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ReBuMat – German-Vietnamese Collaborative Project on resource-efficient construction using sustainable building materials
Three-dimensional hygrothermal properties test on bamboo

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Inhalt

1 Summary

Dr. Zujian Huang used to be a PhD student in the Chair of Building Construction and Material Science, Department of Architecture, Technical University of Munich from 2015 to 2017. After graduation in 2018, he continues his study as a postdoctoral fellow in School of Architecture, South China University of Technology, Guangzhou, China.

Since February 2020, he comes to the Hygrothermics Department of Fraunhofer IBP for doing a 15-month visiting research program, which is funded by the National Natural Science Foundation of China and the China Association for Science and Technology. The topic is »Hygrothermal Performance Oriented Bamboo Building Envelope«. Since bamboo is a hygroscopic and organic building material, the hygrothermal properties of bamboo products and the performance of bamboo constructions are necessary to be determined precisely.

The Fraunhofer IBP's Hygrothermics laboratory in Valley, Germany, has comprehensive indoor and outdoor testing fields and facilities. With these facilities, he has completed several test items on two advanced bamboo-based products, namely the laminated bamboo and bamboo scrimber. Both products include variants in longitudinal, radial and tangential directions. The indoor test items include the bulk density, true density and porosity test, sorption test, water immersion test, capillary absorption test, water vapor transmission test, drying test and thermal conductivity test. These provide necessary parameters for describing the heat and moisture transfer characteristics of bamboo products. In addition, an outdoor exposure test is in progress, and with aid of the NMR facility, it will be used for verification between testing and simulation.

In next step, WUFI® will be applied to evaluate the hygrothermal performance of various bamboo constructions under different climates conditions. With help from the scientists and engineers of the department, he has prepared the meteorological data for hygrothermal simulation for nine cities located in south China. Numerical simulation will be employed to arrive at a climate-specific building envelope design that is more tolerant and efficient, which should help gain more confidence in practical application of bamboo constructions.

2 Introduction

Bamboo is one of the most fast-growing plants on earth. It accumulates more biomass than most fast-growing wood species within same period of time. In the form of bamboo-based panel/square material, industrial bamboo products are regarded as ideal substitute for timber in construction sector. The world's first bamboo-based panel appeared in China in the 1940s, but it was not until the 1980s that the research and development of industrial bamboo made a breakthrough, which was due to the successful introduction of wood-based material processing technologies.

According to the classification method of manufacturing technology, typical bamboo-based panel products include bamboo mat/curtain board developed in the 1980s, laminated bamboo, bamboo particleboard and bamboo oriented strand board developed in the 1990s, bamboo scrimber developed in the 2000s, as well as flattened bamboo panel that is developed in the 2010s and is sometimes not regarded as modified bamboo because no adhesive is added during the manufacturing process. Due to different constituent units, assembly methods, and size specifications, various panels may differ to some extent from each other. Bamboo can also be processed into composite with other materials such as wood, steel, glass fiber, plastic, or concrete. In terms of product system, dozens types of bamboo-based panel products have been developed [1]. However, among the bamboo-based panel products, only bamboo mat/curtain board, laminated bamboo and bamboo scrimber have been successfully applied on an industrial scale and enjoy market-oriented product promotion for various end uses. Others stay at the stage of initial production in the laboratories, due to many reasons such as commercial infeasibility of technology, lack of low-priced raw material and labor supply, insufficient understanding and use of the environmental and social-economic benefits of bamboo industry, and so on [2].

So far, many countries in the Asia-Pacific bamboo-growing region, including China, India, Indonesia, Laos, Malaysia, the Philippines, Thailand and Vietnam, have their own bamboo-based panel industry. Bamboo mat/curtain board is produced in almost all these countries. In China, a new form of bamboo mat board, named as »Glubam«, has been widely studied in terms of material properties, structural elements, and utilization in real constructions including buildings and bridges [3]. But only a few countries can produce more latest products like the laminated bamboo and the bamboo scrimber. The core technology and patents of these two products are mainly developed in China, so are the related researches and practices. In recent years, with the technology introduction, some Southeast Asian countries like Vietnam also start to produce similar products and join in the international trade.

2.1 Material production and application

2.1.1 Laminated bamboo

Laminated bamboo is a kind of bamboo-based panel or bamboo-based square material formed by gluing regular bamboo strips together. Its main production steps include: raw bamboo preparation; strip making; strip processing (including rough planning, strip selection, carbonization, drying, and fine planning); glue applying to strips; pressing strips to one-layer board; glue applying to one-layer board; pressing multiple one-layer boards to multi-layer board; post-processing (including sawing, sanding and dust absorption). Limited by the diameter and wall thickness of bamboo culm, the cross-sectional size of bamboo strips is generally width × thickness = (10-30) mm × (3-10) mm. For laminated bamboo production, only those bamboo species that have culms of large diameter can be the suitable raw materials, such as Dendrocalamus giganteus, Dendrocalamus membranaceus and Phyllostachys edulis [4].

Compared with some other kinds of bamboo-based panel or square products that are made of bamboo slivers, bamboo fibers or bamboo particles, laminated bamboo retains the original bamboo wall structure to a greater extent. It keeps the appearance characteristics of raw bamboo, including the bamboo fiber texture and bamboo nodes. Therefore, it is considered to have aesthetic advantages and is usually used as an exposed material for decoration in construction industry. There are different textures formed by different assembly methods of the bamboo strip units (Figure 1 and Figure 2).

Figure 1:
Photos of laminated bamboo production.

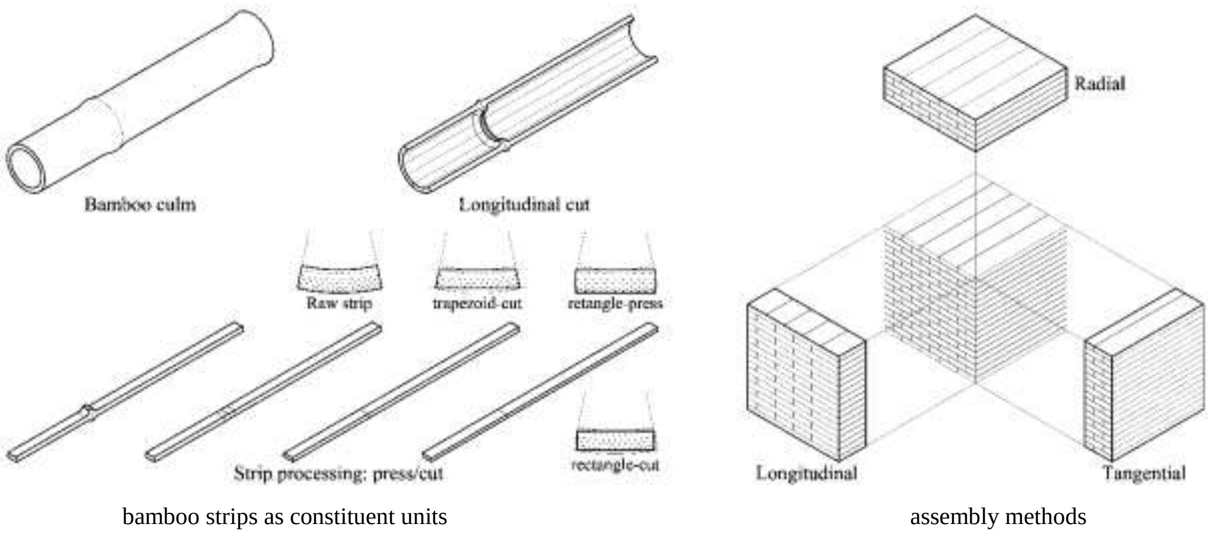


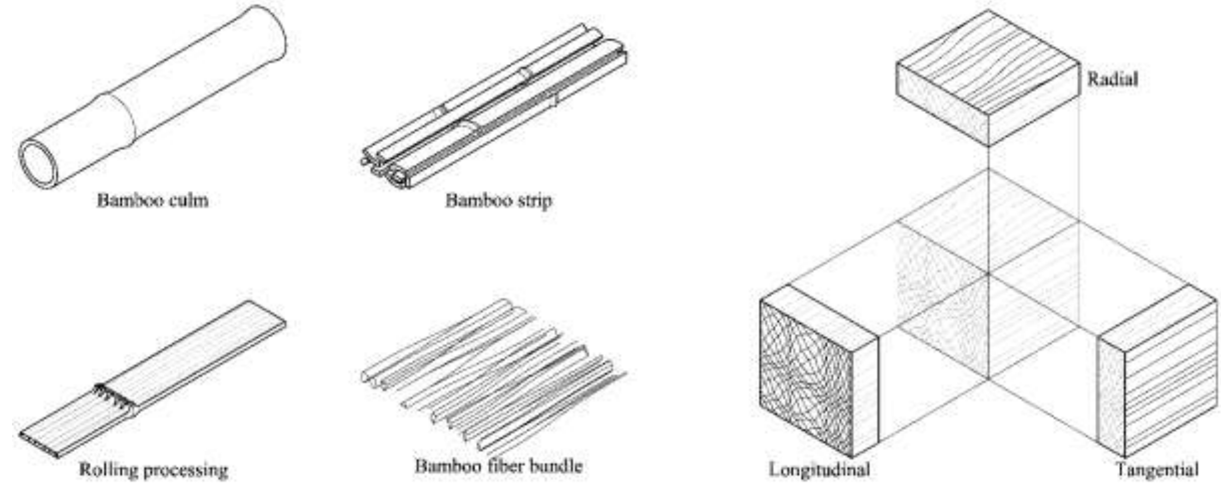
Figure 2:
Schematic diagram of laminated bamboo products in different direction.

2.1.2 Bamboo scrimber

Microscopically, bamboo fibers are arranged in parallel and have higher strength than wood fibers [5], which prompts that bamboo fiber-based products are beneficial to play their inherent mechanical advantages. However, bamboo medium-density fiberboard (MDF) composed of sufficiently separated and non-oriented fibers has not been successfully promoted, which is due to its low added value and complicated manufacturing process. Bamboo scrimber has been developed since the 1980s, but it is not matured technically until the 2000s [6]. It simplifies its constituent unit as loose bamboo fiber bundle that is arranged in parallel during the manufacturing process.

The manufacturing process of bamboo scrimber consists of the following steps: raw bamboo preparation; bamboo fiber bundle processing (strip making, rough planning, carbonization, drying, crushing strips to bamboo fiber bundle); glue application to bamboo fiber bundle; pressing to beam, activating glue in oven; post-processing (sawing beams, sawing planks, and sanding planks). The bamboo strip crusher can process 38 to 40 m bamboo strips per minute. The carbonization of bamboo strips shall be done in two rounds with each round lasting for 150 to 170 min, followed by two rounds of drying lasting for 168 h and 72 h, respectively. When bamboo strips are pressed into beams, a steel mould is used and the pressure is up to 2,200 t. When beams are placed in a large oven for 8 h, the adhesive will be activated at 140 to 150 °C (Figure 3, Figure 4).

Figure 3:
Photos of bamboo scrimber production.



bamboo fiber bundle as constituent units   assembly methods

Figure 4:
Schematic diagram of bamboo scrimber products in different direction.

The raw materials for producing bamboo scrimber can be derived from herbal bamboo species and small-diameter bamboos, and can also improve the utilization rate of raw materials. Due to the uniform fiber orientation of the constituent units, bamboo scrimber has mechanical strength. It rapidly becomes the mainstream of bamboo fiber-based panel products, which are widely applied in load-bearing building components, indoor and outdoor finishes, furniture and even wind turbine blades [7].

2.2 Hygrothermal research status

There are previous studies on basic properties, hygric properties, and thermal properties of bamboo, including bulk density, porosity, sorption isotherm, water vapor permeability, specific heat capacity, and thermal conductivity.

In terms of basic properties, Huang et al. (2015) analyze the density distribution of bamboo culms by computer tomography scanning method, showing that the bulk density of Moso bamboo (Phyllostachys edulis) nodes and internodes vary from 600 to 800 kg/m^3 [8]. Huang et al. (2017) also observe the pore structure of bamboo culms by computed tomography and backscattered electron imaging methods, showing that the average porosity of Moso bamboo internode is from 44.9 % to 63.4 % [9]. Both studies show that density distribution and pore structure of Moso bamboo have significant inhomogeneity on the scale of bamboo culm.

In terms of hygric properties, Jiang et al. (2012) carry out sorption isotherm research on bamboo blocks, bamboo powder, parenchyma cells and chemically macerated fibers of Moso bamboo, showing that the parenchyma cells demonstrate the highest hygroscopic capability followed in turn by bamboo fibers, bamboo powder, and bamboo blocks [10]. Wang (2010) compares the moisture sorption properties among bamboo blocks, bamboo fiber, bamboo lignin, and bamboo hemicelluloses, showing that under same relative humidity, the equilibrium moisture content (EMC) of the bamboo hemicelluloses is much higher than the bamboo lignin and the EMC of bamboo fiber is higher than the bamboo block [11]. Zhang et al. (2018) measure the sorption isotherms at 25 °C in a relative humidity range of 0 % to 98 % using a dynamic vapor sorption apparatus, showing that all the obtained sorption isotherms can be predicted agreeably with the Guggenheim-Anderson-de Boer (GAB) and Hailwood-Horrobin (H-H) models, and using the GAB and H-H models, the fiber saturation point values are determined, which results in a range from 16.37 % to 27.91 % for different bamboo species [12]. Huang et al. (2017) measure the water vapor diffusion resistance factor (μ) of Moso bamboo by dry cup, showing that the μ values in the radial and tangential directions vary from 30 to 57 [13]. Huang (2017) also measures the liquid water-related properties, showing that the capillary saturation moisture contents are 572, 479, and 385 kg/m^3 for exterior, middle, and interior parts of Moso bamboo culm and the water adsorption coefficients are 0.014, 0.008 and 0.0019 kg/(m^2·s$^{0.5}$), respectively [14]. Ohmae et al. (2009) investigate the water adsorption properties of Moso bamboo in longitudinal direction, showing that the hygroscopicity is affected by the distribution of hygroscopic saccharides such as the hemicelluloses and less-hygroscopic bundle sheaths [15]. Zhan et al. (2020) test the moisture sorption and diffusion properties of Moso bamboo blocks cut from different height locations of the culm, showing that the moisture transportation efficiency is affected by the graded hierarchical structure, and the moisture diffusion is quicker at higher heights or outer radial locations [16].

