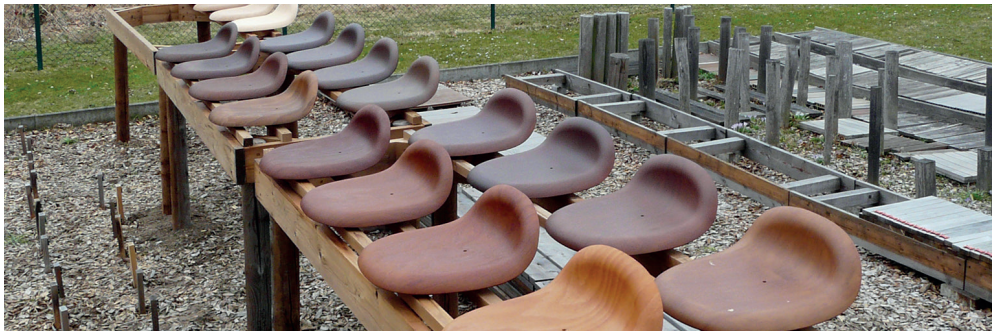
Definition of Terms: TMT, Thermowood

Wood modification

Modification of wood is the persistent change of wood with view of wood improvement for increasing its durability against fungal attack as well as for enhancing its dimensional stability and strength. Procedures include thermal and chemical modification as well as depositing resins (Holz-Lexikon, DRW-Verlag 2008).
The professionally correct term is thermally modified timber, technically abbreviated as TMT; thermowood is used synonymously, but is not defined or proprietary. ThermoWood® is the trademark for procedures and products of the International Thermowood Association. The normative basis for TMT is the European technical specification CEN/TS 15679:2007 "Thermally Modified Timber – Definitions and characteristics".



Seating elements (Gubi barstool) made of thermally modified veneers subjected to several stages of treatment, in outdoor weathering (thermal treatment by IHD and OWI, manufactured by REHOLZ)

Definition and operating principle

TMT or thermowood is timber that has been treated at temperatures of usually 160-230° at reduced oxygen concentration and whose properties have permanently been changed across its entire crosssection (see CEN/TS 15679).
Thermal modification is a partial pyrolysis in a low-oxygen atmosphere. It results in changing the chemical composition of the timber, more precisely of the cell wall: degradation of hemicelluloses (from 140-150 °C), α-cellulose (above 150 °C), degradation and partial restructuring of the lignin (an increase in the relative lignin share), expulsion of volatile accessories (resins, etc.). Organic acids, for example, occur as degradation products; the pH-values decreases. A significant effect is the clear reduction in the number of OH-groups (hydroxyl groups).

TMT as a semi-finished product

The result of TMT manufacture is modified round and sawn timber. TMT is characterised by the wood species, grading, its manufacturer, procedures and stages of treatment and has a specific property profile. Generally, TMT can be considered as an innate "group of wood species" and particular TMT as a technically generated "wood species".
Compared to natural timber, TMT distinguishes by an increased resistance against wood-destructive fungi, by improved dimensional stability, lower equilibrium moistures as well as darker color shades. As a rule, an increasing intensity in the modification treatment (high-temperature level) will result in decreasing stability.

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03/18-M TMT.01

Durability of TMT

Durability and Durability Classes

Natural durability of wood is the term for its resistance against the attack by wood-decay organisms, such as fungi, insects or marine organisms.
Wood-decay fungi require local moisture in wood starting from about fibre saturation. Certain fungi, e.g., dry rot, already develop at lower wood moisture levels of above 20 %. Wood-decay fungi include basidiomycetes, causing brown rot and white rot, and soft rot that require higher wood moisture than basidiomycetes.
The European Standard EN 350 serves as a guideline for determining natural durability or for allocating natural wood species to durability classes (examples cf. Table 1).

Table 1: Durability classes of solid wood acc. to EN 350-2 and examples

Durability class	Explanation	Wood species (sapwood-free heartwood)
1	very durable	teak (1-3), makoré
2	durable	white oak, bangkirai, robinia (1-2)
3	moderately durable	pine, larch (3-4)
4	little durable	spruce, fir
5	not durable	sapwood in general, beech

Use Classes of Solid Wood

The installation situation for wood-based components and their consequential exposure to moisture and harmful organisms is expressed in use classes (UC). These are defined in DIN 68800-1:2011-10 „Wood Preservation. Part 1: General" and largely correlate with the European use classes acc. to EN 335. However, use class 0, as it is determined in Germany, does not exist there. Table 2 describes those use classes where an infestation by wood-decay fungi is principally to be expected. Moreover, the required durability for damage-free use in the use classes is indicated in EN 460.

