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THERMALLY MODIFIED BEECHWOOD AS A STRUCTURAL MATERIAL: ALLOCATION TO EUROPEAN STRENGTH-CLASSES AND RELEVANT GRADING PROCEDURES

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1 INTRODUCTION

In recent years products made of thermally modified timber (TMT) are being used increasingly in a wide field of application. For outdoor use its superior durability and dimensional stability makes TMT being a good substitute for tropical hardwoods or impregnated softwoods. For indoor uses the wide range of possible colours of TMT made it being competitive to naturally dark coloured tropical hardwoods.
The EC-funded FP6 project Holiwood aimed at widening the field of application for TMT made of European hardwoods – here in particular beech (*fagus sylvatica*) - to structural applications in an outdoor environment, e.g. for noise barrier elements.
It is known that a downside of TMT is its reduced strength compared to untreated timber. For a given thermal treatment hardwoods show even higher strength losses than softwoods. Therefore an extensive test program had been set up to determine the strength and stiffness parameters of thermally modified beech timber (TMTB) and to assess its suitability for structural applications and to assign it to European strength classes.
In the following bending-, tension- and compression tests on TMTB specimens are presented. Additionally selected data are chosen and analyzed in such a way that the feasibility of a machine grading for this material can be judged.

2 MATERIAL AND METHODS

2.1 RAW MATERIAL

The beech wood was taken from three different stands in Austria. It was bought appearance graded and not strength graded. All specimens met the requirements for (visual) strength class LS13 according to the German standard DIN 4074-5 which would permit an assignment of the untreated timber to strength class D35 according to EN 1912.

2.2 THERMAL MODIFICATION

The specimens were thermally treated by Mitteramskogler GmbH in Gaflenz, Austria. This company uses the THA thermal treatment process where the respective modification is executed under a gas atmosphere. For all tests TMTB with the brand "Buche forte" was used. This thermal treatment has to be considered as being an intensive wood modification.

2.3 SPECIMENS

There were $n = 100$ square-cut TMTB specimens and n = 40 boards per sample available for testing. The square-cut specimens were used for the bending- and compression tests as well for determination of the density whereas tension tests were executed on boards. The dimensions were chosen in order to fulfil the requirements of EN 408 and EN 384. A small untreated beech sample served as reference for the bending and compression tests.

Table 1: *Overview of the three TMTB samples and the untreated beach samples. The parameters were determined on the bending specimens.*

Series	Treatment	Density ρ [kg/m^3]	Moisture content u [%]
TMT1	forte	500 - 670	4.6-6.5
TMT2	forte	530 - 800	5.2-6.2
TMT3	forte	570 - 760	4.6-6.3
Beech2	untreated	670 - 820	11.9 – 13.7

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2.4 EXPERIMENTAL PROCEDURES

Before the bending tests were executed, the dynamic MOE E_{dyn} was determined using an ultrasonic device "Sylvatest" in order to verify the possibilities for future machine grading of TMTB.
The bending, tension and compression tests were executed according to EN 408. The characteristic strength and stiffness parameters were calculated according to EN 384.

3 RESULTS AND CONCLUSION

Several samples of TMTB have undergone standard tests in order to investigate their structural behaviour and to assign this timber to a strength class according to EN 338. From the tests executed so far it can be concluded that:

- The stiffness values of TMTB are similar to or slightly exceed those of untreated beech timber and thus could lead to a classification of TMTB into high strength classes, e.g. D50. See local bending MOE as an example in Figure 1.
- Density of TMTB permit to assign TMTB to high strength classes, e.g. D50 or D55.
- With the exemption of compression parallel to grain the strength values of TMTB are lower than those of untreated beech timber and thus could lead to a classification of TMTB into low strength classes, e.g. D30. See bending strength as an example in Figure 2.
- The conclusions mentioned above suggest not to assign TMTB to existing EN 338 strength classes but to state discrete properties for its structural use.
- The brittle behaviour of the material and the big variation of the test values is the main problem regarding its strength properties. Poor rigidity parallel to grain and great sensitivity to stress concentrations are likely to significantly limit the structural use of TMTB.
- Conversion factors to determine unknown strength and stiffness properties as given in EN 384 for solid wood cannot be used for TMTB.
- The TMTB tested up to now was of a high visual grade. It can be assumed that in particular the strength properties of TMTB of a lower visual grade (timber containing knots and other defects) might further decrease compared to the material tested so far.
- The prediction of the static MOE of TMTB by ultrasonic together with density measurements works well. However, the possibility of (bending) strength prediction is only limited as can be recognized in Figure 3.
- A strict quality management for the thermal modification process has to be installed in order to obtain a reliable quality of the structural TMTB products.

Overall it looks like the application of TMTB that underwent a strong thermal modification (like the one used for this study) as a structural material in an important quantity will be difficult to realize. Good stiffness properties (that are often decisive for the design of a timber structure) face relatively low strength properties which in addition vary strongly. The brittleness of the material and it's susceptibility to stress concentrations and multidimensional stresses are other important downsides that will come into play when it gets to the load-bearing behaviour of joints. Therefore it is suggested to use intensively treated TMTB only for low loaded structural members.

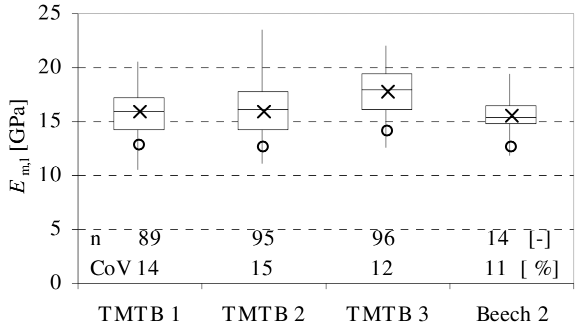

Figure 1: *Local bending MOE $E_{m,l}$ of three TMTB samples and one untreated beech sample*

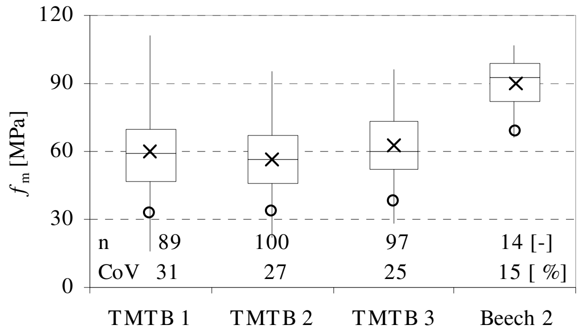

Figure 2: *Bending strength f_m of three TMTB samples and one untreated beech sample.*

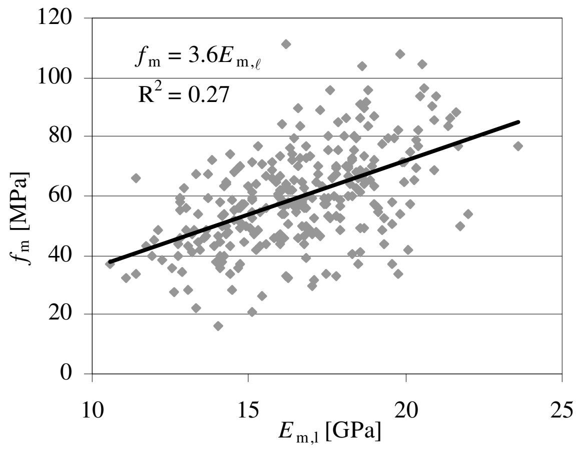

Figure 3: *Linear correlation of measured local MOE $E_{m,l}$ and bending strength f_m (n = 280) as an example for the difficulty to strength-grade TMTB*