In terms of thermal properties, Huang et al. (2016) and Wu et al. (2004) measure the specific heat capacity (c) of Moso bamboo at 40 °C by the differential scanning calorimetry (DSC) method, showing that the c values vary from 1.7 to 2.3 kJ/(kg·K) [17], and from 1.08 to 2.29 kJ/(kg·K) [18], respectively. Shah et al. (2016) investigate the thermal properties of engineered bamboo products, confirming that the thermal conductivity (λ) of bamboo is structure-dependent, and the λ values can be well-predicted by the volumetric composition, reflected by the bulk density [19]. The studies from Huang et al. (2013) show that Moso bamboo is non-homogenous in terms of thermal properties in the radial, longitudinal and tangential directions [20]. Cui et al. (2018) study the c and λ values of bamboo scrimber at elevated temperature using TGA-DSC and Hot Disk methods, showing that the c and λ values increase gradually with temperature increasing from 20 °C to 100 °C, and the λ values parallel to grain is 1.26 to 1.63 times the conductivity perpendicular to grain [21].

2.3 Deficiencies of current studies

In term of material objects. Among the existing studies, most of the bamboo samples are made from raw bamboo, mainly the Moso bamboo. However, today's bamboo product system has been greatly expanded and various industrial bamboo products have been developed. During the manufacturing process of industrial bamboo products, the differences of constituent units, assembly methods, glue application, as well as protective treatments such as the anti-corrosion, fire prevention and anti-cracking cause changes to the material properties. Therefore, it is necessary to carry out independent material test for each of the industrial bamboo products.

In terms of material parameters. With the development of coupled heat and moisture transfer (HAM) theoretical models and HAM model-based computer tools, the heat and moisture storage and transfer processes of building envelope can be better described. HAM models require more complete material parameters. However, the existing test for bamboo cannot provide the material parameters required to support a complete HAM model, and most of them are directed to a certain basic property, thermal or hygric properties under steady-state conditions, which cannot be used to characterize the properties in the state where coupled heat and moisture occurs. In addition, part of these tests are based on the methods of micro-material science, using samples that are much smaller than the actual size in practical engineering.

2.4 Motivation of this study

Since bamboo is a hygroscopic and organic building material, the hygrothermal properties of bamboo products and the performance of bamboo constructions are necessary to be determined precisely. The material objects targeted in this study are two advanced bamboo-based products, namely the laminated bamboo and the bamboo scrimber. Both products include variants in longitudinal, radial and tangential directions.

The aim of the study is to obtain necessary material properties for HAM model by methods in accordance to the respective architectural standards. The acquisition of three-dimensional parameters can show the difference in heat and moisture transfer properties in different directions and is expected to provide a basis for the two-dimensional and even three-dimensional simulation of bamboo constructions. A comparison with reference timber products is carried out, in order to show the difference between corresponding bamboo and timber products and prejudge the hygrothermal properties feasibility of »substituting timber with bamboo« in building envelope.

3 Material and specimens

3.1 Laminated bamboo

The specimens in this test are produced by a bamboo company from Zhejiang Province, China (the Dasso Industrial Group Co. Ltd. Hangzhou). The cross-sectional size of the bamboo strip units is width × thickness = 20 mm × 6 mm. The raw bamboo used is the Moso bamboo (Phyllostachys edulis), a dominant temperate bamboo species. The adhesive applied to the products is Urea formaldehyde resin, with a mass proportion of about 5 % (Figure 5).

B(l), longitudinal B(r), radial B(t), tangential

Figure 5:
Photos of laminated bamboo specimens.
Note: The specimens in the photos are for thermal conductivity test, size: length × width × height = 25 cm × 25 cm × 3 cm.

3.2 Bamboo scrimber

The specimens are provided by a bamboo company from Zhejiang Province, China (the Dasso Industrial Group Co. Ltd. Hangzhou). The raw material used is the Moso bamboo (Phyllostachys edulis). The adhesive applied to the products is Phenol formaldehyde resin, with a mass proportion of about 10 % (Figure 6).

B(l), longitudinal B(r), radial B(t), tangential

Figure 6:
Photos of bamboo scrimber specimens.
Note: the specimens in the photos are for thermal conductivity test, size: length × width × height = 25 cm × 25 cm × 3 cm.

4 Test methods

The test is divided into three groups, including nine test items. The thermal analysis is done at South China University of Technology, Guangzhou, China, while the rest eight items are carried out in the Hygrothermic Department of Fraunhofer IBP, Valley, Germany.

4.1 Basic properties test items

The preparation of main equipments and specimens is shown in Table 1 and Figure 7. The operation methods are introduced as follows:

1) Bulk density test
   Dry the specimens, and cool them to room temperature in a desiccator; then carry out weighing and size measurement for calculating the dry bulk density.

2) True density test
   Dry the specimens and weigh them for dry mass, and then use the true density analyzer to measure the volume of the solid skeleton by gas displacement method; then calculate the true density.

Table 1:
Test items, main equipments and specimens preparation (basic properties test items).

Groups	Items	Main equipments	Specimens
Basic properties	Bulk density test	Drying oven, T = 70°C, with dry air for ventilation Balance: accuracy, 0.01 g Vernier caliper: accuracy, 0.01 mm	Quantity: a total of 18 copies, including 6 copies for each B(l) / B(r) / B(t) group Size: 5×5×3 cm Moisture content (MC) state: dry
	True density test	True density analyzer: analysis gas, Helium; test temperature, 22.6°C; number of purges, 10; equilibrate rate, 0.005 psig/min Balance: accuracy, 0.001 g	Quantity: 1 copies, about 2.8 g (laminated bamboo); 3.8 g (bamboo scrimber) Size: Granules and powders, particle size ≤ 5 mm MC status: dry


Bulk density test

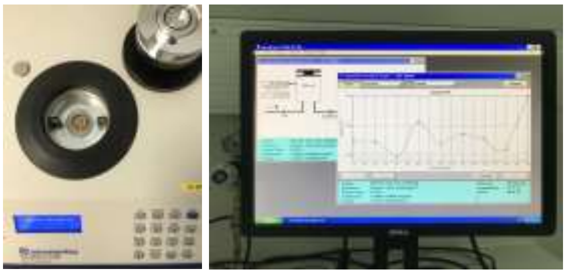

True density test

Figure 7:
Photos of bamboo properties test (basic properties test items).

4.2 Hygric properties test items

The preparation of main equipments and specimens is shown in Table 2 and Figure 8. The operation methods are introduced as follows:

1) Sorption test
   Refer to the ISO 12571:2012 [22]. For moisture adsorption process, dry the specimens and cool them to room temperature; move the specimens into

the climate room or climate chamber for curing; weigh the specimens twice a week, until the specimens reach their equilibrium moisture content (EMC). For moisture desorption process, the curing and weighing methods are same with the adsorption process, but the specimens are soaked in water for two weeks before curing and they are dried in the oven for dry mass after curing.

2) Water immersion test
   Dry the specimens and cool them to room temperature, record the dry mass and the size; immerse the specimens in water, and take them out at regular time intervals, wipe off the attached water with a soft moist cloth, weigh, and then put them back in the water to continue absorbing water; stop absorbing water until the quality of the test piece no longer changes, record the final mass and measure the size immediately; calculate the free water saturation with consideration to the size change of the specimens.

3) Capillary absorption test
   Refer to the ISO 15148:2002(E) [23]. Seal the specimens, record the mass and test (exposed) area of the specimens; place the specimens on the bracket in the water sink for absorbing water; take out the specimens at regular intervals, wipe off the attached water with a soft damp cloth, weigh the specimens, and place them back on the bracket to continue absorbing water; linearly fit the curve of the mass increase of the specimens, and calculate the capillary water absorption coefficient.

4) Water vapor transmission test
   Refer to the ISO 12572:2001(E) [24]. Place the desiccant/saturated salt solution at the bottom of the experiment cups; seal the specimens onto the opening of the cups; move the specimens (together with cups) into the climate room for curing; weigh twice a week, until the mass of the specimens changes linearly for no less than five times; calculate the water vapor permeability coefficient and the water vapor diffusion resistance factor according to the above standard, where the local air pressure is 933.26 hPa, and the local vapor permeability coefficient of still air is $2.120E^{-10}$ kg/(m·s·Pa).

5) Drying test
   Immerse the specimens in water for four weeks; take out and weigh, then immediately seal the four sides and bottom with aluminum foil and reweigh; move the specimens into the climate room for curing; recording mass at regular time intervals; the recording time interval is: 1 h for the first day, 2 h for the second to fifth days, 1 d for the second to sixth week, and two times a week after six weeks (Tuesday and Friday); after air-drying in the climate room, remove the aluminum foil and weigh; dry the specimens in the oven and weigh for the dry mass (Table 2, Figure 8).

Table 2:
Test items, main equipments and specimens preparation (hygric properties test items.

Groups	Items	Main equipments	Specimens
Hygric properties	Sorption test	Constant temperature and humidity climate room: *T* = 23°C, *RH* = 50%/65%/80% Constant humidity chamber: *RH* = 93%/97% (ambient *T* = 23°C) Balance: accuracy, 0.01 g	Quantity: a total of 24 copies, including 3 copies for each of the 8 groups (5 adsorption + 3 desorption groups) Size: 5×5×1.35 cm MC status: corresponding to the adsorption / desorption process, the specimens are dried / soaked in water first, and then cured to the EMC
	Water immersion test	Water sink: with a stainless steel hollow bracket at the bottom Water: about 2 cm above the upper surface of the specimens Balance: accuracy, 0.01 g	Quantity: 3 copies Size: 5×5×3cm MC status: dry
	Capillary absorption test	Water sink: with a stainless steel hollow bracket at the bottom; the top of the bracket is about 6 mm below the water surface Water: *T* = 22°C, slow flowing Balance: accuracy, 0.1 g	Quantity: 3 copies Size: 5×5×3 cm MC status: original (approximately corresponding to *RH* = 50%) Sealing treatment: use wax to seal the four sides, as well as the area within 5 mm from the edges of the upper and lower surfaces
	Water vapor transmission test	Constant temperature and humidity climate room: *T* = 23°C, *RH* = 50%/75%/80% Experiment cups: 10×10×10 cm cube glass cup, with an opening side as the test port Desiccant and saturated salt solution: *RH* = 3%/33%/93% Balance: accuracy, 0.01 g	Quantity: a total of 12 copies, including 3 copies for each *RH* gradient Size: 10×10×1.35 cm MC status: original (approximately corresponding to *RH* = 50%) Sealing treatment: use wax to seal the four sides, as well as the area within 5mm from the edges of the upper and lower surfaces
	Drying test	Constant temperature and humidity climate room: *T* = 23°C, *RH* = 50% Balance: accuracy, 0.01 g	Quantity: 3 copies Size: 10×10×1.35 cm MC status: close to saturated after immersing in water for 4 weeks Sealing treatment: use aluminum foil to seal the four sides and the bottom surface of the specimens

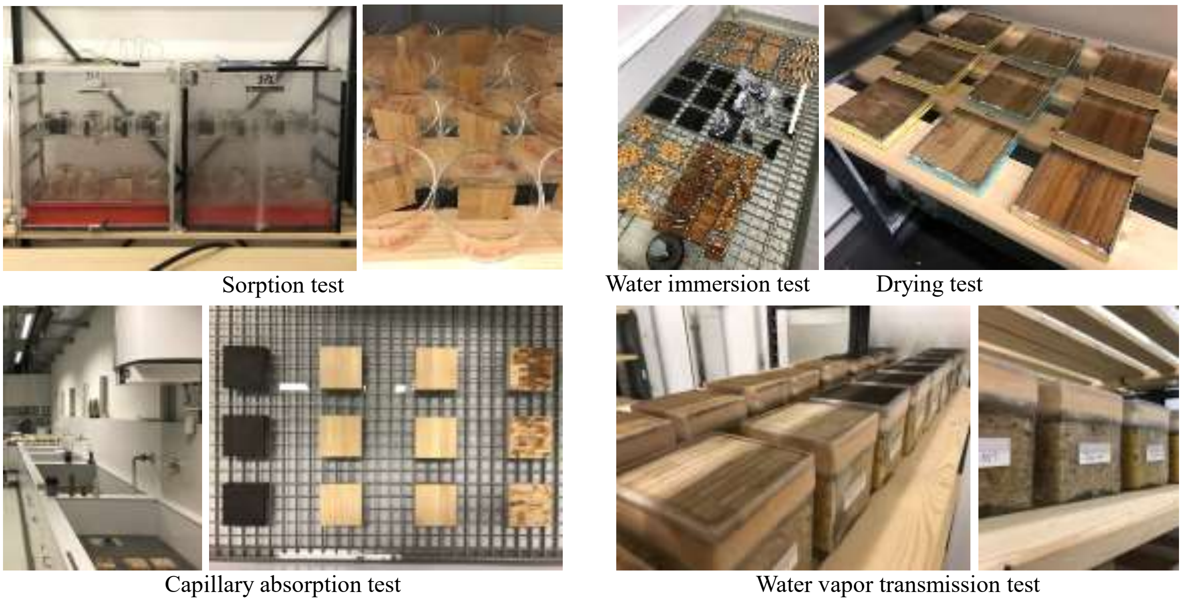


Figure 8:
Photos of bamboo properties test (hygric properties test items).

