Determination of Embedment Depth of Timber Poles and Piles using Wavelet Transform

Jianchun Li [1], Keith Crews [2], Bijan Samali[3], Mahbube Subhani[4] and Amir Zad[5]

Abstract This paper presents an application of Wavelet Transform (WT) for identification of the condition and underground depth of embedded timber poles in service. Wavelet Transform (WT) analysis was used to analyse data from experimental testing that was conducted on intact and damaged timber poles of 5 m length with free-end condition. The results were presented in both time domain and time-frequency domain for comparisons. In addition, the wavelet transform was applied to data obtained from numerical analysis of 12 m timber poles to investigate its capability to identify the damage location and to predict embedment length. The results of the investigation showed that wavelet transform analysis can be a reliable analysis tool for non-destructive testing in terms of length determination and damage identification of timber poles in-service.

Keywords non-destructive testing, timber pile, timber pole, stress wave, wavelet transform

1. INTRODUCTION

Utility poles represent a significant part of Australia's infrastructure. According to Nguyen et al. (2004), there are nearly 5 million timber poles being used in the current network for distribution of power and communications in Australia. The utility pole industry in Australia spends about 40-50 million annually on maintenance and asset management to avoid failure of utility lines, which is very costly and may cause serious consequences. Surface non-destructive testing (NDT) methods such as Sonic Echo, Bending Waves and Ultraseismic methods have been considered over the past decade to be simple and cost-effective tools for identifying the condition and underground depth of embedded structures, such as timber poles or piles in-service. Despite the wide spread use of these stress wave methods, the effectiveness and reliability of the methods on determination of embedded length and evaluation of underground conditions of poles, especially timber poles, are not addressed. The presented research focuses on using surface NDT methods in combination with WT analysis for condition assessment and underground depth determination of in-service timber poles.

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[1] Jianchun Li, Centre for Built Infrastructure Research, University of Technology Sydney, Australia, jianchun.li@uts.edu.au
[2] Keith Crews, Centre for Built Infrastructure Research, University of Technology Sydney, Australia, keith.crews@uts.edu.au
[3] Bijan Samali, Centre for Built Infrastructure Research, University of Technology Sydney, Australia, bijan.samali@uts.edu.au
[4] Mahbube Subhan, Centre for Built Infrastructure Research, University of Technology Sydney, Australia, MdMahbube.Subhani@student.uts.edu.au
[5] Amir Zad, Centre for Built Infrastructure Research, University of Technology Sydney, Australia, aazad@eng.uts.edu.au

2. THEORETICAL BACKGROUND

In surface stress wave testing, an impact hammer is utilised to generate stress waves. The speed of stress wave propagation is a function of the modulus of elasticity, Poisson’s ratio, the density, and the geometry of the structure (American Concrete Institute 1998). Due to these dependencies, monitoring and analysis of stress wave propagation can be used to assess the condition of structures. In general, multiple types of waves are generated in stress wave testing, e.g. longitudinal, transverse and Rayleigh waves. When data is analysed in the time or frequency domain only, testing results can be error-prone due to transient effects. To overcome this issue, data can be processed by time-frequency analysis using techniques such as Wavelet Transform (WT). In the presented research work, the continuos wavelet transform (CWT) is used as advanced signal processing technique. In CWT, the Fourier transform is applied to individual sections/windows of a time-history signal and thereby both, the frequency content and time information, are preserved.

3. EXPERIMENTAL TESTING AND RESULTS

In experimental testing, timber poles of 5 m length were excited with a modally tuned impact hammer to generate stress waves in intact and damaged test specimen. The timber poles were tested under free-end condition (specimen were suspended by two ropes) and impact was imparted from either the centre top or the side of the poles. From the results of time domain analysis (without CWT processing) and time-frequency domain analysis (with CWT processing), it was found that for impact excitation from the side of the pole and for the damaged pole, time domain analysis was unable to give clear indications on the determination of the pole length and/or condition. Using CWT, which reflects the different frequency components in the measured time-history signals, the length and damage characteristics of test timber poles could be predicted for all investigated cases.

4. NUMERICAL ANALYSIS AND RESULTS

For finite element analysis, the software ANSYS (2007) was used to create three-dimensional models of intact and damaged timber poles, which were 12 m in length and between 0.17 m and 0.35 m in diameter (dimensions of poles typically found in the field). Using transient dynamic analysis, an impact force was applied to the poles at either the centre end or the side of the structure and the structural response was recorded to monitor stress wave propagation. From the numerical investigations, the observations previously made from experimental testing could be confirmed; i.e. signal processing in the time-frequency domain using CWT preserves the transient behaviour of the signals and hence improves signal patterns to enable evaluation of length and heath condition.

5. CONCLUSIONS

In this paper, Continuous Wavelet Transform (CWT) technique has been studied for the determination of embedment depth of timber poles through numerical and experimental investigations. The results have demonstrated that CWT is an effective tool for processing stress wave signals for identifying reflective waves, especially under more complicated situations such as impact from the side of specimens and existence of damage. For these cases, traditional time domain analyses encounter problems. Further investigation is needed to gain full understanding on effects of the geotechnical conditions and uncertainties of field testing.

REFERENCES

Nguyen, M., Foliente, G. and Wang, X. (2004). “State of the practice & challenges in Non-destructive evaluation of utility poles in service.” *Key Engineering Materials*, 270-273, 1521-1528.

American Concrete Institute (1998), “*Nondestructive Test Methods for Evaluation of Concrete in Structures*”, Report ACI 228.2R-98, Farmington Hills, Michigan, US.