Table 2: Use classes that can be threatened by fungi (extract from DIN 68800-1:2011-10, Table 1)

UC		Wood moisture / exposure	General conditions of use
2		occasionally moist (> 20 %) mean relative humidity above 85 % or temporary moistened by condensation	wood or wood-based product under roof, not exposed to weathering; high ambient humidity may lead to occasional, but not permanent moistening
3	3.1	occasionally moist (> 20 %) an accumulation of water in the wood, not even in locally limited areas, is not to be expected	wood or wood-based product not under roof, being weather-exposed, but not permanently in soil or water contact; an accumulation of water in the wood, not even in locally limited areas is not to be expected due to rapid back drying
	3.2	frequently moist (> 20 %) accumulation of water in the wood, also locally, is to be expected	wood or wood-based product not under roof, being weather-exposed, but not permanently in soil or freshwater contact; accumulation of water in the wood, also locally, is to be expected
4		mainly to permanently moist (> 20 %)	wood or wood-based product in permanent soil or water contact
5		permanently moist (> 20 %)	wood or wood-based product permanently exposed to seawater

Durability Testing

Durability of wood is best tested in outdoor testing. It is evaluated by comparing the exposure time (duration up to destruction) of test and referential wood. Wood species of lower durability serve as referential wood; pine sapwood is used for testing coniferous wood and European beech is used for testing deciduous wood. Outdoor testing takes several years. More short-term laboratory testing (test duration approx. five months) allows preliminary grading in durability classes. Laboratory testing is performed in conditions favourable to fungal growth. Basidiomycete testing is performed by applying several test fungi deliberately injected into wood test samples. For soft rod testing, the test samples are placed into a soil substrate. Table 3 provides an overview of relevant test methods.

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Table 3: Test methods for determining the biological (natural) durability of wood

UC	Threatened by	Laboratory testing	Outdoor testing
3	basidiomycete fungi	CEN/TS 15083-1	CEN/TS 12037 (lap-joint test) IRG/WP 04-2019 (double-layer test)
4	basidiomycete fungi	CEN/TS 15083-1	EN 252 (dig-in test)
	soft rot fungi	CEN/TS 15083-2	
5	marine organisms	-	EN 275

Use classes and durability classes are correlated in both EN 460 and DIN 68800-1:2011. This is where the required durability for damage-free use in the use classes is indicated. Table 4 quotes the respective table from DIN 68800 (modified).

Table 4: Minimum requirements of durability of sapwood-free dark-coloured heartwood towards fungal infestation for application in use classes 2 to 4

GK	Durability class acc. to DIN EN 350-2			
	1	2	3	4
2	+	+	+	-
3.1	+	+	+	-
3.2	+	+	-	-
4	+	-	-	-
+ natural durability sufficient - natural durability insufficient				

Durability of TMT towards wood-decay fungi

Thermally modified timber (TMT) distinguishes itself by considerably increased durability towards wood-decay fungi. This is mainly due to the degradation of wood components, preferably of hemicelluloses (wood sugar), and to lower equilibrium moisture, reduced by 50 % on average. Capillary water intake is possible despite the reduced hygroscopic equilibrium moisture. Hence, TMT can be attacked by wood-decay fungi under unfavourable conditions with long-term or permanent moistening.
EN 350-2 includes details regarding the natural durability of wood species of special importance to Europe; modified or otherwise treated wood species are not listed there. However, the requirements of durability, as per EN 460 or DIN 68800, for example, can also be applied in that sense to modified timber.
Up to now, durability specifications regarding TMT are mainly based on laboratory testing. TMT durabilities identified there could partly be verified by outdoor testing (inter alia Plaschkies et. al, 2010).
Depending on the wood species, procedures and intensity of treatment, different durability classes are achieved in TMT. With the same intensity of treatment, higher durability is obtained in deciduous species of wood than in coniferous species. TMT made of hardwood is mostly graded in lasses 1 and 2; TMT of softwood is usually found to be graded in Classes 2 and 3.

Durability of TMT against wood-colouring fungi

Compared to native wood, the risk of TMT being infested by wood-colouring mould and blue-stain fungi is lower, with less intensive growth, respectively. Infestation can, however, not be precluded in unfavourable conditions, since TMT represents an organic substrate without any biocidal substances contained in them and having a certain, albeit low moisture content.

Durability of TMT against wood-decaying insects

As several investigations have shown, TMT has a higher resistance towards wood-decaying insects, such as the long-horned beetle or anobia, which use the wood as a breeding and feeding substrate. However, no increased resistance towards termites could be determined so far.

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Usability of Thermally Modified Timber for Load-bearing and Reinforcing Purposes

Fact Sheet TMT.03

Usability

The use of TMT (thermally modified timber) for load-bearing applications is only permissible, if its usability for such purposes has been proven appropriately. The reasons for that are particularly

- its usually reduced strength, and therefore its load-bearing capacity, as well as the altered behaviour of rupture of TMT as compared to untreated wood,
- the absence of statically secured values for calculations and measurements,
- the requirements of construction law: TMT is not to be regarded as a regulated construction product since its properties substantially deviate from regulated construction products[1].

1) On a European level, the usability of TMT in load-bearing applications is currently not permitted for formal reasons as long as no strength profile is available. The strength profiles as specified in EN 338 and the allocation of wood species to them (acc. to EN 1912) apply to native species of wood only.