4.3 Thermal properties test items

The preparation of main equipments and specimens is shown in Table 3 and Figure 9. The operation methods are introduced as follows:

1) Thermal analysis
Refer to the ISO 11357-4-2005 [25]. Dry the specimens and cool them to room temperature; put them into the crucible and weigh; move the specimens into the DSC device; start the control program to raise and lower the test temperature; record the DSC curve and calculate the corresponding specific heat capacity.

2) Thermal conductivity test
Refer to the ISO 8302-1991 [26]. Dry the specimens or cure them to the specific EMC; use the guarded hot plate apparatus to create a temperature gradient on the upper and lower surfaces of the specimens, which drives the heat flow through the specimens; collect the heat flow density and surfaces temperature from the heat flow meters and thermocouples and then calculate the thermal conductivity (Table 3, Figure 9).

Table 3:
Test items, main equiments and specimens preparation (thermal properties test items).

Groups	Items	Main equipments	Specimens
Thermal properties	Thermal analysis	Differential scanning calorimeter (DSC): atmosphere, Helium; test temperature range, –20-40°C; heating and cooling rates, 3.0°C/min; Calibration/measurement range, 0/5000 µV Crucible: Pan Al, closed	Quantity: 2 copies, about 2.64 mg and 2.90 mg, respectively (laminated bamboo); about 3.55 mg and 3.78 mg, respectively (bamboo scrimber); Size: powder MC status: dry

	Thermal conductivity test	Self-assembled guarded hot plate apparatus, including main components: 1 cold plate, T = 10°C, 1 hot plate, T = 30°C; 3 thermocouples and 1 heat flow meter on both upper and lower surfaces of the specimen; multi-channel data collector, scanning interval, 2 min	Quantity: a total of 12 copies, including 3 copies for each MC status Size: 25×25×3 cm MC status: original / dry / EMC (RH=50%) / EMC (RH=80%)

Thermal analysis

Thermal conductivity test

Figure 9:
Photos of bamboo properties test (thermal properties test items).

5 Test results

Through the above test items, the dry bulk density (ρ_d), true density (ρ_t), porosity (Φ), isothermal adsorption and desorption curve (u-RH/w-RH, 23 °C), Free water saturation moisture content (w_{cap}), capillary water absorption coefficient (A), moisture dependent water vapor diffusion resistance factor or water vapor permeability coefficient (μ-RH/δ-RH), drying rate (U-u), specific heat capacity (c), and the moisture dependent thermal conductivity (λ-u) are obtained.

The indicators characterizing the basic properties, as well as the heat and moisture storage-related properties, including the ρ_d, ρ_t, Φ, u/w, w_{cap}, and c, are the same among the specimens in different directions. As for the indicators characterizing the heat and moisture transport-related properties, namely the A, δ/μ, U, and λ, there are differences among the longitudinal, radial and tangential directions. The test results are analyzed as follows.

5.1 Laminated bamboo

5.1.1 Basic properties

Test result of the dry bulk density (ρ_d) shows that, the average ρ_d of laminated bamboo is 0.621 g/cm^3, which is equivalent to 621 kg/m^3. Among the 18 specimens, the ρ_d values have a deviation of +/–28 kg/m^3. If the material »inhomogeneity« is defined as »(max. value – min. value)/average value» or »deviation/average value × 2«, then the inhomogeneity among the specimens is about 9.0 %.

Test result of the true density (ρ_t) shows that, the average ρ_t obtained from ten sampling of the granular specimen is 1.386 g/cm^3, which is equivalent to 1.386 kg/m^3. The corresponding deviation is +/–35 kg/m^3.

With the ρ_d and the ρ_t, the porosity (Φ) is calculated as:

$$\Phi = (\rho_t - \rho_d) / \rho_t \times 100\ \%$$

When the average ρ_d and ρ_t are substituted into the above formula, the resulted Φ value is 55.2 % (Table 4).

Table 4:
Test results of the basic properties, laminated bamboo.

Items	Notation	Value	B(l)	B(r)	B(t)
Dry bulk density	ρ_d [kg/m^3]	average max. min. deviation	621 656 600 +/–28		
True density	ρ_t [kg/m^3]	average max. min. deviation	1386 1414 1344 +/–35		
Porosity	Φ [-]	average	55.2%		

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

5.1.2 Hygric properties

Moisture storage-related properties

1) Isothermal adsorption and desorption curve (u-RH/w-RH, 23 °C)
   In the adsorption test, the dry specimens are cured in the climate rooms or climate chambers, with ambient air temperature (T) constant as 23 °C, and relative humidity (RH) constant as 50 %, 65 %, 80 %, 93 %, 97 %. The resulted equilibrium moisture content (EMC) in mass rate (u) corresponding to the five RH gradients is 6.28 %, 8.49 %, 12.15 %, 18.14 %, 23.72 %, which is equivalent to a moisture content in mass-volume rate (w) 39.0 kg/m^3, 52.8 kg/m^3, 75.4 kg/m^3, 112.6 kg/m^3, 147.3 kg/m^3, respectively.

   In the desorption test, the wet specimens after two-week water immersion are cured in climate room, with ambient air T constant as 23 °C, and RH constant as 50 %, 65 %, 80 %. The resulted u and w values are 8.84 %, 11.64 %, 15.70 % and 54.9 kg/m^3, 72.3 kg/m^3, 97.5 kg/m^3, respectively (Table 5, Figure 10).

Table 5:
Test results of the hygric properties (moisture storage-related), laminated bamboo.

Items	Notation	Value	B(l)	B(r)	B(t)
Isothermal adsorption and desorption curve (23 °C)	u [-]	 $u_{RH=50\%}$ $u_{RH=65\%}$ $u_{RH=80\%}$ $u_{RH=93\%}$	adsorption process: 6.28 8.49 12.15 18.14		desorption process: 8.84 11.64 15.70 /

		$u_{RH=97\%}$	23.72	/
	w [kg/m³]		adsorption process:	desorption process:
		$w_{RH=50\%}$	39.0	54.9
		$w_{RH=65\%}$	52.8	72.3
		$w_{RH=80\%}$	75.4	97.5
		$w_{RH=93\%}$	112.6	/
		$w_{RH=97\%}$	147.3	/
Free water saturation moisture content	w_{cap} [kg/m³]	average	test result: 563 corrected value considering volume expansion: 526	

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

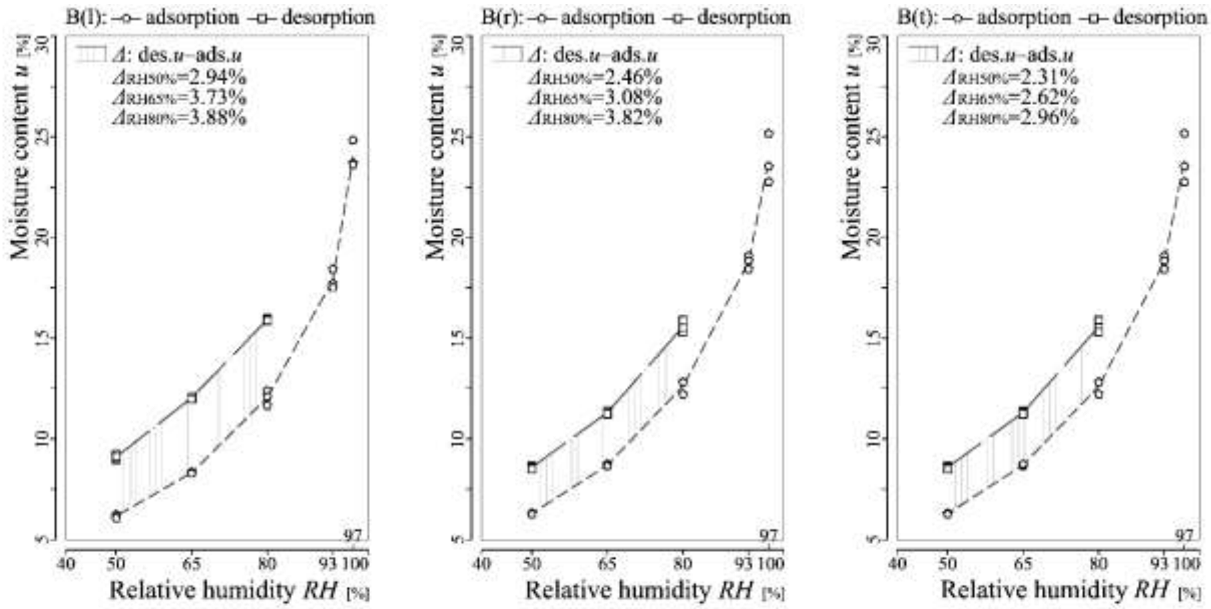


Figure 10:
Test result of the adsorption EMC and desorption EMC, laminated bamboo.

It can be seen from the comparison between the moisture desorption curve and moisture adsorption curve that bamboo has obvious hysteresis effects. Corresponding to the three RH gradients of 50 %, 65 %, and 80 %, the desorption u values are 2.57 %, 3.15 %, and 3.56 % higher than the adsorption values on average, which are equivalent to w values of 15.9 kg/m³, 19.5 kg/m³, and 22.1 kg/m³.

2) Free water saturation (w_{cap})
   It is worth noting that in the immersion test, the specimens reach their saturation status after about 4.5 months, and this water absorption process is accompanied by volume expansion of the specimens. The average u value after immersion is 90.7 %, which is equivalent to a w value of 563 kg/m³. It looks like that the volume proportion occupied by water is as high as 56.3 %, which exceeds the Φ value (55.2 %). In this test, the volume expansion of the specimens is also taken into consideration. The radial, tangential, and longitudinal dimension of the specimens after immersion ex-

pands to, respectively, 102.8 %, 103.9 %, and 100.2 % of the corresponding specimens in dry state, which means a total volume expansion of 107.0 %. Considering the extra water absorption caused by this part of volume, the free water saturation moisture content w_{cap} can be corrected to 563/107.0 % = 526 kg/m³. When the w_{cap} is converted to volume ratio, it is 52.6 %, which is slightly lower than the Φ.

Moisture transport-related properties

1) Capillary water absorption coefficient (A)
The water absorption test shows that, the capillary water absorption coefficient (A) values of laminated bamboo in longitudinal, radial, and tangential directions, are 1.36 kg/($m^2 \cdot h^{0.5}$), 0.13 kg/($m^2 \cdot h^{0.5}$), and 0.14 kg/($m^2 \cdot h^{0.5}$), respectively. The A value in radial direction is slightly lower than that in tangential direction, and both are about 1/10 of the value in longitudinal direction (Figure 11).

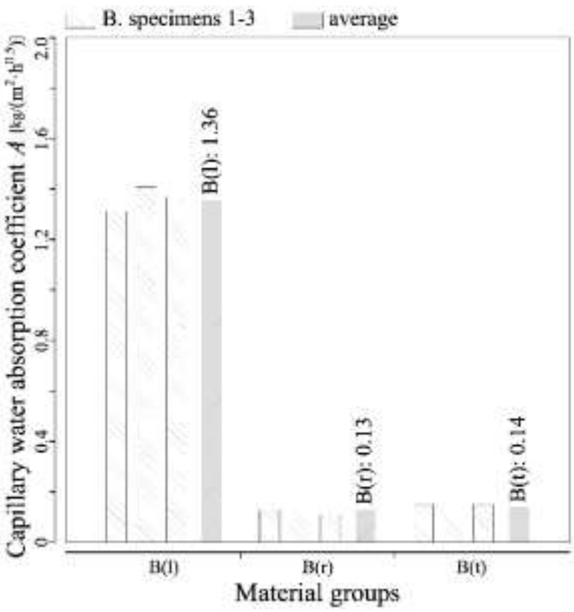


Figure 11:
Test result of the capillary water absorption coefficient (A), laminated bamboo.

2) Water vapor diffusion resistance factor (μ-RH/δ-RH)
In this test, the temperature condition is constant as T = 23 °C, and relative humidity conditions include four RH gradients, namely RH = 3% – 50 %/ 33 % – 75 %/93 % – 50 %/93 % – 80 %. When the water vapor permeation rate is stable, it can be approximately considered that the moisture content of the specimens corresponds to RH = 26.5 %/54 %/71.5 %/ 86.5 %. The test shows that the water vapor permeability rate is strongly affected by the moisture content of the specimens. For example, the water vapor diffusion resistance factor (μ) values of laminated bamboo specimens in longitudinal/radial/tangential directions decrease from $\mu_{RH3\%-50\%}$ =

27.4/1148.7/1392.8 to $\mu_{RH93\%-80\%}$ = 9.8/52.2/33.3. When we fit the test results between the water vapor permeability coefficient (δ) and the RH, we can find that a general exponential function, $\delta = a \cdot e^{b \cdot RH}$ (where »a« and »b« are fitting parameters), can describe this relationship. The resulted goodness of Fit (R^2), is in the range 0.865 – 0.982.

The water vapor permeability rate also shows difference in the three directions. Considering that in the RH gradients of 93 % – 50 % and 93 % – 80 %, there are mould growth on the specimens' lower surfaces facing to the salt solution, which may have influence on the test results, here the test results from RH = 33 % – 75 % gradient are taken for comparison. The $\mu_{RH33\%-75\%}$ values in longitudinal, radial, and tangential directions are 23.5, 449.2 and 343.8, respectively. The $\mu_{RH33\%-75\%}$ value in radial direction is 30.7 % larger than that in tangential direction, and the $\mu_{RH33\%-75\%}$ values in radial and tangential directions are, respectively, 19.1 and 14.6 times that in longitudinal direction. This difference is larger than the difference of A values among the corresponding specimens (Table 6, Figure 12).

