Material Characterization of Timber Utility Poles using Experimental Approaches

by

Roman Elsener

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Principal Supervisor:	A/Prof Dr Jianchun Li
Second Supervisor:	Dr Ulrike Dackermann

University of Technology Sydney
Faculty of Engineering
Centre for Built Infrastructure Research
15 Broadway
Ultimo, NSW 2007
Australia

Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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ABSTRACT

Utility poles made of timber are a significant part of Australia's infrastructure for power distribution and communication networks. Wood as a natural material deteriorates under the influence of environmental conditions such as weathering, fungus and insect attack which results in a reduction of the strength of the poles. Determining soundness and the remaining strength of timber utility poles in service is crucial in order to maintain a reliable and secure power network.

This thesis presents an investigation of using static and dynamic material testing approaches to determine material properties and detecting internal damage of timber utility poles from two hardwood eucalyptus tree species, i.e. Spotted Gum and Tallowwood. The comparative study of static and dynamic tests based on the wave transmission time or time of flight (TOF) is necessary for the development of novel non-destructive testing (NDT) techniques for the health assessment of in-situ utility poles. In order to develop accurate non-destructive models, knowledge of the orthotropic material properties is necessary.

In open literatures, comparative studies on orthotropic material properties are scarce to find for most eucalyptus species used for utility poles. Typically, material properties are only available in the longitudinal (i.e. along main wood fibre) direction, and most international standards cover only details on material testing in such direction with no coherent or comprehensive guidelines being given for the testing of the other two secondary directions (radial and tangential) of timber. TOF measurements were conducted by several researchers for a number of timber species, however non on high density woods such as the investigated eucalyptus species.

Based the full set of material properties (Modulus of Elasticity and Poisson's ratios) of two new utility poles determined with static tests in all three orthotropic directions (longitudinally, radially and tangentially), the dynamic tests were calibrated and used for the non-destructive material characterization and internal damage detection. The tests were also conducted taking into account varying moisture contents and different grain angles as they occur in the field. Ultimately, an orthotropic numerical model was created to simulate the experimental damage detection case which could be used to simulate further damage cases. The results revealed that the formulas used for the dynamic material characterization must be adjusted for the investigated species. The numerical model was capable of simulating the experimental case and predicting the TOF for damaged poles. The method has potential for the prediction of internal damage of eucalyptus timber poles in the field.

Keywords: Timber Properties, Material Testing, Damage Detection, Eucalyptus

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Nomenclature

AT	Acoustic tomography
CS	Compression strength
COV	Coefficient of variation
FE	Finite element
FSP	Fibre saturation point
LVDT	Linear variable differential transducer
MAE	Mean absolute error
MAPE	Mean absolute percentage error
MC	Moisture content
MFA	Micro fibril angle
MOE_l	Modulus of elasticity in longitudinal direction
MOE_r	Modulus of elasticity in radial direction
MOE_t	Modulus of elasticity in tangential direction
MOR	Modulus of rupture
NDE	Non-destructive evaluation
NDT	Non-destructive testing
P-wave	Compressional or longitudinal wave
S-wave	Shear or transversal wave
TOF	Time of flight
TS	Tensile strength

WTT	Wave transmission time
WSP	Water saturation point

Symbols

c_{LL}	P-wave in longitudinal direction
c_{RR}	P-wave in radial direction
c_{TT}	P-wave in tangential direction
$c_{LR.RL}$	S-wave in longitudinal radial plane
$c_{LT,TL}$	S-wave in longitudinal tangential plane
$c_{RT,TR}$	S-wave in radial tangential plane
ε	Strain
σ	Stress
f	Frequency
G	Shear modulus
λ	Wavelength
$\bar{x}$	Mean value
ν	Poisson's ratio
V	Wave velocity
V_L	Longitudinal wave velocity