In Germany, proof of usability for load-bearing and reinforcing purposes can be provided by

- load tests of structural components of playground toys acc. to DIN EN 1176,
- tests and proof within the scope of a single-case approval (German abbrev. "ZiE") by a lower building authority,
- tests and proof within the scope of a general building supervision approval (German abbrev. "abZ") by Deutsches Institut für Bautechnik Berlin (DIBt).

Thereby, strength values that have been established with the help of small, clear samples must not be applied to the dimensioning of load-bearing and reinforcing structural components.
These limitations also apply to „subordinate" building constructions of timber, e.g., to carports, and to staircases and self-supporting balconies. Staircases explicitly represent a load-bearing application, exposed to dynamic stress (e.g., by persons jumping or falling) and to high static load (e.g., by moving furniture). This also applies to staircase steps screwed onto panels and only partially resting on them. Neither self-supporting and attached balconies nor those with load-bearing components of TMT are permissible without any proof of usability. Only to the extent that the staircase or balcony flooring is supported over its entire surface, there will be no restrictions to the application of TMT from the load-bearing aspect.
The individual federal state construction ordinances (LBO) provide for differing regulation as to when a structural component is to be regarded as a load-bearing component. This is usually the case if or when a structural part, e.g., terrace flooring, is arranged higher than 0.5 m above solid ground (soil, concrete slab).
The experts of IHD and of the accredited test laboratory of the Entwicklungs- und Prueflabor Holztechnologie GmbH (EPH) are available for further information and consultancy regarding special cases of application as well as for material and product testing.

Test, Application and Product Standards

A project on the standardisation of thermally modified timber (TMT) was performed in 2006 under the direction of DIN e. V. Thereby, more than 250 test, application and product standards from the field of wood were reviewed with regard to their relevance to TMT and critical items or deficits were determined. The need for clarification and adaptation became obvious especially with view to the requirements or specifications of wood moisture in correlation with dimensions and strengths.
The notes that resulted do not only serve standardisation efforts, but appear to be useful tools for the users of standards, e.g., in planning, in designing scopes of performance or in drafting purchase, supply or works contracts. A 2007 follow-up project especially focused on the requirements of CE marking and of the Building Products Act.
Reports can be obtained from DIN (www.din.de) or IHD (www.ihd-dresden.de).

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03/18-M TMT.03

TMT Colour Shading Stability

Long-term exposure to light or sun radiation and weathering has an impact on all wood species, including TMT, resulting in changes in their colour and their surface structure. In other words: untreated natural timber and also thermally modified timber is not resistant to light without any further protection.

TMT in Outdoor Applications

The greying of wood is due to the degradation and washout of lignin close to the surface. The white cellulose remains and causes silvery-grey appearance. The course and extent of greying are mainly dependent on exposure (directly or indirectly weathered or exposed to solar radiation). Greying does not deteriorated the technical function of weathered timber products. Thermal modification does increase durability towards wood-discolouring fungi (mould, blue stain), nonetheless wood-discolouring fungi (mould or blue-stain fungi) or algae may deposit on surfaces in unfavourable conditions (at high moisture levels, shading) and due to the fact that TMT does not contain any biocidal substances. But the timber is not attacked thereby.

Remedial measures: If greying is to be reduced or at least delayed, appropriate surface protection has to be applied and maintained at regular intervals. For that purpose, several products recommendable for TMT can be purchased, e.g., lacquers, varnishes, oils and waxes. Coating systems consisting of priming, intermediate and final coating offer the best protection against greying, whereas opaque coats or dark-pigmented varnishes are to be given preference. But also simple, unpigmented oils or waxes provide a certain degree of protection. Blue-stain, mould or algae infestation can effectively be prevented by applying biocides only.

TMT in Indoor Applications

Also when used in interior applications, TMT changes its colour under the impact of light. While light-coloured timber darkens due to light-induced oxidation reactions, daylight results in the bleaching of dark timber or TMT. The darker the TMT, the stronger the TMT will brighten and the more apparent it will be.

Remedial measures: The surface of TMT flooring can be protected from bleaching with appropriate means. However, light stabilisers that have been developed for native, especially light-coloured timbers are only of limited benefit to TMT. Special agents that provide for long-term stability of the original colour of TMT are still undergoing testing. In combination with suitable coating, those additives can also be applied to outdoor uses.

Native teak before and after 500 h of exposure in the xenon test device

TMT ash 200 before and after 500 h of exposure in the xenon test device

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Standardisation, Quality Assurance, CE Marking of TMT

Definition

See Fact Sheet "Definition of Terms: TMT, Thermowood", TMT.01

CEN/TS 15679 „Thermally Modified Timber"

The European Technical Specification CEN/TS 15679 „Thermally Modified Timber – Definitions and Characteristics" has been published 2007 (CEN/TS have the status of a pre-issue). CEN/TS 15679 was confirmed in 2013.
If TMT is declared as such with reference to CEN/TS 15679, it is the manufacturer's obligation to provide for its internal production control, to document several data of production (inter alia, stages of treatment, moisture content, cracking) and mark its products stating the following information: manufacturer's name, retraceability of the production plant and internal production control, assortment or specification, reference to the CEN/TS, wood species as well as use class and scope of application.