Table 6:
Test results of the hygric properties (moisture transport-related), laminated bamboo.

Items	Notation	Value	B(l)	B(r)	B(t)
Capillary water absorption coefficient	A [kg/(m²·h^0.5)]	average	1.36	0.13	0.14
		max.	1.41	0.13	0.15
		min.	1.31	0.11	0.13
		deviation	+/–0.05	+/–0.01	+/–0.01
Water vapor diffusion resistance factor	μ [-]	average			
		$\mu_{RH3\%-50\%}$	27.39	1148.67	1392.83
		$\mu_{RH33\%-75\%}$	23.52	449.20	343.78
		$\mu_{RH93\%-50\%}$	15.67	139.45	80.90
		$\mu_{RH93\%-80\%}$	9.80	52.18	33.25
		deviation			
		$\mu_{RH3\%-50\%}$	+/–2.31	+/–148.93	+/–358.20
		$\mu_{RH33\%-75\%}$	+/–0.42	+/–77.29	+/–12.35
		$\mu_{RH93\%-50\%}$	+/–0.16	+/–28.97	+/–5.05
		$\mu_{RH93\%-80\%}$	+/–0.75	+/–2.99	+/–1.06
Water vapor permeability coefficient	δ [kg/(m·s·Pa)]	average			
		$\delta_{RH3\%-50\%}$	$7.776E^{-12}$	$1.869E^{-13}$	$1.606E^{-13}$
		$\delta_{RH33\%-75\%}$	$9.018E^{-12}$	$4.818E^{-13}$	$6.174E^{-13}$
		$\delta_{RH93\%-50\%}$	$1.353E^{-11}$	$1.572E^{-12}$	$2.628E^{-12}$
		$\delta_{RH93\%-80\%}$	$2.177E^{-11}$	$4.075E^{-12}$	$6.382E^{-12}$
		deviation			
		$\delta_{RH3\%-50\%}$	+/–$5.748E^{-13}$	+/–$2.315E^{-14}$	+/–$4.219E^{-14}$
		$\delta_{RH33\%-75\%}$	+/–$1.580E^{-13}$	+/–$8.385E^{-14}$	+/–$2.230E^{-14}$
		$\delta_{RH93\%-50\%}$	+/–$1.247E^{-13}$	+/–$3.241E^{-13}$	+/–$1.512E^{-13}$
		$\delta_{RH93\%-80\%}$	+/–$1.750E^{-12}$	+/–$2.265E^{-13}$	+/–$1.990E^{-13}$
Drying rate	U [g/(m²·d)]	average			
		$U_{u14\%-13\%}$	16.43	3.49	3.98
		$U_{u13\%-12\%}$	12.02	2.64	3.01
		$U_{u12\%-11\%}$	7.61	1.80	2.04
		$U_{u11\%-10\%}$	3.21	0.96	1.06

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

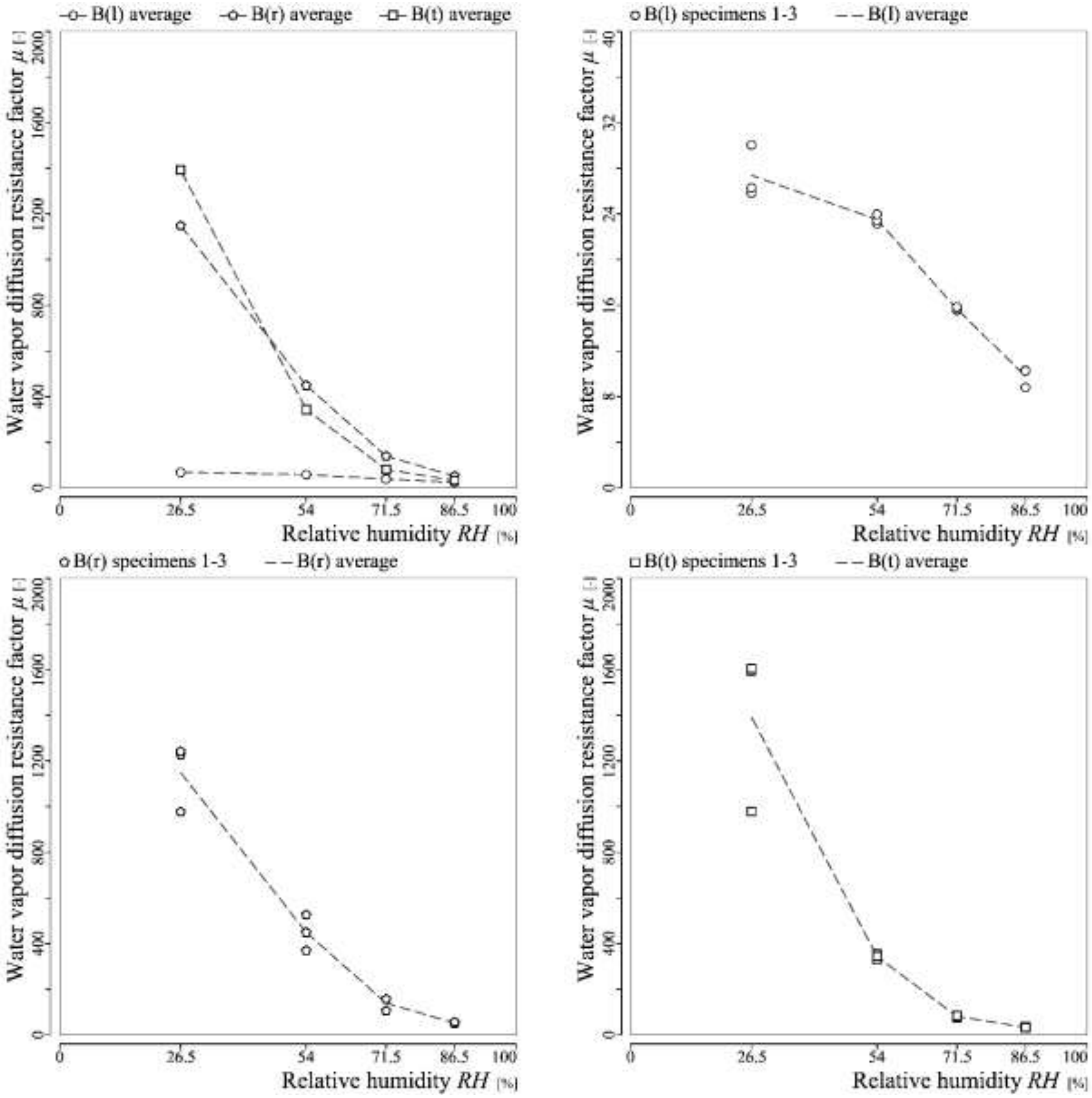


Figure 12:
Test result of the water vapor diffusion resistance factor (μ-RH), laminated bamboo.

3) Drying rate
The drying rate-moisture content curve (U-u) is calculated based on the recorded drying mass. It defines the water evaporation rate per unit area in a constant ambient environment (T = 23 °C, RH = 50 %) corresponding to different moisture content of the specimens. Considering that the desorption EMC values corresponding to RH = 50 %/65 %/80 % are, respectively, 8.84 %/11.64 %/15.70 %, here we intercept the segment corresponding to u = 10 % – 14 % for analysis.

The drying rate is positively related to the moisture content of the specimen. In order to show this relation, the drying rate-moisture content graph is further divided into four segments corresponding to u = 14 % – 13 %/ 13 % – 12 %/12 % – 11 %/11 % – 10 % for comparison. The drying rate of the specimens in longitudinal direction decreases from $U_{u14\%-13\%}$ = 16.4 g/(m^2·d) to $U_{u11\%-10\%}$ = 3.2 g/(m^2·d). These values are 3.2 – 4.7 times and 2.9 – 4.1 times that of the radial and tangential specimens, respectively. Similar to the capillary water absorption coefficient and water vapor permeation coefficient, the drying rate in radial direction is still slightly lower than that in tangential direction (Figure 13).

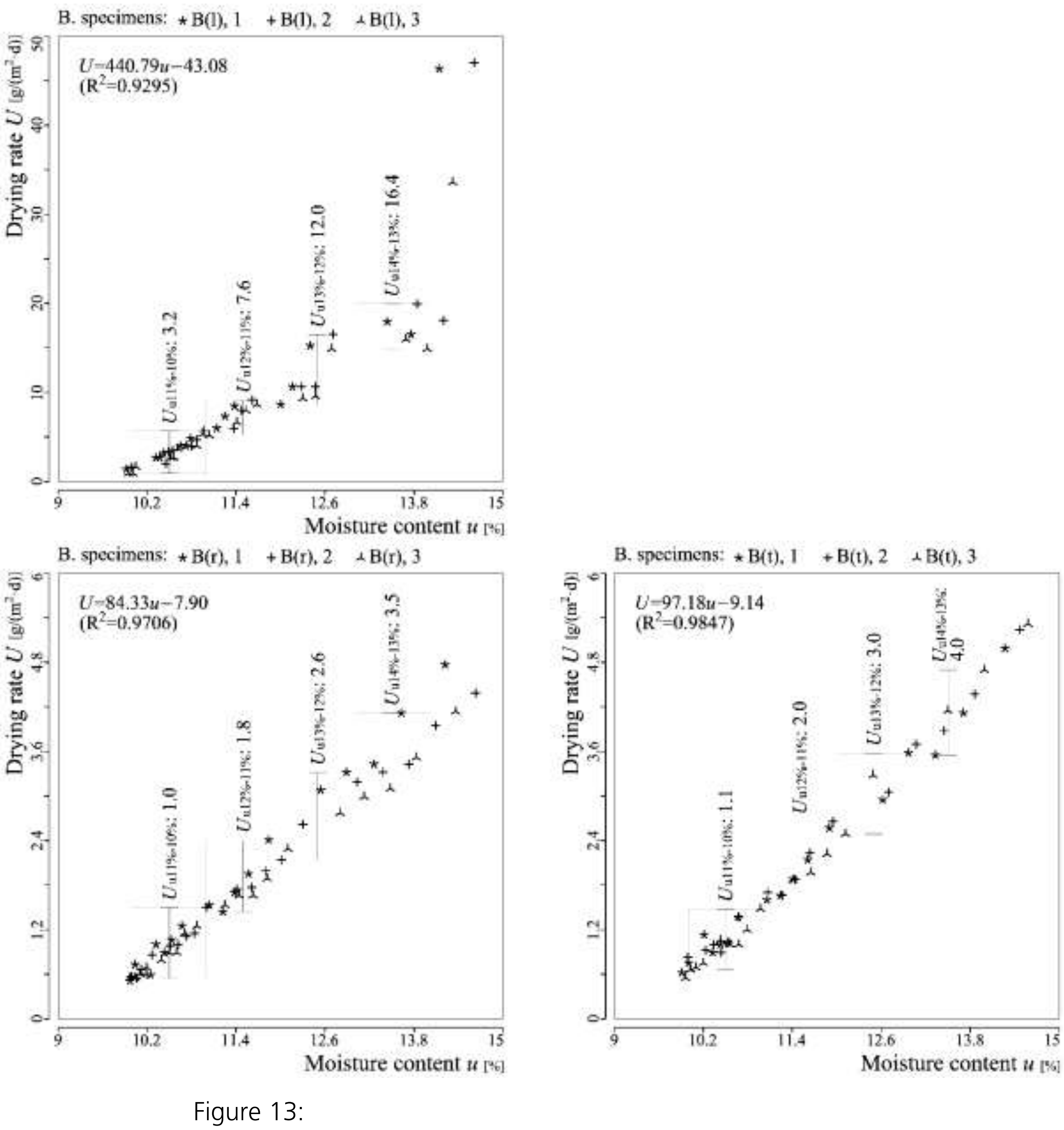


Figure 13:
Test result of the moisture content-related drying rate (U-u), laminated bamboo.

5.1.3 Thermal properties

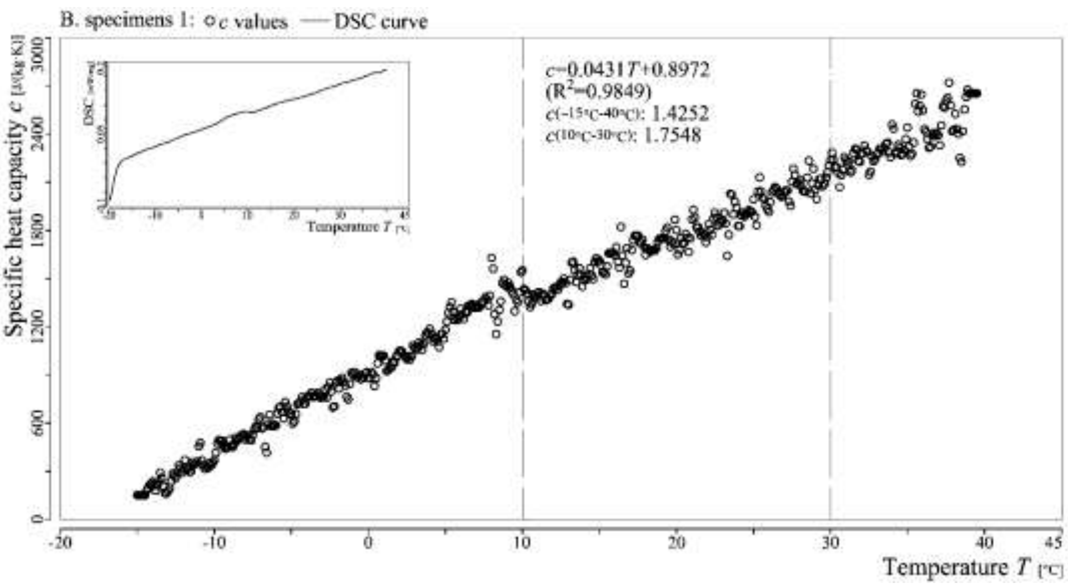
Heat storage-related properties

Heat storage property is closely related to the specific heat capacity (c). The thermal analysis shows that the specific heat capacity of laminated bamboo increases significantly with the temperature. Due to the different temperature ranges considered for testing the c value, large deviations in the results may occur. In the range T = –15 – 40 °C, the resulted average c value is 1,430.6 J/(kg·K). It increases to 1,776.3 J/(kg·K) in the range T = 10 – 30 °C. A linear function, c = a × T + b, can be used to fit the relationship between c and T. The resulted fitting parameters, a and b, are 43.1 – 47.0 and 860.1 – 897.2, with R^2 = 0.9849-0.9896 (Table 7, Figure 14).

