a test system satisfying the following criteria. A test section is determined by a change in original construction continuity, a change in material, or other physical boundary. Once the test system and test sections have been organized a layout of the test components should be performed. This layout is performed by sketching and then dimensioning the structure while making note of doors, windows, primary structural components and members of interest. Assign a different identification number to each test component and record the locations of all test boundaries. It should be noted that no portion of the test component is to be associated with more than one test system. Next determine the number and location of all test regions. For the purpose of data collection a test region consists of any subdivision of a test component satisfying the following criteria. A test region is estab-

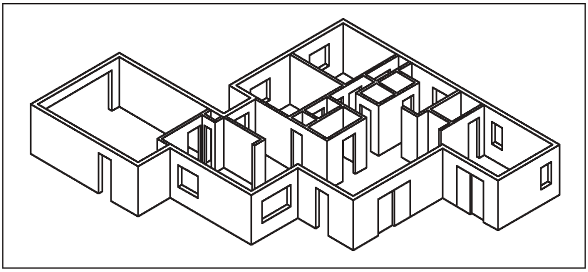

Figure 2
Axiometric View of a Test System

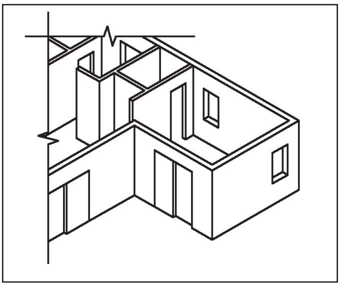

Figure 3
Axiometric View of a Test Section

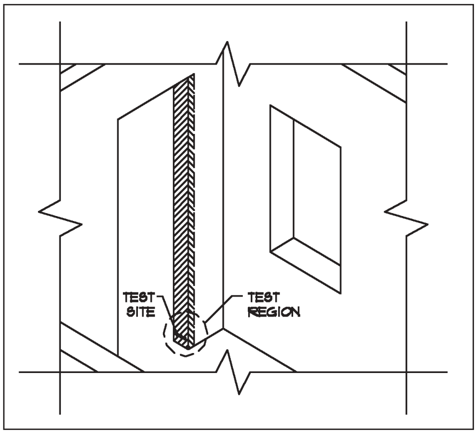

Figure 4
Axiometric View of a Test Component, Region and Site

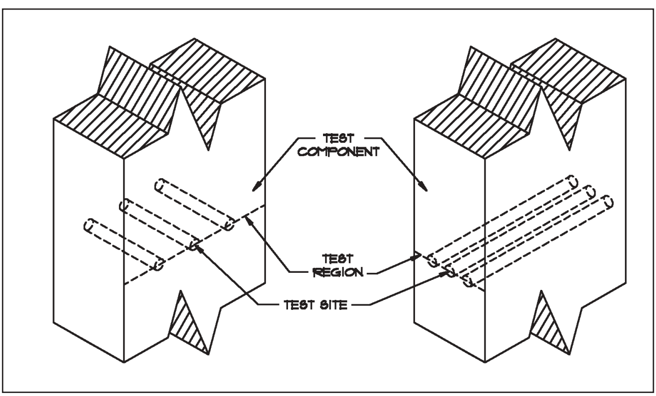

Figure 5
Holes Drilled In A Vertical Member

lished typically at the ends or support locations of the test component. Assign a different identifier to each test region and record their respective locations. Once the test region is established the testing can be performed and the actual location of the testing is identified as the actual test site.

Prior to performing the test all efforts to locate metallic material hidden from view should be made. One device used to locate hidden obstructions would include a commercially available metal locator. Other obstructions such as nails and knots within the wood also remain hidden from view and virtually impossible to locate prior to commencing the test. Therefore, if a very large constant resistance is encountered, discontinue use of the Recorded Torsional Drill Probe at that location so as not to damage either the equipment or the operator.

When testing vertical members holes are typically drilled at a location just above the base plate. When testing horizontal members holes are typically drilled at a location just above the support. If the structural integrity of the member is compromised, adjacent holes are drilled at a location approximately 3 feet from the last location. The maximum recommended number of holes within a test site could be found within the attached tables. The size of the drill probe as well as the number of holes is to be a function of the maximum allowable section loss.