DIN 68800 "Wood Preservation"

Standard DIN 68800 "Wood Preservation", which consists of four parts, has completely been reviewed. "Part 1: General" was published in October 2011 and Parts 2-4 were published in February 2012. Annex A (informative) to Part 1 contains basic information on the thermal or chemical modification for the preservation of wood.

Test, Application and Product Standards

A project on the standardisation of thermally modified timber (TMT) was performed in 2006 under the direction of DIN e. V. Thereby, more than 250 test, application and product standards from the field of wood were reviewed with regard to their relevance to TMT and critical items or deficits were determined. The need for clarification and adaptation became obvious especially with view to the requirements or specifications of wood moisture in correlation with dimensions and strengths.
The notes that resulted do not only serve standardisation efforts, but appear to be useful tools for the users of standards, e.g., in planning, in designing scopes of performance or in drafting purchase, supply or works contracts. A 2007 follow-up project especially focused on the requirements of CE marking and of the Building Products Act.
Reports can be obtained from DIN (www.din.de) or IHD (www.ihd-dresden.de).

CE Marking

The use of TMT in structural products, to which harmonized European standards apply, e.g., to flooring or windows, requires CE marking. Table 1 contains a selection of harmonized EN for applications where TMT can be used and for which CE marking is compulsory.

Table 1: Harmonised standards for timber products (a selection)

Standard	Title/contents
EN 13830	Curtain walling – Product standard
EN 13964	Suspended ceilings – Requirements and test methods
EN 14915	Solid wood panelling and cladding – characteristics, evaluation of conformity and marking
EN 14351-1	Windows and doors – product standard, performance characteristics – Part 1: Windows and external pedestrian doorsets without resistance to fire and/or smoke leakage characteristics;
EN 14342	Parquet and wood flooring. Characteristics, evaluation of conformity and marking
EN 14388	Road traffic noise reducing devices - specifications

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Qualitay Assurance

As a rule, manufacturers have at their disposal their own internal quality assurance or production control, respectively. Special systems of quality assurance by external facilities have been established in Finland, the Netherlands and Germany:

Quality label TMT (registered as an EU community trademark)
Issued by: Entwicklungs- und Prüflabor Holztechnologie GmbH (EPH)

ThermoWood® Production and Product Quality Control
Issued by: International Thermowood Association

KOMO® product certificate "Timber modification"
Issued by: Stichting KOMO (the Netherlands)

Summary

Up to now, TMT has not been covered by standards. Deviations of currently applicable standards or differences towards untreated timber exist, especially with view of wood moisture (equilibrium moisture in various climates). Also, its modified (mostly reduced) strength needs to be borne in mind.
Wood-processors and clients should be provided with at least a minimum of information regarding characteristic specialties or deviations from standards. When selecting TMT products for use in a certain application, specific property profiles should be taken into consideration.

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Methods for the Manufacture of TMT

Procedural Principle

The basic common principle of thermal modification is an impact of increased temperatures of between 160 °C and 250 °C (usually 180...230 °C) in low-oxygen conditions and can be termed as mild pyrolysis (Wienhaus 1999). The methodical types particularly differentiate in their way by which these conditions (an "inert atmosphere") are generated. As yet, the most common practice is thermal modification in an atmosphere of water vapour and wood gas at normal pressure. An overview of currently applied methods is provided by Table 1.
Further differences, apart from the type of oxygen reduction, are to be seen in moisture and pressure conditions and the course of time. These as well as the size and loading of chambers result in varying investment and operational costs. The technical details are proprietary to the plant manufacturers and operators and therefore not generally known. Since its industrial introduction at the end of the 1990s, the methods and plants of continually been improved. The methods are generally suitable for all species of wood.

*Table 1: Types of TMT methods and selected plant manufacturers**

	Special process Conditions	Plant manufacturers*
a	Wood gases + vapour + normal pressure	www.tekmaheat.com (www.jartek.fi); www.mahild.de; www.stellac.fi; www.valutec.fi
b	Wood gases + vapour + increased pressure	www.wtt.dk; www.moldrupsystems.com
c	Wood gases + normal pressure	www.muehlboeck.com
d	Vacuum (+ wood gases)	www.opel-therm.de
e	As a) + an additional high-temperature stage	www.platowood.nl (TMT-Hersteller)
f	Wood gases + nitrogen atmosphere	www.balz-maschinen.ch; Sci Fours et Bruleurs Rey
g	Vegetable-oil immersed	www.scholz-maschinenbau.de

*) no claim to being complete

Evaluation of Methods

Investigations into the various TMT-manufacturing methods (inter alia Welzbacher and Rapp 2002, Scheiding et al. 2005) none proved to be superior over others regarding modification effects. A systematic comparison of the various TMT methods is currently impossible since reliable data with view of economic parameters and of the environmental balance is not (yet) available.
Previous results have shown that the durability achieved against wood-decaying fungi largely depends on the temperature level during the high-temperature stage. This is more decisive than its duration so that the reduction of the temperature level can hardly be compensated by a longer high-temperature stage. Contrary to that, the (negative) impact of treatment on the strength properties is apparently more dependent on the kind of atmosphere or of the oxygen content, respectively.
However, a decisive criterion for the quality and yield is the quality of the assortment of the input material.
The frequently asked question for the "best" TMT method can be answered as follows:

