Title: Optimising the use of sawn timber for structural purposes

1. Background Information on the Project

1.1 Objectives and expected results of the research

Structural sawn timber is a material showing large variability in strength and stiffness properties. A large variability makes it necessary to assign low strength and stiffness values for the design of timber structures. Reducing the variability allows higher design values and subsequently leads to a more efficient use.

The objective of the cooperative research project is to develop an efficient method to predict the strength and stiffness of sawn structural timber. This method includes the use of several parameters correlated with the strength of the material. The first parameter is the dynamic modulus of elasticity, calculated from the measured eigenfrequency of a piece of timber vibrating in longitudinal direction. The second parameter is the density, calculated from the weight of the timber and its dimensions. The third parameter is the moisture content, measured with an electrical moisture meter. The last parameter is the knot size and shape, evaluated from the outcome of optical scanning of the timber surfaces.

The result of the research is the relation between the mentioned parameters and the strength of timber. Based on the expected result it is possible to build a strength grading machine incorporating all the necessary measuring devices. The expected result would considerably increase the accuracy of the strength prediction, leading to a reduced variability of the material. Compared to the present situation, where timber is mostly graded visually, this reduced variability leads to a much more aim-oriented and efficient use of timber enabling reliable structures using less raw material. This applies even when comparing the envisaged approach to existing machine strength grading procedures, since the use of several parameters will increase the accuracy of the strength prediction.

The following table shows the expected increase in yield for higher strength classes

Comparison of expected yield in different strength classes for different grading procedures				
Grading	Yield for strength class			
	C18	C24	C30	C37
visual	15%	60%	25%	-
new approach	10%	30%	30%	30%

The industrial sectors likely to benefit from the results of the work are the timber construction industry (A04) as the end-user, the mechanical engineering industry (A11) and the wood industry (A21). The project would be a cooperation between the producers of the material (sawmills), the suppliers of electronic measuring equipment, the producers of machinery and the timber construction industry using the reliably graded product. The research is to be performed by two well-known institutes in the area of timber engineering, TNO Centre for Timber Research in Delft and the University of Karlsruhe in Germany.

The research is pre-competitive, since the project only aims at establishing a method. The corresponding grading machine based on the new concept has to be developed afterwards which would require about another one to one and a half years.

1.2 Economic and industrial benefits

Industrial and technical benefits in the event of a successful outcome:

- enables the development of a new strength grading machine
- increases the average strength value of timber
- increases reliability of timber structures
- decreases the use of raw material

Applicability and relevance to a particular or several industrial sectors:

- sawmill industry, timber construction industry: increases competitiveness of their products if the new procedure is used
- machinery and electronic equipment industry: new or extended markets for their products

Potential industrial opportunities and expected impact on the European market:
Due to the increase in yield in higher strength classes the average value of the timber increases by about 8%. Based on a yearly consumption of 15 million m^3 and a value of 250 ecu per m^3, an increase in value of more than 300 million ecu results if all structural timber is machine strength graded. This is a substantial increase in value compared to a yearly turnover of 20 billion ecu for the whole wood industry. Apart from that, the dependency on imports of structural timber (The EC imports about 50% of its wood consumption) would decrease, if the home-grown timber is used more efficiently.

Indication of level of urgency of the research in relation to potential industrial applications:
The wood industry mainly consists of small and medium enterprises with 20 or less employees. Nevertheless, there are about 21.000 companies within the wood sector with more than 20 employees. Due to this structure of the industry which limits its capability to support or perform R&D, the development of an optimal grading procedure for structural timber has to be supported by research funds. Outside Europe, machine strength grading exists already, although on a lower level than the one envisaged here. Nevertheless, because of the new European CEN standards enabling higher strength classes, the interest in more efficient grading procedures grows primarily in North america.

1.3 State of the art and innovation

Strength grading is one way of accounting for the variability in strength and stiffness properties of structural timber. At present, strength grading in a number of European countries is based on a visual examination of timber members, mainly on the knot size. Since there exists only a relatively weak relation between the knot size and the strength and the grading process is largely dependent on the performance of the grader, the accuracy of the strength prediction is low. New methods of machine strength grading combining the information out of several non-destructive measurements are able to increase the accuracy of the grading process considerably. This leads to a much higher yield of high strength timber and consequently increases its average market value.

Introducing Eurocode 5 "Design of Timber Structures" and the corresponding CEN product standards a system of strength classes will be introduced also in Europe. Within this system strength values are defined as characteristic values or lower 5-percentile values of a population, respectively. Contrary to the system of allowable stresses still valid today in a number of European countries, the strength class system enables through an efficient sorting procedure to recognise high

strength timber and use it according to its properties. Thereby a more aim-oriented and consequently more economic use of timber is possible.

2. R&D Approach

2.1 Proposed project methodology and structure

The planned project concerning the establishing of the relation between grading parameters and strength can shortly be outlined as follows:

- sampling of 400 timber beams with four different sizes for different European species like spruce, fir, pine, Douglas fir. These species cover more than 90% of structural timber used in Europe. The specimen depths for the different groups should vary between about 100 and 200 mm.

- determination of machine strength grading parameters for each specimen. The following grading parameters are determined:

  - Average MOE through longitudinal vibration measurements,
  - average density through weighing and measurement of cross-sectional dimensions,
  - moisture content through electrical moisture meter and
  - knots through scanning of the four wood side surfaces of each specimen using the existing scanning equipment of DIMTER for appearance grading of non-structural timber. From the scanner information, knot parameters like knot area size, knot position in the member, knot shape or knot frequency within a certain area are determined.

- determination of bending strength and static bending stiffness for all specimens according to prEN 408 and of moisture content and density according to ISO 3130 and ISO 3131, respectively. The governing strength property is the bending strength, since a classification of timber into a strength class according to prEN 338 is based on bending strength, bending stiffness and density.

- derivation of a mathematical model describing the relation between the measured grading parameters and those properties decisive for the grouping into a strength class according to prEN 338 (bending strength, MOE and density). Apart from regression analysis the application of artificial neural networks to establish a relation between the grading parameters and the strength is considered. Artificial neural networks promise to be more efficient than linear regression analysis since they are able to recognise and describe also highly non-linear relations between the related parameters.

2.2 Candidate R&D Organisations

TNO Building and Construction Research
Centre for Timber Research
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Universität Karlsruhe
Lehrstuhl für Ingenieurholzbau und Baukonstruktionen
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D - 7500 Karlsruhe 1

3. Strategy for Exploitation of Results

(To be completed)

4. Plans for the Expansion Phase and Request for Financial Support

During the expansion phase, project partners representing a large part of the wood chain from forest to sawmill, trade, and end-user will be incorporated to enable the new innovative technology to be influenced by the potential users. TNO Building and Construction Research (Centre for Timber Research) will be used as a consultant to work out the project proposal in detail. At least one meeting, where the project partners will discuss the detailed R&D approach as well as the contractual conditions of the cooperative research project will be necessary.

The necessary budget for the expansion phase is estimated to 22.000,- ecu.