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STRENGTH GRADING OF STRUCTURAL TIMBER BASED ON BUCKLING ANALYSIS AND SCANNING TECHNIQUES

Hans[1] Petersson, Bo[1] Källsner and Sigurdur[1] Ormarsson

ABSTRACT: This paper assesses the potential of grading of structural timber by use of in-plane buckling analysis combined with scanning, employing post processing of both ordinary photo images and images of wood surfaces illuminated by a large number of laser point sources. The results appear very promising in providing accurate predictions of structural strength. Finite element modelling is applied in the buckling analysis and obtained results are compared with experimental results from timber boards tested in accordance to the European standard EN 408 by four point bending tests.

KEYWORDS: Wood, timber, strength, buckling, scanning, grading, image processing

1. INTRODUCTION

In the research on better utilization of wood as a raw material, improved sorting techniques for structural applications are important. As the northern European sawmill industry mostly is using spruce and pine for sawn products, these species are of primary interest.

The structural behaviour of wood depends on a large number of internal properties such as wood density, grain angle distribution, annual ring pattern, compression wood, pith location and occurrence of knots. The grading techniques used today do not consider many of these properties in finding the strength of structural timber and the loadbearing capacity of timber structures.

Grading of timber should be based on models that characterise the material behaviour on a smaller scale, needed in crack propagation analysis of various defects as knots. Global models are needed in stability analysis of buckling phenomena where the material is best characterized by integrated material properties as bending and axial stiffness.

2. MATERIAL MODELLING

The most important parameter for a good prediction of timber strength is the distribution of the grain angle (L-direction) as wood is strongly anisotropic, but also the radial (R-) and tangential (T-) directions need to be well defined. The spatial description of the orientation of the L-R-T-axes is thus a key issue in structural analysis of wood and timber structures.

The material parameters needed for modelling phenomena as elasticity and fracturing are best described with reference to the L-R-T-axes. The way these material parameters are varying in the wood and around knots is strongly dependent on tree growth conditions. Also the property variation in the radial direction due to varying growth conditions and the pith location in the board have to be considered. The problem of finding the main material directions around knots and an approach for material characterization with respect to the radial direction is treated in [1]. In order to illustrate some of the results one example obtained from scanning is given in Figure 1, showing how the grain angle varies around three knots.

Figure 1: *Fibre angle lines at outer face of a timber board computed from laser scanning*

[1] Building technology, Linnæus University, SE 351 95, Växjö, Sweden. Email: hans.petersson@lnu.se

The usefulness of applying an energy approach in strength analysis of timber beams is well known both dealing with buckling and fracturing analyses. A problem has, however, until now been to consider the influence of a varying slope of grain. Also the influence of the pith location and how the longitudinal E-modulus varies over the cross section have to be considered in a more accurate analysis.

3. BUCKLING ANALYSIS

The failure load is expressed by a critical bending moment M_{cr} which then is replaced by a formal bending failure stress $f_m = 6\ M_{cr}/bh^2$. For a case where the longitudinal E-modulus approximately can be considered as constant the bending stiffness is $Ebh^3/12$ and the axial stiffness is Ebh.

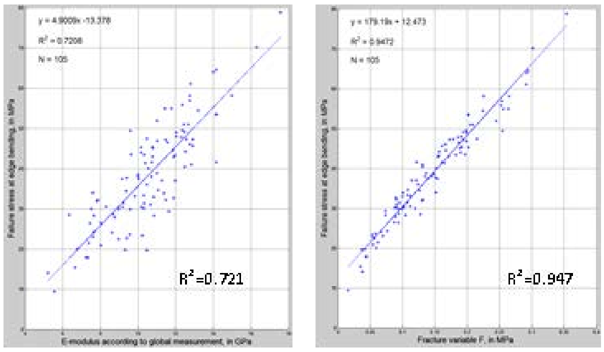
The potential for strength grading of timber based on buckling analysis will be treated in the full paper, considering varying stiffness properties variations both lengthwise and over the cross section. Also the influence of the slope of grain will be considered. In this abstract computed results will be presented only for a model with constant material properties and the results are compared with mean values of experimental results from 520 tested boards.

For determining a proper value of the so called bending strength f_m a hand calculation might be sufficient, otherwise a finite element buckling analysis has to be employed. For a test specimen designed according to EN 408 a bending strength value for f_m of about 0.00404 E has been obtained, using a fine finite element mesh and assuming that E is constant (and the shear modulus is E/16). This relation between strength and stiffness is in good agreement with mean values of the ratio between f_m and E from eight test series performed with different cross sectional data, see Table 1. The boards were tested in accordance with EN 408 in four point bending, see [3].

***Table 1** Results (in MPa) from testing of 520 boards with different cross sectional dimensions (in mm) from 50x100 to 75×250. The values have been adjusted according to EN 384.*

Series	Number	f_m		E_{local}		E_{global}		Ratio	
		m	s	m	s	m	s	f_m/E_{local}	f_m/E_{global}
A	30	31.6	8.6	9401	1916	9014	1525	0.00336	0.00351
B	71	40.3	11.6	11999	2504	11139	2136	0.00336	0.00362
C	36	43.0	11.6	11996	2104	11428	1737	0.00358	0.00376
D	61	44.6	12.5	12000	2337	11365	1866	0.00372	0.00392
E	61	44.6	9.3	11627	1641	11074	1325	0.00384	0.00403
F	78	42.9	12.0	11497	1872	10856	1599	0.00373	0.00395
G	78	43.7	10.4	11186	1861	10832	1579	0.00391	0.00403
A-G	415	42.3	11.6	11509	2161	10923	1805	0.00368	0.00387
CN	105	39.4	13.3	11328	2951	10866	2342	0.00348	0.00363

Results from one of the test series, denoted CN, are shown more in detail. The series consisted of 105 boards (45*145 mm^2). In Figure 2 (a) the failure stress is plotted as a function of the E-modulus, determined as the so called global E-modulus. The obtained R^2-value is substantially higher than for a case where the E-modulus is based on the axial stiffness. The R^2-value is further much higher for a relation between the bending stength and the internal global energy, see Figure 2(b). This almost linear relation clearly indicates the importance of applying an energy criterion in the strength analysis taking second order effects into account.



(a) (b)

***Figure 2:** (a) Relation between failure stress and E-modulus determined as global MOE.*
(b) Relation between the failure stress and the internal global energy

4. CONCLUSIONS

An approach for strength grading of structural timber based on buckling analysis is outlined, considering both variations in slope of grain as well as varying stiffness properties over the cross section.

The results appear promising, providing reasonably accurate predictions of timber strength at grading based on data obtained from scanning and/or data obtained by measuring stiffness properties from the response of applied loads.

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