Table 7:
Test results of the thermal properties (heat storage-related), laminated bamboo.

Items	Notation	Value	B(l) B(r)	B(t)
Specific heat capacity	c [J/(kg·K)]		within –15-40°C	within 10-30°C
		average	1430.6	1776.3
		max.	1436.0	1797.7
		min.	1425.2	1754.8
		deviation	+/–5.4	+/–21.5

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential



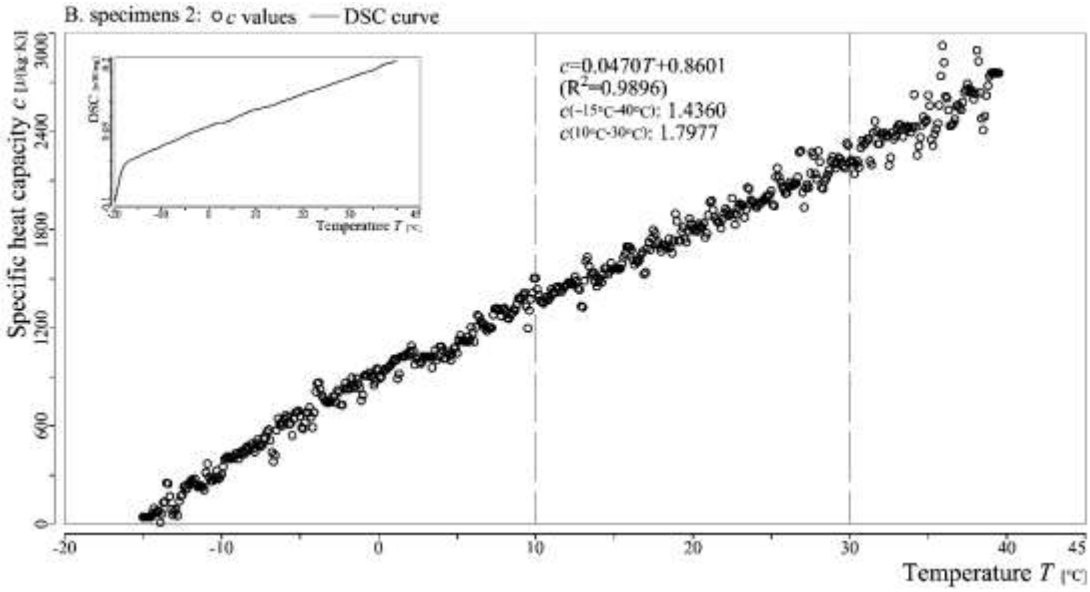


Figure 14:
Test result of the specific heat capacity (c), laminated bamboo.

Heat transport-related properties

Heat transport property is normally characterized by the thermal conductivity (λ). Test result shows that, the dry thermal conductivity (λ_d) values of laminated bamboo in longitudinal, radial and tangential directions are, respectively, 0.308 W/(m·K), 0.209 W/(m·K), and 0.211 W/(m·K), showing difference among the three directions. The λ_d value in radial direction is slightly lower than that in tangential direction and both are about 68 % of the value in longitudinal direction.

The comparison of λ values between the dry specimens and the specimens with original moisture content (approximately corresponding to RH = 50 %, adsorption process) shows that, there different degrees of increase in λ values with the increase of moisture content. In practical applications, a moisture-dependent thermal conductivity supplement (a_w) is used to linearly approximate the relation between λ and mass-ratio moisture content u. The test and fitting results show that the a_w values (%/M.-%) are 1.01, 0.94, and 1.23 for the longitudinal, radial and tangential directions, respectively (Table 8, Figure 15).

Table 8:
Test results of the thermal properties (heat transport-related), laminated bamboo.

Items	Notation	Value	B(l)	B(r)	B(t)
Dry thermal conductivity	λ_d [W/(m·K)]	average max. min. deviation	0.308 0.323 0.297 +/–0.013	0.209 0.214 0.206 +/–0.004	0.211 0.214 0.207 +/–0.003
Moisture-dependent thermal conductivity supplement	a_w [%/M.-%]	average	1.01	0.94	1.23

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

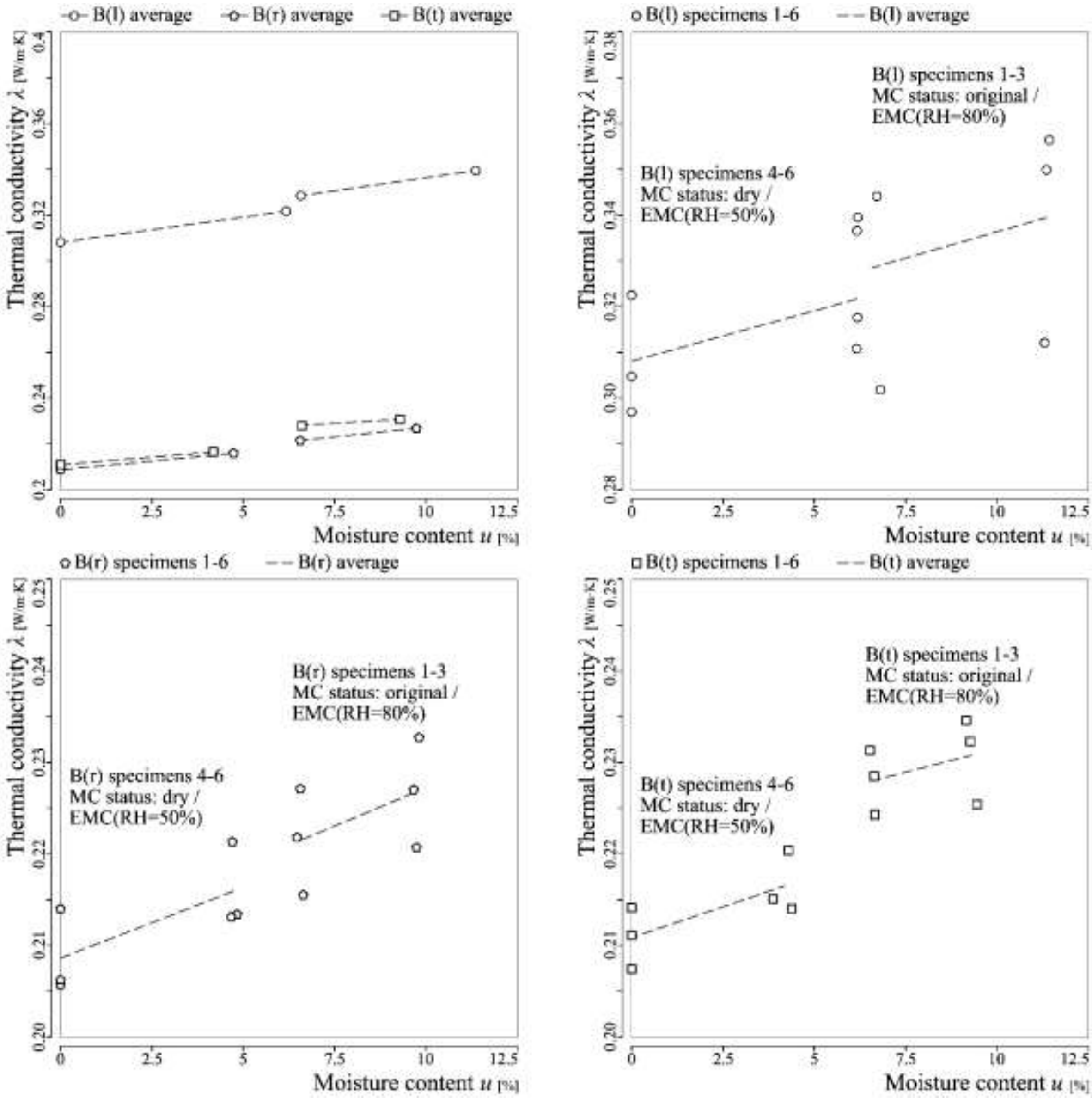


Figure 15:
Test result of the thermal conductivity (λ-u), laminated bamboo.

5.2 Bamboo scrimber

5.2.1 Basic properties

Test result of the dry bulk density (ρ_d) shows that, the average ρ_d of laminated bamboo is 1.127 g/cm^3, which is equivalent to 1.127 kg/m^3. Among the 18 specimens, the ρ_d values have a deviation of +/–67 kg/m^3. If the material »inhomogeneity« is defined as »(max. value – min. value)/average value« or »deviation/average value × 2«, then the inhomogeneity among the specimens is about 11.8 %.

Test result of the true density (ρ_t) shows that, the average ρ_t obtained from ten sampling of the granular specimen is 1.277 g/cm^3, which is equivalent to 1.277 kg/m^3. The corresponding deviation is +/–8 kg/m^3.

With the ρ_d and the ρ_t, the porosity (Φ) is calculated as:

$$\Phi = (\rho_t - \rho_d) / \rho_t \times 100\%$$

When the average ρ_d and ρ_t are substituted into the above formula, the resulted Φ value is 11.7 % (Table 9).

Table 9:
Test results of the basic properties, bamboo scrimber.

Items	Notation	Value	B(l)	B(r)	B(t)
Dry bulk density	ρ_d [kg/m^3]	average max. min. deviation		1127 1218 1085 +/–67	
True density	ρ_t [kg/m^3]	average max. min. deviation		1277 1285 1269 +/–8	
Porosity	Φ [-]	average		11.7%	

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

5.2.2 Hygric properties

Moisture storage-related properties

1) Isothermal adsorption and desorption curve (u-RH/w-RH, 23 °C)
In the adsorption test, the dry specimens are cured in the climate rooms or climate chambers, with ambient air temperature (T) constant as 23 °C, and relative humidity (RH) constant as 50 %, 65 %, 80 %, 93 %, 97 %. The resulted equilibrium moisture content (EMC) in mass rate (u) corresponding to the five RH gradients is 5.57 %, 7.16 %, 9.60 %, 14.94 %, 21.68 %, which is equivalent to a moisture content in mass-volume rate (w) 62.8 kg/m^3, 80.7 kg/m^3, 108.2 kg/m^3, 168.4 kg/m^3, 244.3 kg/m^3, respectively.

In the desorption test, the wet specimens after two-week water immersion are cured in climate room, with ambient air T constant as 23 °C, and RH constant as 50 %, 65 %, 80 %. The resulted u and w values are 7.51 %, 9.54 %, 12.25 % and 84.6 kg/m^3, 107.5 kg/m^3, 138.1 kg/m^3, respectively.

It can be seen from the comparison between the moisture desorption curve and moisture adsorption curve that bamboo has obvious hysteresis effects. Corresponding to the three RH gradients of 50 %, 65 %, and 80 %, the desorption u values are 1.95 %, 2.38 %, and 2.65 % higher than the adsorption values on average, which are equivalent to w values of 21.8 kg/m³, 26.8 kg/m³, and 29.9 kg/m³ (Table 10, Figure 16).

Table 10:
Test results of the hygric properties (moisture storage-related), bamboo scrimber.