- The types of methods mainly differ in their way of oxygen reduction ("inert atmosphere"), moisture and pressure conditions and course of time. These as well as the size and loading of chambers result in varying investment and operational costs.
- Regardless of the type of method, certain thermal work needs to be applied in order to obtain the desired effects.
- All types of methods yield similar basic effects (increased biological durability, reduction in swelling/shrinkage, equilibrium moisture and strength).
- However, TMT-treated products differentiate in their specific characteristics profiles.
- The methods cannot objectively be differentiated into "good" or "bad" ones.

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Fire Behaviour of TMT

Normative Bases and Requirements

Fire behaviour as a principal property of construction products is well defined by building law (EU Construction Products Regulation, building regulations as adopted by the individual states). On the European level, the normative basis is EN 13501-1 "Fire classification of construction products and building elements. Classification using data from reaction to fire tests". The most important test standards are the EN ISO 11925-2 (Ignitability in a single-flame source test), the DIN EN 13823 (Single burning item (SBI) test) or for flooring the EN ISO 9239-1 (Radiant panel test). The (still) applicable German standards for determining and evaluating the fire behaviour of are DIN 4102-1 et seq.
In European classification, construction products class B2 "normally flammable" acc. to DIN 4102-1, which applies to common construction timber, is subdivided into Classes D and E. While testing for Classes E or B2, respectively, merely focuses on flammability, the SBI Test and Radiant Panel Test also take into consideration the energy release or critical heat flow as well as the respective emission of smoke. The products are classified following the European fire classification acc. to EN 13501-1 within the scope of the CE marking of sawn construction timber acc. to EN 14081-1.
The requirements of the fire behaviour of construction products and hence of TMT derive in particular from the building regulations as adopted by the federal states and directly depend on the specific use or building project. If requirements exist, fire behaviour testing is compulsory for the individual case.

Fire Behaviour of TMT

TMT as technically modified timber cannot a priori be classified like native timber can. The modification process has different effects on fire behaviour. For example, the degradation of substances contained in the timber (e.g., resins, terpenes) has a rather inhibiting effect, while the reduction of wood moisture rather promotes fire behaviour. Since this – as do other properties, too – depends on the wood species and on the method of treatment, the specific TMT or construction parts must be subjected to fire testing. Up to now, there have merely been results of single-case investigations of an orientating character since no special requirements exist regarding the purposes of application. Individual investigations have shown that, with view of its flammability, TMT behaves like natural wood. However, what needs to be borne in mind is its modified smouldering fire behaviour. In that respect, there is no specific or generally acknowledged test method yet. But smouldering fire behaviour is taken into account and evaluated in SBI or Radiant Panel testing. Subject to specific testing, ascribing TMT to European construction products class E or German construction products class B2 should be sensible.

Classification

For assessing the fire behaviour of TMT, it can provisionally be classified, without any further testing, acc. to EN 14081-1:2011-05, Annex C. In accordance to that, timber used for load-bearing purposes of fire behaviour class or Euroclass D-s2 can be graded d0, if its mean raw density is at least 350 kg/m³ and its thickness at least 22. However, this applies only to the wood species listed there (Table B.1).
For the provisional classification without testing, also DIN 4102-4:1994-03 "Fire behaviour of building materials and building components" can be adopted. Acc. to Section 2.3.2, timber can be graded as Building Material Class B2 "combustible, normally flammable" if its raw density is at least 400 kg/m³ and its thickness more than 2 mm or its raw density is at least 230 kg/m³ and its thickness more than 5 mm.

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Thermally Modified European Beech

Fact Sheet TMT.09

Common or Copper or European beech (Fagus sylvatica L.) provides timber of versatile use, most commonly in interior design applications. Its thermal modification increases its durability in a way that allows its use in outdoor applications, too (Use Class 3 acc. to EN 335). The untreated wood of beech is graded under Durability Class 5 (non-permanent). Laboratory tests acc. to EN 350-1 have shown Durability Classes of 2 (permanent) and even 1 (permanent) for TMT beech. Open-air tests and other tests performed by the IHD seem to confirm these findings.

Apart from its low durability, untreated beech is subject to a comparatively high degree of swelling and shrinking. Thermal modification reduces them clearly, by about 50 %. It must be noted that the differential swelling and shrinkage hardly change; however, the clear reduction in equilibrium moistures results in respectively low shrinking and swelling.

Table 1: Equilibrium moisture content and differential swelling ration of TMT beech, compared to untreated beech*

Wood species	Equilibrium moisture [%] in climates as indicated				Different swelling [%/%]	
	20/35	20/65	20/85	23/50	radially	tangentially
TMT Beech	4,0	5,0	7,0	4,8	0,22	0,43
Beech untreated	8,3	11,5	18,5	11,0	0,21	0,42

**) The data were determined at TMT beech from open process (atmospheric pressure). Equilibrium moisture content of TMT from a closed process can be higher*

But what is of greater importance is its maximum swelling which occurs following persistent exposure to moisture since, despite reduced equilibrium moistures, TMT can absorb water through capillary intake. It must be assumed that the moisture of TMT at installation is very low at about 4-6 %.