5% Section Removal	Nominal Size of Member Being Tested (in)				
Probe Diameter (in)	2	4	6	8	10
0.0625 (1/16)	2	4	6	8	10
0.1250 (1/8)	1	2	3	4	5
0.2500 (1/4)	1	1	2	2	3

Table 1
Table of 5% Section Loss Per Test Section

10% Section Removal	Nominal Size of Member Being Tested (in)				
Probe Diameter (in)	2	4	6	8	10
0.0625 (1/16)	4	8	12	16	20
0.1250 (1/8)	2	4	6	8	10
0.2500 (1/4)	1	2	3	4	5

Table 2
Table of 10% Section Loss Per Test Section

Operating the Recorded Torsional Drill Probe consists of placing the Recorded Torsional Drill Probe front against the surface to be tested normal to the longitudinal axis of the drill bit. When possible place the Recorded Torsional Drill Probe directly to the substrate while avoiding finishes. Once the desired depth has been reached the drill is switched off, the drill is reversed so as to extract it from the member and the test strip removed.

Post-Processing and Graphical Presentation

The collection of data is the commencement of the process of identifying and sketching the test areas as well as conducting and collecting test data. The data collected, when keyed to the sketched test area represents the graphical presentation. The test strip portion of the data collected is evaluated based on its relative density readings. More specifically, when competent material is encountered the reading is registered above the base line. The higher up on the relative scale the denser the material. When a void, decomposed or significantly softened material is encountered, the recorded reading drops or often zeros out. Based on the extent of the compromised material and the criticality of the member, additional testing can be determined.

To minimize false interpretations of the graphical results produced by the Recorded Torsional Drill Probe, it is necessary to understand standard results for the material that is being tested. The two most common encountered materials are southern yellow pine and spruce. The resistance of southern yellow pine increases sharply at each ring. The valleys of the spikes could be mistaken as voids within the wood. Spruce is found to be more consistent throughout. For more detailed results for various wood materials please reference "Interpreting Resistograph Readings: A Manual For Users of The Resistograph Decay Detection Instrument".

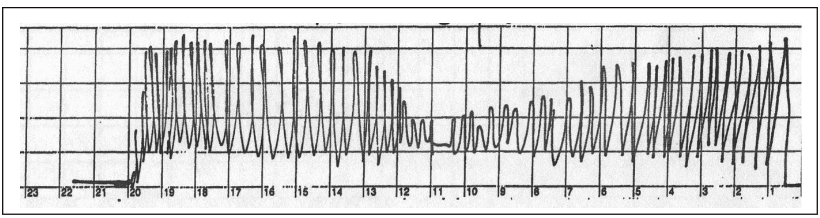

Figure 6
Resistograph Reading of Competent Southern Yellow Pine

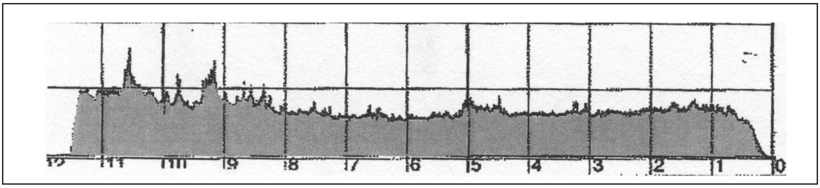

Figure 7
Resistograph Reading of Competent Spruce

Quantitative Evaluation Techniques

By juxtaposing visual observations and a review of the graphical representation, an evaluation of the system and/or components can be made. When performing this evaluation consideration is given to means and methods employed during initial construction, allowable and typical industry construction tolerances, configuration as well as existence and type of collateral damage to adjoining systems or components.

Conclusion

This paper discussed minimally invasive insitu testing procedures and quantitative evaluation techniques that enable a determination of deterioration and/or section loss within wood members and/or components. In most cases this technique yield sufficient information so as to eliminate selective demolition, partial removal and visual examination. As discussed, when evaluating in-service structural and non-structural wood components for deterioration and/or section loss, minimally invasive diagnostic testing techniques help to limit disruption to both the structure and its users.

Reference

1. Dunster, J. A. "Interpreting Resistograph Readings: A Manual For Users of The Resistograph Decay Detection Instrument". Dunster & Associates Environmental Consultants Ltd

2. "IML Resistographs®: Instructions For Use And Guarantee Conditions" Published by IMS – RESI

3. ASCE Standard 11-90: Guide For Structural Condition Assessments of Existing Buildings (General Compliance)