<table>
<tr><th>Items</th><th>Notation</th><th>Value</th><th>B(l)</th><th>B(r)</th><th>B(t)</th></tr>
<tr><td rowspan="12">Isothermal adsorption and desorption curve (23 °C)</td><td rowspan="6">u [-]</td><td></td><td colspan="2">adsorption process:</td><td>desorption process:</td></tr>
<tr><td>$u_{RH=50\%}$</td><td colspan="2">5.57</td><td>7.51</td></tr>
<tr><td>$u_{RH=65\%}$</td><td colspan="2">7.16</td><td>9.54</td></tr>
<tr><td>$u_{RH=80\%}$</td><td colspan="2">9.60</td><td>12.25</td></tr>
<tr><td>$u_{RH=93\%}$</td><td colspan="2">14.94</td><td>/</td></tr>
<tr><td>$u_{RH=97\%}$</td><td colspan="2">21.68</td><td>/</td></tr>
<tr><td rowspan="6">w [kg/m³]</td><td></td><td colspan="2">adsorption process:</td><td>desorption process:</td></tr>
<tr><td>$w_{RH=50\%}$</td><td colspan="2">62.8</td><td>84.6</td></tr>
<tr><td>$w_{RH=65\%}$</td><td colspan="2">80.7</td><td>107.5</td></tr>
<tr><td>$w_{RH=80\%}$</td><td colspan="2">108.2</td><td>138.1</td></tr>
<tr><td>$w_{RH=93\%}$</td><td colspan="2">168.4</td><td>/</td></tr>
<tr><td>$w_{RH=97\%}$</td><td colspan="2">244.3</td><td>/</td></tr>
<tr><td>Free water saturation moisture content</td><td>w_{cap} [kg/m³]</td><td>average</td><td colspan="3">test result: 323
corrected value considering volume expansion: 288</td></tr>
</table>

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

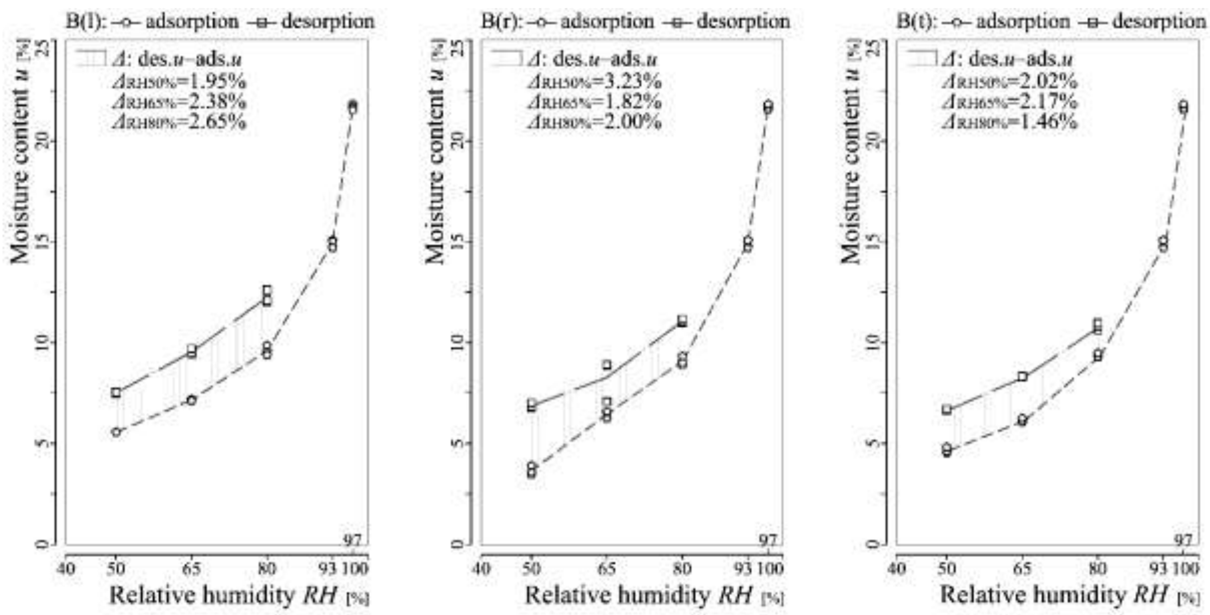


Figure 16:
Test result of the adsorption EMC and desorption EMC, bamboo scrimber.

2) Free water saturation (w_{cap})
   In the immersion test, the specimens reach their saturation status after about 4.5 months and this water absorption process is accompanied by volume expansion of the specimens. The average u value after immersion is

28.3 %, which is equivalent to a w value of 323 kg/m^3. The radial, tangential and longitudinal dimension of the specimens after immersion expands to, respectively, 103.2 %, 108.3 %, and 100.4 % of the corresponding specimens in dry state, which means a total volume expansion of 112.2 %. Considering the extra water absorption caused by this part of volume, the free water saturation moisture content w_{cap} can be corrected to 323/ 112.2 % = 288 kg/m^3. When the w_{cap} is converted to volume ratio, it is 28.8 %, which is higher than the Φ.

Moisture transport-related properties

1) Capillary water absorption coefficient (A)
   The water absorption test shows that, the capillary water absorption coefficient (A) values of bamboo scrimber in longitudinal, radial and tangential directions, are 0.10 kg/(m^2·h$^{0.5}$), 0.02 kg/(m^2·h$^{0.5}$), and 0.02 kg/(m^2·h$^{0.5}$), respectively. The A values in radial direction and tangential direction are both about 1/5 of the value in longitudinal direction (Figure 17).

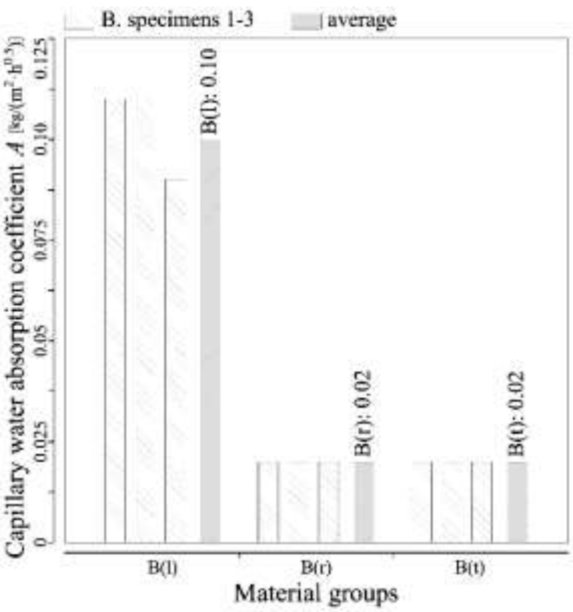


Figure 17:
Test result of the capillary water absorption coefficient (A), bamboo scrimber.

2) Water vapor diffusion resistance factor (μ-RH/δ-RH)
   In this test, the temperature condition is constant as T = 23 °C, and relative humidity conditions include four RH gradients, namely RH = 3% – 50 %/ 33 % – 75 %/93 % – 50 %/93 % – 80 %. When the water vapor permeation rate is stable, it can be approximately considered that the moisture content of the specimens corresponds to RH = 26.5 %/54 %/71.5 %/ 86.5 %. The test shows that the water vapor permeability rate is strongly affected by the moisture content of the specimens. For example, the water vapor diffusion resistance factor (μ) values of bamboo scrimber specimens

in longitudinal/radial/tangential directions decrease from $\mu_{RH3\%-50\%}$ = 74.2/9,245.2/3,572.9 to $\mu_{RH93\%-80\%}$ = 36.4/1,574.6/736.0. When we fit the test results between the water vapor permeability coefficient (δ) and the RH, we can find that a general exponential function, $\delta = a \cdot e^{b \cdot RH}$ (where »a« and »b« are fitting parameters), can describe this relationship. The resulted goodness of Fit (R^2), is in the range 0.679 to 0.940.

The water vapor permeability rate also shows difference in the three directions. Considering that in the RH gradients of 93 % – 50 % and 93 % – 80 %, there are mould growth on the specimens' lower surfaces facing to the salt solution, which may have influence on the test results, here the test results from RH = 33 % – 75 % gradient are taken for comparison. The $\mu_{RH33\%-75\%}$ values in longitudinal, radial, and tangential directions are 70.8, 2,392.2, and 1,673.7, respectively. The $\mu_{RH33\%-75\%}$ value in radial direction is 42.9 % larger than that in tangential direction, and the $\mu_{RH33\%-75\%}$ values in radial and tangential directions are, respectively, 33.8 and 23.6 times that in longitudinal direction. This difference is larger than the difference of A values among the corresponding specimens (Table 11, Figure 18).

Table 11:
Test results of the hygric properties (moisture transport-related), bamboo scrimber.

Items	Notation	Value	B(l)	B(r)	B(t)
Capillary water absorption coefficient	A [kg/(m²·h^0.5)]	average	0.11	0.02	0.02
		max.	0.11	0.02	0.02
		min.	0.09	0.02	0.02
		deviation	+/–0.01	+/–0.00	+/–0.00
Water vapor diffusion resistance factor	μ [-]	average			
		$\mu_{RH3\%-50\%}$	74.20	9245.20	3572.93
		$\mu_{RH33\%-75\%}$	70.83	2392.22	1673.67
		$\mu_{RH93\%-50\%}$	57.25	1887.86	1015.79
		$\mu_{RH93\%-80\%}$	36.35	1574.63	735.96
		deviation			
		$\mu_{RH3\%-50\%}$	+/–8.46	+/–4536.39	+/–404.06
		$\mu_{RH33\%-75\%}$	+/–2.75	+/–34.95	+/–130.80
		$\mu_{RH93\%-50\%}$	+/–12.83	+/–513.01	+/–134.32
		$\mu_{RH93\%-80\%}$	+/–2.00	+/–175.36	+/–207.91
Water vapor permeability coefficient	δ [kg/(m·s·Pa)]	average			
		$\delta_{RH3\%-50\%}$	2.884E^{-12}	2.632E^{-14}	5.985E^{-14}
		$\delta_{RH33\%-75\%}$	2.997E^{-12}	8.867E^{-14}	1.273E^{-13}
		$\delta_{RH93\%-50\%}$	3.817E^{-12}	1.189E^{-13}	2.114E^{-13}
		$\delta_{RH93\%-80\%}$	5.846E^{-12}	1.364E^{-13}	3.077E^{-13}
		deviation			
		$\delta_{RH3\%-50\%}$	+/–3.330E^{-13}	+/–1.010E^{-14}	+/–6.461E^{-15}
		$\delta_{RH33\%-75\%}$	+/–1.171E^{-13}	+/–1.286E^{-15}	+/–9.710E^{-15}
		$\delta_{RH93\%-50\%}$	+/–6.657E^{-13}	+/–3.450E^{-14}	+/–2.832E^{-14}
		$\delta_{RH93\%-80\%}$	+/–3.234E^{-13}	+/–1.519E^{-14}	+/–9.594E^{-14}
Drying rate	U [g/m²·d]	average			
		$U_{u12\%-11\%}$	18.06	2.03	2.85
		$U_{u11\%-10\%}$	14.47	1.63	2.44
		$U_{u10\%-9\%}$	10.88	1.22	2.04
		$U_{u9\%-8\%}$	7.29	0.81	1.63

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

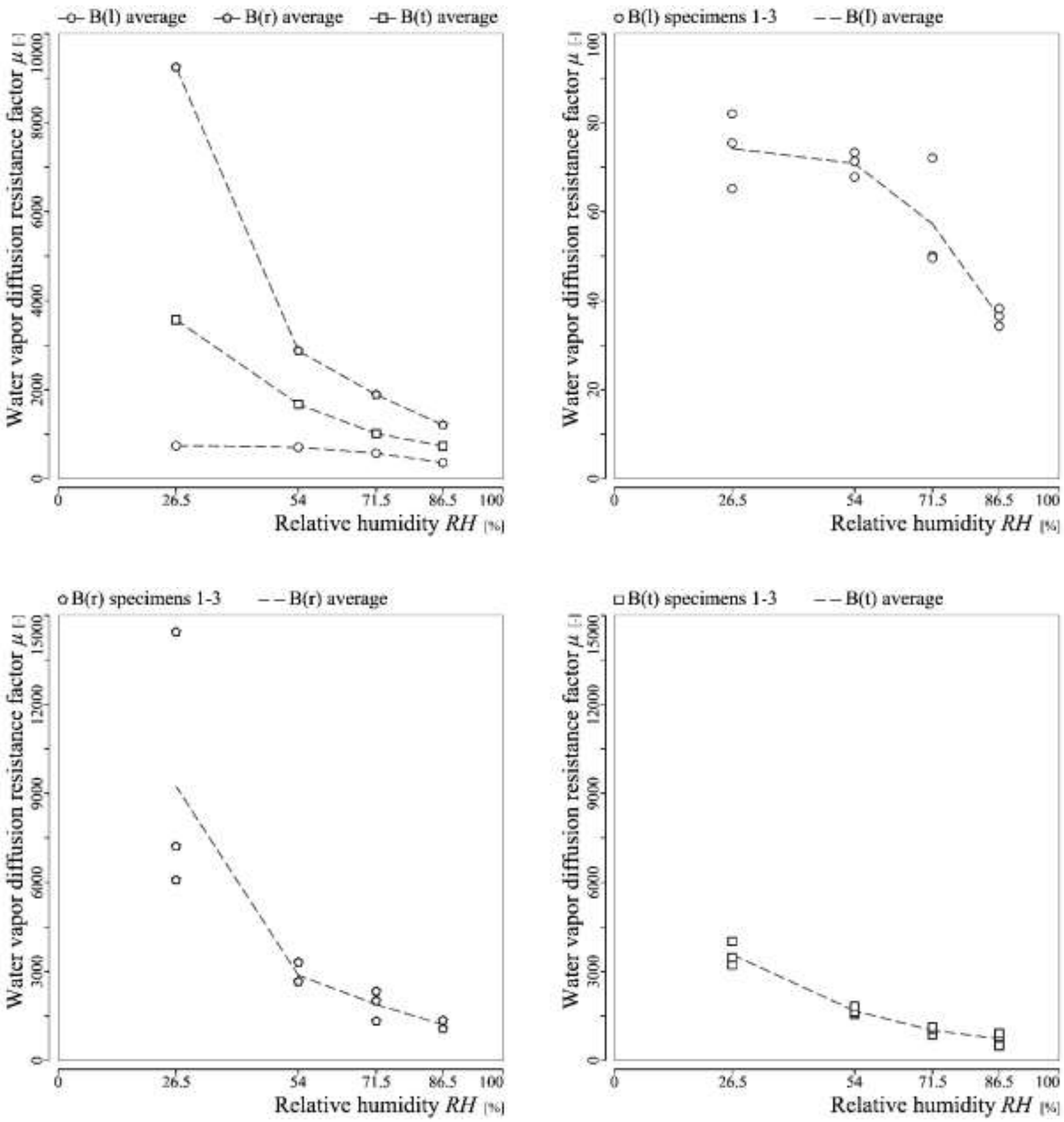


Figure 18:
Test result of the water vapor diffusion resistance factor (μ-RH), bamboo scrimber.

3) Drying rate
The drying rate-moisture content curve (U-u) is calculated based on the recorded drying mass. It defines the water evaporation rate per unit area in a constant ambient environment (T = 23 °C, RH = 50 %) corresponding to different moisture content of the specimens. Considering that the desorption EMC values corresponding to RH = 50 %/65 %/80 % are, respectively,

7.51 %/ 9.54 %/12.25 %, here we intercept the segment corresponding to u = 8 % – 12 % for analysis.