For beech modified at 200 °C a swelling value of 1,9 % (radially) and 3.8 % (tangentially), respectively, was determined 14 d of being soaked in water; for comparison: according to the "Holzatlas" (Wagenführ 2007) the shrinkage rate of beech is 5.8 % (rad) and 11,8 % (tan), respectively. Despite the remarkable reduction to about one third, 4 % of swelling (radially) at 145 mm floorboard width still mean almost 6 mm. GD Holz states in its fact sheet for terraces a minimal spacing of 4 mm in a fully swelled state. 8-10 mm gap width is indicated as a measurement proven in practice 8-10 mm when laying the boards.

Even after thermal modification, beech shows higher swelling and shrinkage values as compared to other species of wood and is thus more likely prone to cracking. Cracks occur due to internal tension which exists in the wood already (growth-related tension) or which is caused by pre-drying or thermal treatment, respectively. Under certain conditions, such tensions are released not until much later, e.g., due to changes in temperature and moisture when exposed to weather, and become apparent in the form of cracks. Therefore, as it has been observed in some cases, TMT beech in exterior applications will show cracks after some time has lapsed. Hence, pre-drying and thermal treatment should be applied with special care. Experience has also shown that red heartwood of beech is increasingly prone to cracking. It is recommended therefore to abstain from using the red heartwood of beech for making TMT.

It is generally true for thermally modified timbers that they are, as it is also the case with untreated, natural wood, not resistant to light if no additional protective treatment is applied. Also the occurrence of wood-discolouring fungi on their surfaces is possible. Should these effects be prevented or delayed, appropriate surface protection, preferably using pigmented products, should be applied.

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03/18-M TMT.09

TMT in Window Manufacture

Fitness of TMT for Use as Window Frame Material

The main aspects of using TMT as window frame material consist in increased resistance towards wood-decaying fungi, reduced swelling and shrinkage as well as decreased heat conductivity. The durability of most TMTs ranges from classes 1 "very durable" to 3 "moderately durable". The equilibrium moisture as well as swelling and shrinkage are reduced by approx. 50 %. The reduction of its mechanical strengths and brittling of the wood due to modification have a limiting effect on its use. The intensity of treatment should be selected in such a way that an optimal characteristics profile is achieved. The target should not be highest possible durability since Durability Class 3 is required by both DIN 68800-1:2011-10 and VVF Fact Sheet H0.06; however, this should definitely be attained. The window design and procedural steps in the manufacture need to be accorded with the specific characteristics profile. The fitness of a certain TMT for use in window design must be identified by testing.

Normative Bases (Windows)

CE marking has been statutorily required for windows and external pedestrian doorsets (no fire protection and/or no smoke leakage) since 1 February 2010. This is based on DIN EN 14351-1/A1 (current issue: 2010-08), which is independent of material and, therefore, also applies to windows in which TMT is used. Marking is performed by manufacturers (or importers) in their own responsibility in accordance with Conformity Level 3. For that purpose, mandatory properties are to be specified after initial testing (Initial Type Testing ITT) and an Internal Production Control must be introduced to be permanently maintained. Properties for which no performance has been determined or for which no determined performance is to be declared, the abbreviation npd (no performance determined) can be indicated (unless legal requirements exist in the country of destination). In Germany, for example, parameters for the heat transition coefficient and air permeability are required by building law (cf. energy saving ordinance EnEV).

Timber Selection, Required Qualities

The application of TMT as frame material presupposes that the wood properties relevant to window manufacture are guaranteed. Therefore, at least the species of wood, assortment, process or treatment step and batch or the date of manufacture need to be specified for each specific TMT. This is also required if declared acc. to CEN/TS 15679. Generally, a quality acc. to Class J2, blue-stain free acc. to EN 942, is recommended. The statements according to DIN EN 13307-1, EN 14220, DIN EN 14221 and to VFF Fact Sheets H0.02 and H0.06-1 must be complied with. Moreover, TMT can be approved as timber fit for window making on the basis of VFF Fact Sheet H0.06-4: 2010-03 "Wood species for the manufacture of windows Part 4: Modified timber". Also, on-going quality assurance in the TMT manufacture is of importance. The production process and the product can be certified by the "Quality label TMT" granted by the EPH.

Manufacture of Scantlings

Laminated scantlings can be manufactured both homogeneously (all lamellas similar) and in combination with lamellas of natural wood (Fig. 1). The required bonding quality (the glueing of surfaces and dovetailing) can be secured by applying PVAc (D4), EPI or PUR glueing systems. Due to the lower wood moisture and the more hydrophobic nature of TMT, manufacturers' recommendations need to be observed or suitability tests performed. Pressure and pressing time need to be adjusted to the modified properties. Especially with view of asymmetrically designed scantlings, the processing moisture should largely correspond to the moisture during usage in order to limit later dimensional changes and provide for sufficient dimensional stability. The raw densities and swelling coefficients of adjacent lamellas must not differ widely for the same reason.

