Manufacturing and Properties of Glulam made of TMT Spruce and TMT Beech

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ABSTRACT

Despite the reduced strength of TMT, there is a market demand for its use for load bearing applications. The strength loss may be compensated by increase of the dimension, and the probable way is not to treat bigger logs, but to make glulam beams from usual TMT boards. The objectives of a research project, executed by IHD, were to prove that the production of glulam from TMT is possible, to investigate the effect of gluing on strength properties and type of failure, and to determine the strength level of both lamella and glulam. Furthermore, technological aspects have been addressed, like manufacturing and quality of finger joints, applicability of different glues (face and finger joint gluing), and specialties of production lines. Materials were TMT Spruce and TMT Beech from industrial processes, treated both at a lower and a higher level, and native wood for comparison. As adhesive systems, MUF and PUR were used. Beams of 110×235 mm² (Spruce, 5 layers) and 110×192 mm² (Beech, 6 layers), with a length of 4.2 m, were produced at two industrial plants. Strength tests showed that the order of the strength influencing factors, like strength of the wood, glue line, defects (*e.g.* knots) and finger joints, at TMT is changed, comparing to untreated wood. Therefore, the effect of lamella gluing on strength of the whole beam was not determined as expected. The altered profile of strength properties resulted in a equal or higher MOE and a reduced MOR. For TMT (equal if as board or as glulam) the same rule is valid: Limiting factor and base of calculation for untreated wood is the maximum deflection, for TMT this is the maximum load bearing capacity. For calculations of wooden constructions according to the semiprobalistic design concept (Eurocode 5), this circumstance may be considered e.g. by a higher safety margin. Durability tests according to CEN/TS 15083-1 showed different results, depending on the test fungus species.

INTRODUCTION

The market request on durable, not impregnated home grown wood species is still increasing. Although thermally modified timber (TMT) has a reduced strength, there is a demand on the market for use of TMT for load bearing outdoor applications. It is obvious that the strength loss caused by thermal treatment may be partly compensated by increasing of the size of cross-section. Here, the promising way is not to treat bigger logs, but to make glued beams (glulam) from regularly manufactured TMT assortments (boards). The objectives of a research project of IHD, executed from 2006 to 2008 (Scheiding, Gecks 2008), were to prove that the production of glulam from TMT is possible, to investigate the effect of gluing on strength properties and type of failure, and to determine the strength level of both lamella and glulam. Furthermore, technological aspects have been addressed, like manufacturing and quality of finger joints, applicability of different glues (face and finger joint gluing), and specialties of production lines to be considered.

MATERIAL

Materials were TMT Spruce and TMT Beech from industrial processes, treated both at a lower and a higher level, and native wood for comparison (table 1).

Table 1: Material variants

variant	thickness [mm]	width [mm]	density [kg/m³]		EMC [%] at climate 20/65	
			average	s	average	s
Spruce			455	22	12.2	1.4
TMT Spruce 190	47	110	424	20	6.3	0.7
TMT Spruce 212			419	28	5.0	0.6
Beech			696	57	9.0	1.4
TMT Beech 185	32	110	668	38	4.4	0.9
TMT Beech 200			659	37	3.9	0.6

As adhesive systems, melamine resins (MUF) and polyurethane adhesives (PUR) were used. These adhesives are approved for load bearing applications up to service class 2.

PRODUCTION TRIALS

Laboratory scale beam manufacturing

At IHD laboratories, short glulam beams of 1100 mm length were manufactured, without finger-jointing. The adhesives were applied manually; for pressing a Höfer type SWP press was used, ensuring the requirements on pressure and pressing time. MUF and PUR were used for lamella bonding.

Finger-jointing

Tests on finger-jointing were carried out at Grecon Dimter Holzoptimierung Nord GmbH & Co. KG, Alfeld. Finger jointed samples of all 12 variants were made, using different pressures. The strength of the finger joints was determined by bending tests at IHD.

Industrial scale beam manufacturing

The production trials were done by two glulam manufacturers: Holzwerke Bullinger GmbH & Co. KG, Neuruppin, and STRAB Holzbau GmbH, Hermsdorf. From all 6 TMT assortments, beams of 110×235 mm² (Spruce, 5 layers) and 110×192 mm² (Beech, 6 layers), with a length of 4.2 m, were produced. Neither the adjustments of the production lines nor the adhesive system (only MUF is used) were changed or adapted.

RESULTS

Properties of lamella

All boards/lamella were visually stress-graded according to DIN 4074. For glulam, only Beech boards (untreated) of at least grade LS 7 were used. From Beech, 235 boards were used for the 185 °C process and 237 boards for the 200 °C one; 201 boards were left untreated for comparison. In difference to Beech, Spruce was delivered in three variants (189 boards untreated, each 112 treated at 190 °C and 212 °C process).