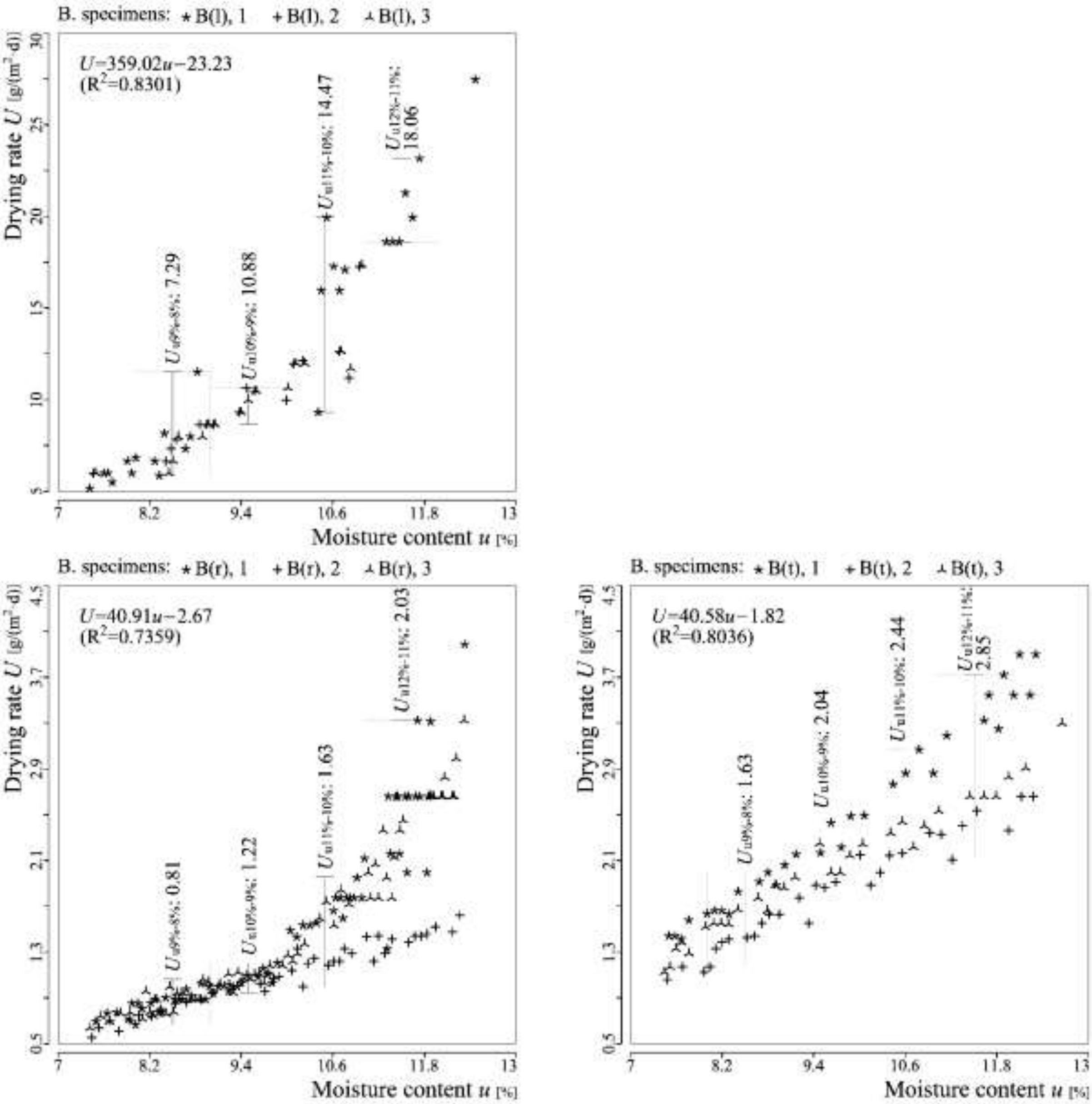


Figure 19:
Test result of the moisture content-related drying rate (U-u), bamboo scrimber.

The drying rate is positively related to the moisture content of the specimen. In order to show this relation, the drying rate-moisture content graph is further divided into four segments corresponding to u = 12 % – 11 %/11 % – 10 %/ 10 % – 9 %/9 % – 8 % for comparison. The drying rate of the specimens in longitudinal direction decreases from $U_{u12\%-11\%}$ = 18.1 g/(m²·d) to $U_{u9\%-8\%}$ = 7.3 g/(m²·d). These values are 8.9 – 9.0 times and 4.5 – 6.3 times that of the radial and tangential specimens, respectively. Similar to the water vapor permeation coefficient, the drying rate in radial direction is lower than that in tangential direction (Figure 19).

5.2.3 Thermal properties

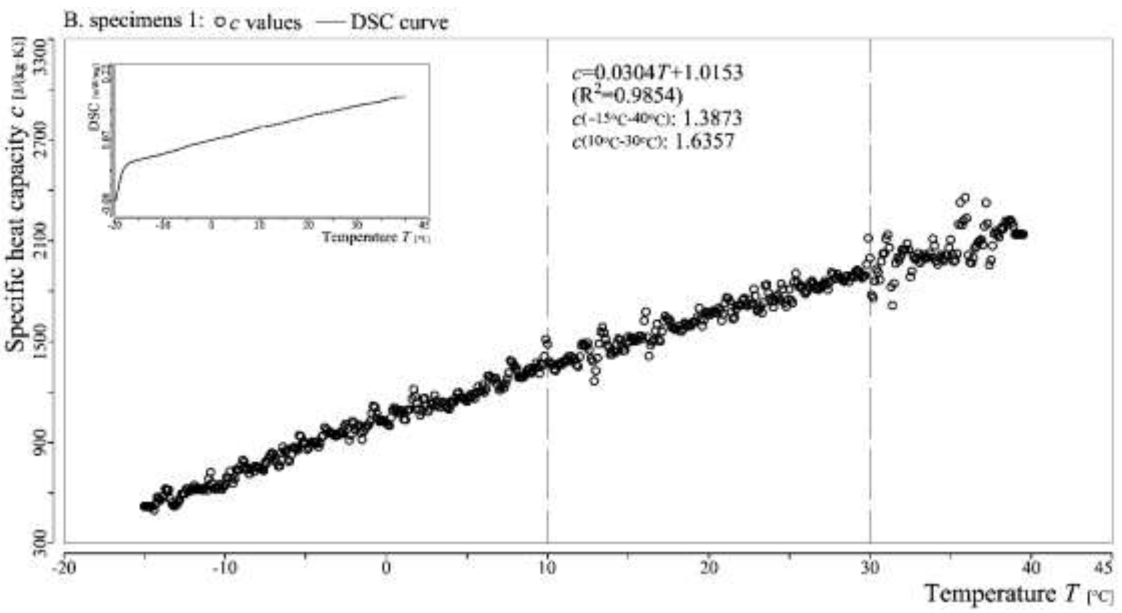
Heat storage-related properties

Heat storage property is closely related to the specific heat capacity (c). The thermal analysis shows that the specific heat capacity of bamboo scrimber increases significantly with the temperature. Due to the different temperature ranges considered for testing the c value, large deviations in the results may occur. In the range T = –15 – 40 °C, the resulted average c value is 1,630.8 J/(kg·K). It increases to 1,882.1 J/(kg·K) in the range T = 10 – 30 °C. A linear function, c = a×T+b, can be used to fit the relationship between c and T. The resulted fitting parameters, a and b, are 30.4 – 36.8 and 1,015.3 – 1,423.3, with R^2 = 0.9847 – 0.9854 (Table 12, Figure 20).

Table 12:
Test results of the thermal properties (heat storage-related), bamboo scrimber.

Items	Notation	Value	B(l) B(r)	B(t)
Specific heat capacity	c [J/(kg·K)]	 average max. min. deviation	within –15-40°C 1630.8 1874.3 1387.3 +/–243.5	within 10-30°C 1882.1 2128.4 1635.7 +/–246.4

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential



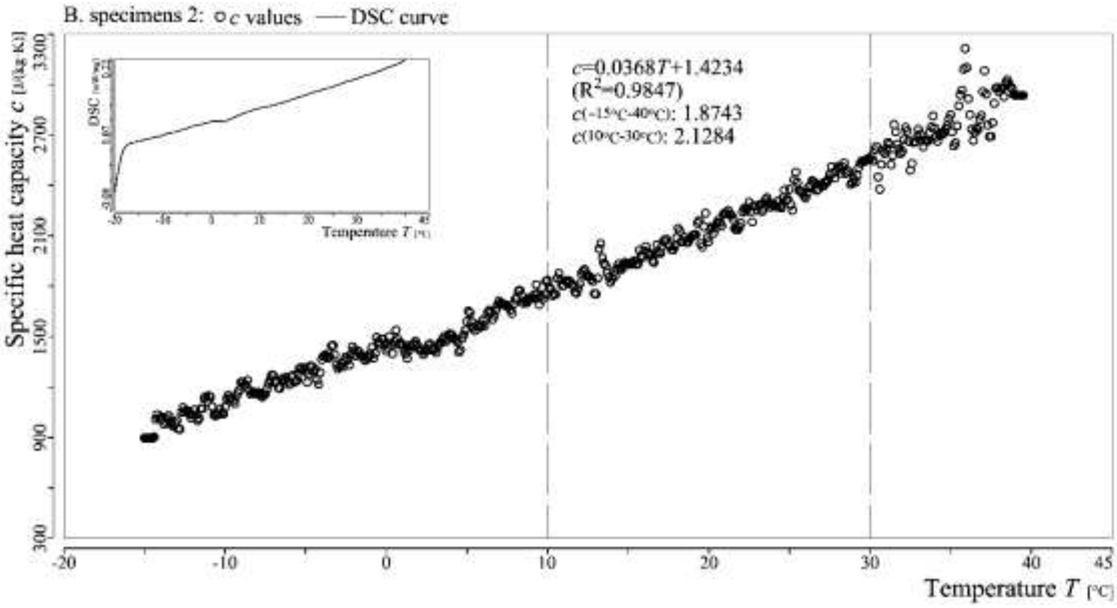


Figure 20:
Test result of the specific heat capacity (c), bamboo scrimber.

Heat transport-related properties

Heat transport property is normally characterized by the thermal conductivity (λ). Test result shows that, the dry thermal conductivity (λ_d) values of laminated bamboo in longitudinal, radial, and tangential directions are, respectively, 0.427 W/(m·K), 0.270 W/(m·K), and 0.299 W/(m·K), showing difference among the three directions. The λ_d value in radial direction is slightly lower than that in tangential direction and both are 63.2 % to 70.0 % of the value in longitudinal direction.

The specimens with different moisture content (MC) are prepared, including the MC_{dry} (dry specimens), $MC_{original}$ (specimens with original moisture content, which is approximately corresponding to RH = 50 %, adsorption process)/$EMC_{RH=50\%}$ (specimens from group MC_{dry} are dried, then cured in climate chamber RH = 50 %)/$EMC_{RH=80\%}$ (specimens from group $MC_{original}$ are dried, then cured in climate chamber RH = 80 %).

The λ values between the MC_{dry} specimen group and the $MC_{original}$ specimen group shows that, there different degrees of increase in λ values with the increase of moisture content. In practical applications, a moisture-dependent thermal conductivity supplement (a_w) is used to linearly approximate the relation between λ and mass-ratio moisture content u. The test and fitting results show that the a_w values (%/M.-%) are 1.02, 1.70, and 1.72 for the longitudinal, radial and tangential directions, respectively (Table 13, Figure 21).

Table 13:
Test results of the thermal properties (heat transport-related), bamboo scrimber.