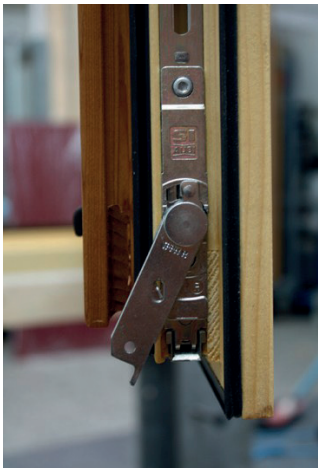

Fig. 1: Window sash of a composite scantling

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Window Manufacture

Profiling

Profiling can be performed applying usual tools and settings. The sharpness of tools (carbide-tipped edges) is, especially for TMT, a decisive prerequisite for high-level woodworking quality. If required, the feed rate needs to be adjusted. Sharp-edged profiles should be avoided and profiled edges chamfered. Since the handling of TMT produces very fine sawdust and a distinctive odour, intensive exhaust facilities and ventilation must be guaranteed and in place.

Surface Coating

An improved surface quality after profiling is an advantage (fibres are squeezed to a lesser extent), so that intermediate sanding may be omitted. Also TMT requires high-quality and overall coating (impregnation, including protection against blue stain, priming, intermediate coating and surface finishing). Thick-layered and well pigmented coating systems are recommended, since UV resistance of TMT as compared to natural wood has not been improved. If coating is missing, deficient or damaged, also TMT can be infested by mould or bluestain fungi in unfavourable conditions.
The required maintenance and care intervals during the lifetime of TMT can be extended thanks to its improved dimensional stability and lower tendency to cracking.

Glazing, Sealing

Pre-tests with the specific TMT assortment are required to test the compatibility and fitness of sealants, sealing profiles and space-glazing blocks (cf. VFF Fact Sheet H0.06-4).

Fasteners and Fittings

Predrilling for screwed joints is advisable in order to prevent predetermined breaking points. Regarding the application of fittings to TMT windows, the requirements of burglar protection apply. Due to the lower pH-values of TMT, dark complex joints may emerge in spots of contact with base metals and in the presence of moisture, as it is known of species of wood which are rich in tannin (oak, larch).

Window Design

Proven window designs of natural wood can be transferred to TMT windows if the described material-specific characteristics are observed and subject to above-mentioned limitations. All partitions (supports, sash bars, muntins), types of window glazing, etc., are possible, also any well-known window systems, such as single-glazed windows, double-glazed windows, box-type windows and material composites (e.g., wood/aluminium). Regardless of the improved durability of TMT, all possibilities of structural wood preservation should be exhausted. Above-mentioned advice regarding the manufacture of scantlings applies to the corner joints of frames respectively. Mortise and tenon joints, dowel joints and mechanical joints are possible.

Product properties of TMT Windows and Their Areas of Application

Generally, no restrictions regarding TMT windows are to be expected with view of their performance (resistance to driving rain, permeability of joints, resistance to wind load), of their mechanical strength (vertical load and static warping) as well as to their permanent mechanical functionality. Limitations may exist due to their reduced breaking strength, possibly in the event of exposure to high impact, extreme wind load and, with large formats, in conjunction with the large mass of glass. For that reason, the testing of a TMT window design is recommended mainly with view of mechanical-dynamic stress (EN 12211 “Safety test”, EN 13049 “Resistance to impact”). Due to its restrictions, scantlings completely made of TMT for use in burglar-proof windows are not recommended. By using composite scantlings (fittings fastened to natural wood), the benefits of TMT, also in burglar-proof windows, can be made use of. In any case, their design must be accorded to and tested for specific requirements.
A special aspect results from its reduced heat conductivity, as compared to natural wood of the same wood species. Depending on the window, the value of the heat transfer resistance of the entire window (Uw) can thereby be improved by between 0.1 to 0.2 W/m²K.

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The Coating of Modified Timber

Fact Sheet TMT.11

Introduction

Attractive, darker colour shades represent a positive side-effect of thermal modification. Should they be preserved (cf. Fact Sheet "TMT Colour Shading Stability", TMT.04) or should the timber additionally be protected, surface finishing must be taken into consideration.

The same principles as applicable to natural wood apply to modified timber.

- The type of coating is to be selected with view of its purpose of use, of the stress it is exposed to and of the wood species.
- The thinner the coating, the lower its protective effect, the shorter is the maintenance interval, but the easier is maintenance.
- Increasing requirements of dimensional stability require higher layer thickness.
- Blanks in thick coating may reverse the protecting effect (cases of wetness).

Owing to modification, coating can be affected as follows:

- a more hydrophobic surface (larger contact angle),
- reduced wettability and water intake capability,
- reduced pH value,
- possibly modified surface hardness,
- higher surface quality (planing) and
- lower swelling and lower tendency of fibre turning upright.

