Strength characterisation of timbers for building construction in Uganda

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ABSTRACT

Inadequate knowledge of timber species' strength and lack of timber standards in Uganda formed the basis of the study in which selected timber species were characterised. The overall objective was to investigate strength properties of timbers used for building construction and develop mechanisms for predicting flexural strength. The specific objectives were to: assess timber-use practices; determine strength properties of timber species; develop a strength class system; model flexural behaviour of timber; investigate the relationship between flexural strength of structural size and small clear timber and ascertain the effect of knots on MOE and MOR; and to develop a non-destructive approach for predicting flexural strength.

Small clear tests were conducted in bending, compression and shear parallel to grain using standard procedures of the American Society for Testing and Materials (ASTM), ISO 8905 (1988), and BS 373 (1957) while structural size bending tests were conducted following ASTM ISO 8905 (1988), AS/NZS 2878 (2000) and BS 373 (1957). Twenty three *E. grandis* structural size specimens with visible knots and 23 without visible knots; and 19 *P. caribea* specimens with knots and 26 without visible knots were tested according to BS 4978; ASTM D198-02 and ISO/FDIS 13910:2004. Finite Element Modeling of timber flexural behaviour was accomplished using COMSOL Multi-Physics 3.4. An approach for non-destructive evaluation of flexural strength was also developed and evaluated basing on the load-deflection relationship. A prototype to operationalise the approach was developed and used to measure the force (P_{5mm}) required to cause a non-destructive deflection of 5 mm. The prototype was calibrated using 54 structural size timber specimens tested for MOR and MOE in series on both the prototype and the Universal Testing Machine. Regression analysis was used to predict MOE and MOR with P_{5mm} as the predictor. The allowable bending stresses of the investigated timbers varied from 3.9 N/mm^2 to 20.3 N/min^2 whereas the mean MOE varied from 5,760 N/mm^2 to 13,440 N/mm^2; shear parallel to grain varied from 7.2 N/mm" to 13 N/mm"; compression parallel to grain varied from 20 N/mm" to 59 N/mm^2; and density varied from 322 Kg/m^{3}to 595 Kg/nr.

It was discovered that a number of lesser-known timbers have sufficient strength to serve as building construction timber, thus reducing pressure on well-known but scarce timbers. Four timber strength classes: SG4, SG8, SGI2 and SGI6 were proposed using arithmetic and geometrical progressions to set class boundaries. ANOVA showed significant differences between MOR and MOE of structural size specimens with and without visible knots. It was concluded that structural size MOE and MOR can be estimated from small clear MOE and MOR using reduction factors of 40% and 20% respectively. The study noted that visual grading based on visible knots cannot serve as stand-alone method of predicting timber strength quality. There was a good correlation between the predictor, $p5_{mm}$ and MOE/MOR; and it was concluded the NDE approach can be used to predict flexural behaviour of timber. It was concluded that flexural deflection of timber can be modelled using Finite Element Methods but only up to the elastic limit. The study generated new knowledge in form of: extensive timber strength data for 17 tropical timbers and a timber strength classification system; which will guide timber structure designs, timber trade, and provide input parameters for numerical models; a relationship between structural and small clear flexural strength and an NDE approach with a new flexural strength predictor. However, more research into the effect of other defects e.g. complex knots, cross-grain and grain angle on timber strength is needed. Finite Element Methods should be explored to model inelastic behaviour of wood. There is also need to improve the NDE prototype to enable timber grading and testing of round wood.

Keywords: Building construction, timber strength, standards, small clear specimens, MOB, MOR. flexure, allowable stress, strength class, lesser-known species, modelling, non-destructive evaluation