GPR in Wood Structures

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Ground penetrating radar (GPR) is a nondestructive inspection tool based upon the electromagnetic (EM) theory that radio wave propagation is governed by the EM properties of a dielectric material. GPR has many characteristics that make it attractive as an inspection tool for wood: it is faster than many acoustic and stress wave techniques; it does not require the use of a couplant; while it can also detect the presence of moisture. Moisture detection is of prime concern, and several researchers have labored to measure internal moisture using GPR.

Keywords: ground penetrating radar ; GPR ; wood ; nondestructive testing ; inspection

1. Introduction

The use of GPR on wood structures began to grow in popularity at the turn of the millennium. It can be used to probe any low-loss dielectric material such as concrete, asphalt, and wood [2]. The basic GPR unit is comprised of three components: a transmitting and receiving antenna(s), an EM pulse generator, and a data acquisition system. GPR inspection can be performed either through an object or from one side of the object.

2. Limitations and Advantages of GPR

Ground penetrating radar has several characteristics which make it an attractive inspection tool for wood [1][2][3][4][5][6][7]. One of the strongest attributes of GPR is the rapid speed of inspection. During an inspection using GPR, the antenna is moved across the surface of the inspected object/structure. Another advantage is the ability to estimate feature depth in addition to location. Data collected can be displayed in 1D, 2D, or 3D images.

GPR, as an inspection tool, has several limitations. The propagation of radar through wood is affected by the moisture content, density, temperature, shape and size of the inspected object, shape and size of the internal feature, and preservative treatments [1][6][8][9]. It is not uncommon for several of these factors to be present simultaneously, which can complicate data interpretation. While the location of internal features is intuitive, identifying the nature of a located defect (knot, void, metal connected, etc.) requires an experienced technician [3]. GPR systems have several user configurable settings including gain and frequency pass filters. The ability of the inspector to locate and identify internal features is greatly affected by these settings. Overly high gain can make otherwise inconsequential features appear large (false positive); insufficient gain can diminish relevant features causing them to be overlooked (false negative). Frequency range of the radar wave affects penetration depth and resolution. As frequency decreases, penetration depth tends to increase, but the minimum size defect that is detectable increases. Conversely, as frequency increases, the size of the detectable defect decreases, but penetration depth tends to decrease [4]. Compensating for the loss of penetration depth using gain can lead to false positive errors, as described above. The configuration of the settings must account for the shape and size of the inspected object. Knowledge of how the settings affect the GPR output can be taught in a classroom setting, but the understanding necessary to properly apply that knowledge in the field comes with experience.

3. Applications of GPR on Wood Material

There are several aspects of ground penetrating radar that make it an attractive inspection tool for use on wood and wood structures. GPR is commercially available, portable, does not require the use of a couplant, and is faster than point by point inspection methods. Studies have shown that GPR is capable of detecting moisture pockets, voids, and metal connectors which are critical for assessment of wood structures. Locating internal features using GPR can be accomplished by inexperienced inspectors.

Discontinuities in the dielectric constant in the direction of the wave are detected by GPR. The dielectric constant is the real component of the ratio of the permittivity of radar in the inspected material to the permittivity in a vacuum. DC is frequency dependent and increases with decreasing frequency in wood. Wood below the fiber saturation point has a DC of four or less. As the moisture content within the wood increases, the DC can increase above four to a maximum of 80 for pure water. Similar to strength properties, DC is orthotropic in wood with the highest DC parallel to the wood grain.

Correlating aspects of the radar signal to moisture content has been a focus of many studies. There has been some success in this area; however, the GPR output is also affected by many factors including, but not limited to, grain orientation, temperature, size of inspected object, and density. Given the positive results obtained from research in this area, the development of a GPR based method of moisture content measurement for wood structures at some time in the future is not unreasonable.

The most obvious gap in GPR inspection is the identification of internal features and the location and identification of decay. However, this gap is partially mitigated by the ability of GPR to detect moisture pockets, which are often an indicator of interior decay. As previously stated, an inexperienced inspector using GPR can easily locate internal features within wood structures. Unfortunately, identifying the nature of the feature is more difficult. Knots, voids, and nails produce similar output in GPR radargrams. There is a need for a method by which internal features can be quickly characterized in the field.

There is little research in the area of locating decayed wood with GPR. Currently, inspections using GPR rely upon the presence of moisture as an indicator of decay. However, in the absence of moisture, decay may still be present. There is a need for a method to locate and identify internal decay through characteristics of the GPR signal. Ideally the method will be independent of the presence of moisture. If these two areas of research can be addressed, GPR will be a powerful inspection tool for wood-based structures.

References

1. Mai, T.C.; Razafindratsima, S.; Sbartaï, Z.M.; Demontoux, F.; Bos, F. Non-destructive evaluation of moisture content of wood material at GPR frequency. Constr. Build. Mater. 2015, 77, 213–217.
2. Cassidy, N.J. Electrical and Magnetic Properties of Rocks, Soils and Fluids. In Ground Penetrating Radar Theory and Applications; Elsevier: Amsterdam, The Netherlands, 2009; pp. 41–72.
3. Muller, W. Trial of ground penetrating radar to locate defects in timber bridge girders. In Proceedings of the Riding the Wave to Sustainability: IPWEAQ 2002 State Conference, Nossa Lakes, QLD, Australia, 6–10 October 2002.
4. Müller, W. Timber girder inspection using ground penetrating radar. Insight Non Destr. Test. Cond. Monit. 2003, 45, 809–812.
5. Rodríguez Abad, I.; Martínez Sala, R.; García-García, F.; Capuz Lladró, R.; Diez Barra, R. A non-destructive method for the evaluation of density and moisture content. In Proceedings of the 12th International Conference on Ground Penetrating Radar, Birmingham, UK, 16–19 June 2008.
6. Hans, G.; Redman, D.; Leblon, B.; Nader, J.; La Rocque, A. Determination of log moisture content using early-time ground penetrating radar signal. Wood Mater. Sci. Eng. 2015, 10, 112–129.
7. Hans, G.; Redman, D.; Leblon, B.; Nader, J.; La Rocque, A. Determination of log moisture content using ground penetrating radar (GPR). Part 1. Partial least squares (PLS) method. Holzforschung 2015, 69, 1117–1123.
8. Torgovnikov, G.I. Dielectric Properties of Wood and Wood-Based Materials; Springer: Berlin/Heidelberg, Germany, 1993.
9. Redman, J.D.; Hans, G.; Diamanti, N. Impact of Wood Sample Shape and Size on Moisture Content Measurement Using a GPR-Based Sensor. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 2016, 9, 221–227.