The Coating of TMT for Use in Interior Design

Many end-users expect TMT colour shades to be permanent, since TMT is technically modified timber; this applies to products intend for use in both interior and exterior applications. Investigations performed at the IHD (Beyer 2010) have confirmed that the colour shades generated by thermal modification are not resistant to light. Therefore, it is recommended to apply light-protective measures to surfaces of TMT products intended also for use in interior design.

The higher the intensity of treatment, the more and darker, but light-sensitive compounds are formed. Therefore, the bleaching effect due to irradiation becomes more apparent. One advantage of TMT is, however, that the darker colour shades very simply permit the application of certain, darker colour pigments as reasonably-priced and proven light-protecting agents.

It was also found out at the IHD that traditional light-protecting agents developed for light-shaded timbers do not work with TMT, even causing strong modification in colour, preferably greying, in certain cases. A light-protection concept developed at the IHD especially for thermowood has started to show very good results in interior conditions. This light-protection concept consists of an impregnation with an additive that reacts either as a deactivator or stabiliser, possibly complemented by colour-shading additives in the coating. The development of coatings for exterior use based on that concept is in preparation.

The Coating of Windows Made of TMT

It is also highly recommended to provide wooden windows of TMT with coating. A coating system to be applied to a specific TMT should be tested for fitness and adapted, if necessary.

Tests conducted at the IHD (Schweitzer 2007) of several coating systems revealed clear differences in quality. Variants of thick layers showed better results, in general, in comparison to variants of medium-thick layers (varnish and opaque), so that it appears not advisable to omit intermediate coating. The application of natural oils and waxes is possible; however, frequent care and maintenance are advised. Open-air weathering tests have so far not allowed any conclusions regarding differences with view of weather resistance of coatings on TMT in comparison with natural wood. Investigations of the degree of drying of water-based systems acc. to DIN 53150 have shown that they are applicable to TMT if the manufacturers' instructions are observed. But due to an extended time of drying, the risk of blocking must be borne in mind.

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Blanks, especially cracks or spray craters, form entrances for moisture and fungus spores to intrude. Due to the capillary transport of moisture with dark-coloured compounds in the longitudinal direction of the grain, discolouring may occur close to such blanks.

Protection against blue stain is highly recommendable since the thermal treatment does not provide for any preventive biocidal effect. A classical coating structure is recommended to be applied to wooden windows made of thermowood, consisting of impregnation, priming as well as intermediate and final surface coating.

Due to the very good surface quality after the mechanical processing of the window profiles, intermediate sanding may be waived when applying the coating. The very fine dust of TMT requires a high degree of cleanliness and good exhaust facilities with regard to both occupational safety and health and the risk of soiling parts that have already been coated.

The Coating of TMT Facade Cladding

As for façade cladding, the necessity of any coating must be checked. If it is desired or required, it should be applied in top quality; the same principles as applicable to wooden windows apply here. Regarding TMT, too, special care must be taken when reliably protecting narrow edge, preferably the end grain. Edge chamfering should be of a 2...5 mm radius. Oil-based systems may be of advantage when coating profiled boards.

Coating is recommended for multi-layered solid-wood panels (SWP) in order to protect glued joints at their wide and narrow edges against the intrusion of moisture. As investigations at the IHD (Weber, Krug 2007) have shown, insufficient quality of wood cannot be compensated by any coating. Hence, at least in the case of surface cover lamellas, very good quality of wood (low knottiness or fibre deviation) must be paid attention to. High-quality surface cover lamellas as rift/semi-rift will probably not be taken into account for cost reasons.

Conclusion

The same principles as applicable to natural species of wood apply to the coating of modified timber. Coating in interior design is recommendable for reasons of protection from light. In exterior applications it mainly serves, apart from aesthetic aspect, the protection from fading, moistening and infestation by blue stain. Hence, when coating modified timber, no concession should be made regarding neither the structure and manufacturing quality nor maintenance and care.

Several coating systems suitable for modified timber are available in the market. For the large variety of modified timbers characterised by the modification method, wood species and treatment stage and the modification of properties, the coating system must be tuned to the specific material. Manufacturers' recommendations must be observed for that purpose. In the event of uncertainty or of missing information or experience, the fitness of a coating system for a certain material should be checked; if required, the coating and the application methods must be accorded.

The main benefits of modified timber with regard to coating are the improvement in the swelling behaviour and enhanced surface quality. Drawbacks may be seen in its reduced wettability and adhesive strength. The modified pH-values regarding corrosion, discolouring and adhesion must be borne in mind.

Light-coloured and unpigmented forms of coating to be applied to modified timber are less recommendable. Strongly pigmented or opaque forms of coating offer themselves for use with TMT due to the darker shading it shows anyway. Hydrophobic forms of coating do naturally provide a certain protection against weathering and fading.

Despite its increased durability towards wood-decaying fungi, infestation by blue stain or mould or algae can be slowed down or reduced, but not prevented at any rate. If the protection of the surface is to be achieved or required, it can, in most cases, only be attained by applying suitable biocidal agents that may be suspended in the impregnation, priming or coating fluids.

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