Table 2: Properties of lamella

variant	n	MOE [N/mm²] average (stand. dev.)	MOR [N/mm²] average 5-%-fractile	compr. strength ⊥ [N/mm²] average 5-%-fractile	impact bend.s. [kJ/m²] average
Spruce	15	17260 (2070)	47.5 32.9	4.2 3.3	37.8
TMT Spruce 190	20	16910 (2860)	31.8 21.8	3.0 2.4	30.7
TMT Spruce 212	17	17340 (2470)	30.4 16.4	2.7 2.1	27.5
Beech	16	16860 (2600)	89.5 56.0	11.9 10.4	61.2
TMT Beech 185	16	20890 (1980)	53.3 30.5	10.3 8.6	37.9
TMT Beech 200	20	21420 (3000)	50.2 22.2	8.9 7.5	17.0

Properties of glulam beams

Results from mechanical tests are given in table 3. As it is known, MOR decreased with treatment level, but MOE was found increased, comparing to untreated wood.

Table 3: Mechanical properties of glulam beams from industrial manufacture

Variant	MOR value		5-% fractile		MOE	
	Average value [N/mm²]	Deviation from untreated wood [%]	Average value [N/mm²]	Deviation of from untreated wood [%]	Average value [N/mm²]	Deviation from untreated wood [%]
Spruce	34.5	-	21.3	-	14100	-
TMT Spruce 190	21.6	-37	13.8	-35	17000	+20
TMT Spruce 212	20.3	-41	9.1	-57	16500	+17
Beech	70.9	-	41.9	-	14900	-
TMT Beech 185	32.1	-55	16.3	-61	17600	+18
TMT Beech 200	30.0	-58	11.9	-72	17500	+17

Assessment of glue lines

The bonding quality was assessed according to EN 392 (shear test) with specimens from glulam beams. After storage in dry climate 20/65 and in cold water for 24 h, the percentage of wood breaking was mostly 100 % for all variants. After boiling in water for 6 h, most of the glue lines failed. It has to be noted that both adhesive systems are not produced for service class 3. The modified variants, particularly of Beech, showed less failure after boiling, due to less swelling.

Durability

Depending on the test fungus (*Coniophora puteana* in any case, *Trametes versicolor* for Beech and *Poria placenta* for Spruce), the durability tests according to CEN/TS 15083-1 showed different results: TMT Spruce 190 class 4, TMT Spruce 212 class 3 (total class 3), TMT Beech 185 class 1 and 4 (total class 4), TMT Beech 200 class 1.

Calculation example

To check the useability of TMT glulam beam as girder, data for a beam supporting a roof with span of 2.0 m were calculated. The load was set as a uniform one. The permanent loads (from dead weight and from roof construction) were set by 1.5 kN/m, the changing loads by 1.0 kN/m. Structural analyses were calculated for bending, share and initial deflection. All analyses could be fulfilled. For a width of 100 mm, the required beam height was calculated for untreated Spruce to be 160 mm, for TMT Spruce 190 to be 180 mm (+13 %) and for TMT Spruce to be 220 mm (+ 38 %).

DISCUSSION

Compared to untreated wood, the characteristics of TMT for strength grading as well as strength of finger joints and lamella bonding have a much lesser influence on the load bearing capacity of the glulam beams. Thus, it is not possible to draw conclusions from the strength grading of primary (untreated) material to the strength of TMT glulam, but it is recommended that a strength graded assortment is used as raw material.

While the structural analysis of deflection is the limiting criteria for the design at untreated timber, for thermally modified timber it is the structural analysis of bending strength. Within construction practice, deflection often plays the most important role for the required dimension of a beam. Due to the higher MOE, it is less important for TMT. Furthermore, the calculation example showed, that the dimension (beam height) has to be bigger, but not in the same extend as would result from the reduction of MOR.

CONCLUSIONS

The calculation example showed that TMT is applicable for load bearing application *in principle*. The reduced strength may be considered by a higher safety margin. However, to use TMT for those applications – regardless if as solid wood or as glulam – a suitable proof of applicability (technical approval) is required by EU and national building laws. This is mentioned in CEN/TS 15679:2007 "Thermally Modified Timber" as a pre-standard. Here, no data for an assessment procedure are given. Currently, such a structural analysis is not known for any TMT assortment. An approval for TMT glulam and all characteristic strength values will refer only to one specific assortment, which is defined by wood species, grading, process, treatment level and gluing system.

REFERENCES

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