Items	Notation	Value	B(l)	B(r)	B(t)
Dry thermal conductivity	λ_d [W/(m·K)]	average max. min. deviation	0.427 0.444 0.409 +/–0.017	0.270 0.293 0.250 +/–0.021	0.299 0.303 0.297 +/–0.003
Moisture-dependent thermal conductivity supplement	a_w [%/M.-%]	average	1.02	1.70	1.72

Note: B(l): Bamboo longitudinal; B(r): Bamboo, radial; B(t): Bamboo, tangential

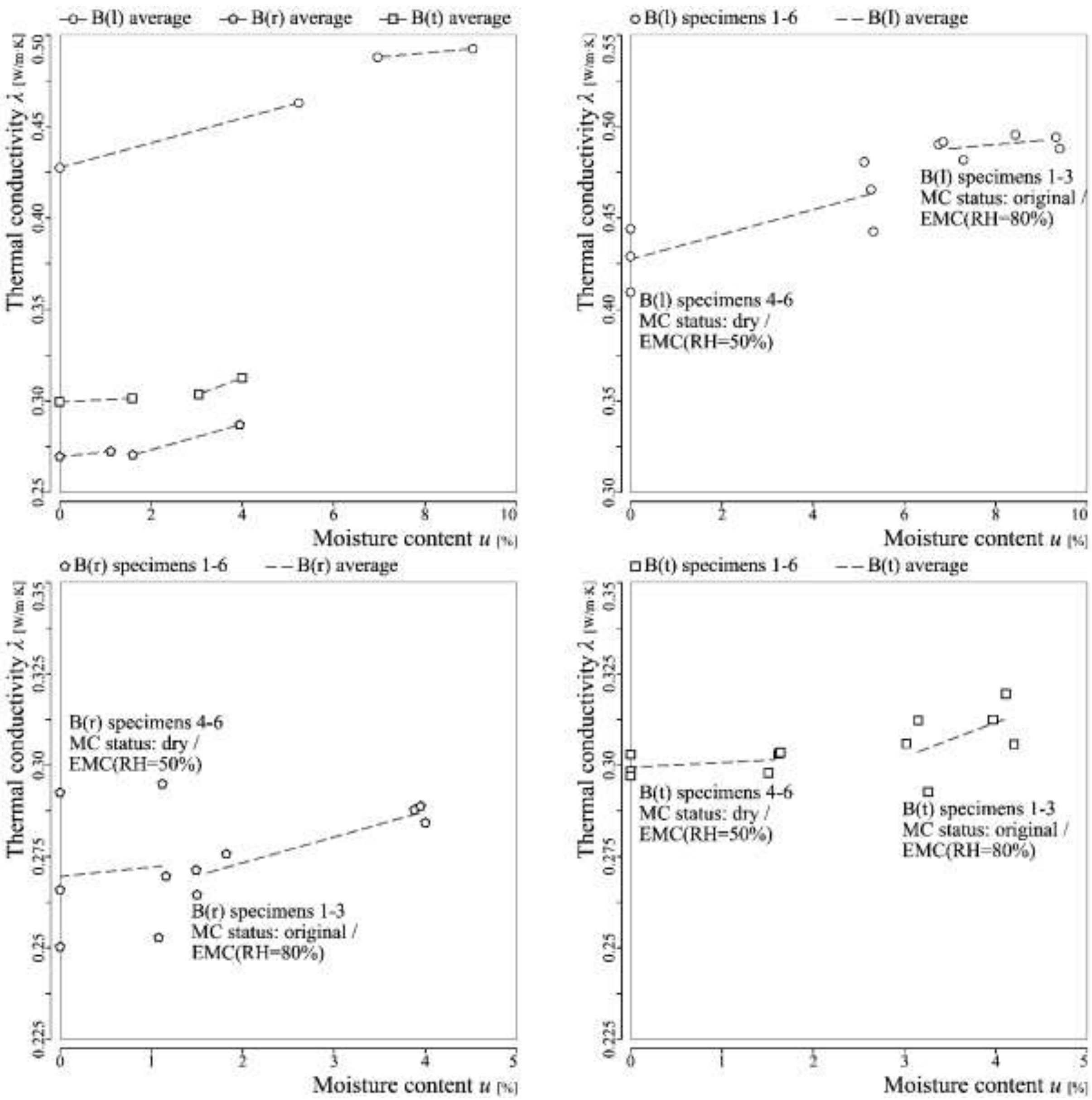


Figure 21:
Test result of the thermal conductivity (λ-u), bamboo scrimber.

6 Comparison with reference timber products

In order to form a database for comparison with bamboo, the property parameters of different timber products are collected from the WUFI® Pro 6.5. A total of 73 timber products are available, shown in the A.3. They are grouped to softwood (15 kinds), hardwood (four kinds), laminated timber (four kinds), plywood (eleven kinds), wood-wool board (two kinds), wood fibreboard (eight kinds), oriented strand board (16 kinds), chipboard/particle board (twelve kinds) and other (one kind).

However, the comparison between laminated bamboo or bamboo scrimber and some kinds of timber products, for example, the wood-wool board, wood OSB and chipboard/particleboard does not make sense. Furthermore, among the rest timber products, there are varying degrees of difference among the parameters from different sources. For example, the c values of the products from the North America Database (NA) is given as 1,880 J/(kg·K), higher than most of the corresponding values from the other sources. In addition, the μ values of the products from NA are always many times higher than the values from the other databases. Different test methods may also cause large differences to the test results. For example, the Φ value of the »Spruce (density: 600 kg/m³)« from University of Technology Vienna is only 0.2, while the value of »Spruce« from NA is as high as 0.9 (A.3).

The indicators for comparison are listed in the following table. Considering that the A value is not available in most of the timber products, the DWS_{80} is used as indicator to characterize the liquid water transport rate (Table 14).

Table 14:
Properties indicators for comparison between bamboo and reference timber.

Catalog		Items	Representative value	Notation	Unit
Basic properties		Bulk density	Dry state	ρ_d	[kg/m³]
		Porosity	Dry state	Φ	[-]
Hygric properties	Moisture storage	Equilibrium moisture content	Equilibrium moisture content (*RH*=50%)	w_{50}	[kg/m³]
			Equilibrium moisture content (*RH*=80%)	w_{80}	[kg/m³]
			Free water saturation	w_{cap}	[kg/m³]
	Moisture transport	Water vapor diffusion resistance factor	Dry state	μ_d	[-]
			Wet state (*RH*=50%)	μ_{50}	[-]
			Wet state (*RH*=80%)	μ_{80}	[-]
		Liquid transport rate	Liquid transport coefficient, suction (*RH*=80%)	DWS_{80}	[m²/s]
			Water absorption coefficient	A	[kg/m²·s$^{0.5}$]
Thermal properties	Heat storage	Specific heat capacity	Dry state	c	[J/(kg·K)]
	Heat transport	Thermal conductivity	Dry state	λ_d	[W/(m·K)]
			Moisture-dependent λ supplement	a_w	[%/M.-%]

Considering that among the longitudinal, radial and tangential directions, there is no difference in terms of the heat and moisture storage-related properties, while the difference may be very large in terms of the transport-related properties. For this reason, the thermal and hygric properties are further divided to storage-related and transport-related items, and the comparison is separated into two groups.

6.1 Laminated bamboo

In view of the above situation, the reference timber (RT) for comparison with laminated bamboo only adopts twelve timber products provided by Fraunhofer IBP, and one additional »Spruce, tangential« from the LTH Lund University. RT contains a total of four groups, namely the softwood (four kinds), the hardwood (three kinds), the laminated timber (three kinds), and the plywood (three kinds).

6.1.1 Basic properties, moisture and heat storage-related properties

The softwood and softwood-based products have ρ_d values in a range 400 – 500 kg/m^3, and the hardwood and hardwood-based products have ρ_d values in a range 650 – 708 kg/m^3. The ρ_d of laminated bamboo is 621 kg/m^3, which is closer to hardwood. The given range of Φ among the RT is 0.47 – 0.74, showing no clear difference between softwood and hardwood-based products. The Φ of laminated bamboo is 0.552, lower than the mid. value of RT (0.61).

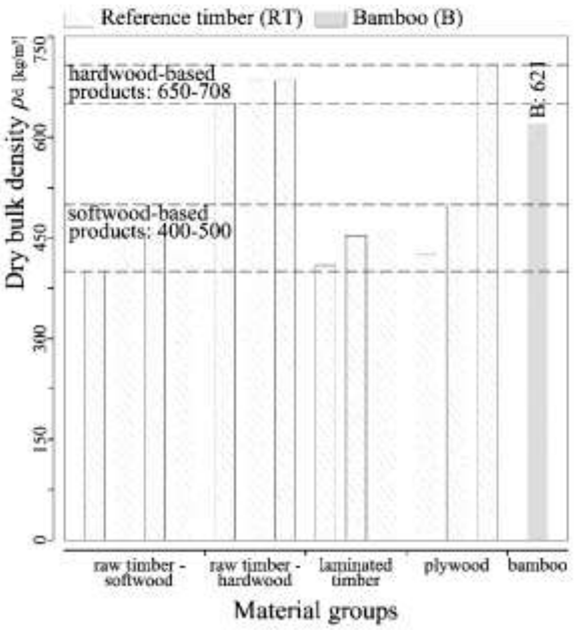
In terms of the equilibrium moisture content, both the w_{50} and w_{80} values of laminated bamboo fall in the middle area within the RT range. However, the w values of laminated bamboo are taken by the average of the adsorption and desorption processes, while most of the RT values may be obtained through adsorption process. If the adsorption w is used for comparison, it can be seen that the w_{50} and w_{80} of laminated bamboo will be in a significantly lower position in the RT range. In terms of the w_{cap}, there are large differences among different timber products, ranging from 140 to 678 kg/m^3. If converted to the volume ratio, some of them are quite closed to the corresponding Φ, the theoretically possible max. value, while the others are far lower than their Φ values. This may be caused by different test methods. In the test for w_{cap} of laminated bamboo, the specimens are immersed in water for about 4.5 months, until the mass no longer changes. This may be far longer than the time required by general test methods, and it allows the specimens to fully absorb water. The resulted w_{cap} of laminated bamboo is quite close to its Φ value, and higher than the mid. value of RT.

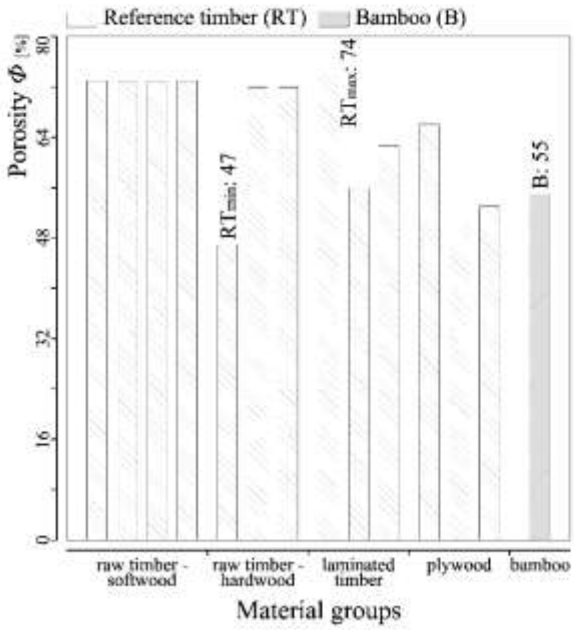
As explained in section 5.1.3, the specific heat capacity increases significantly with the temperature. If the c value corresponding to the temperature range 10 to 30 °C is taken, it will be higher than the max. value of RT. However, if the temperature range –15 to 40 °C is considered, the c value of laminated bamboo is close to the mid. value of RT (Table 15, Figure 22).

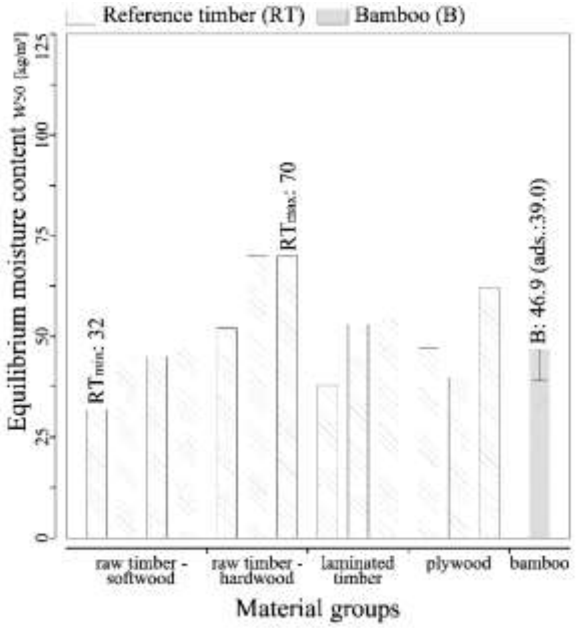
Table 15:
Comparison between laminated bamboo and reference timber (basic properties, moisture and heat storage-related properties).

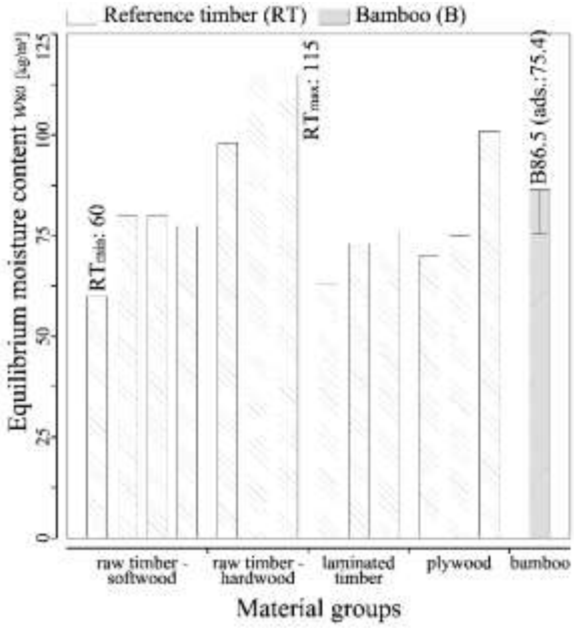
Group	Product name	ρ_d	Φ	w_{50}	w_{80}	w_{cap}	c	Source
Raw material - softwood	Softwood	400	0.73	32	60	575	1400	IBP
	Spruce, longitudinal	455	0.73	45	80	600	1400	IBP
	Spruce, radial	455	0.73	45	80	600	1400	IBP
	Spruce, tangential	430	0.73	47.5	77.5	140	1600	LTH
Raw material - hardwood	Hardwood	650	0.47	52	98	370	1400	IBP
	Oak, longitudinal	685	0.72	70	115	500	1400	IBP
	Oak, radial	685	0.72	70	115	500	1400	IBP
Laminated timber	Stora Enso CLT (cross laminated timber)	410	0.74	38	63	678	1300	IBP
	3-ply cross-laminated panel	454	0.56	53	73	534	1400	IBP
	Laminated veneer lumber	462	0.627	55	76	525	1400	IBP
Plywood	Veneer plywood BFU 100	427	0.66	47	70	572	1400	IBP
	Plywood board	500	0.5	40	75	350	1400	IBP
	veneer plywood beech BFU-BU	708	0.53	62	101	530	1400	IBP
RT.max		708	0.74	70	115	678	1600	
RT.min		400	0.47	32	60	140	1300	
RT.mid		554	0.61	51	87.5	409	1450	
Bamboo		621	0.55	46.9 (39.0)*	86.5 (75.4)*	526	1776 (1431)**	

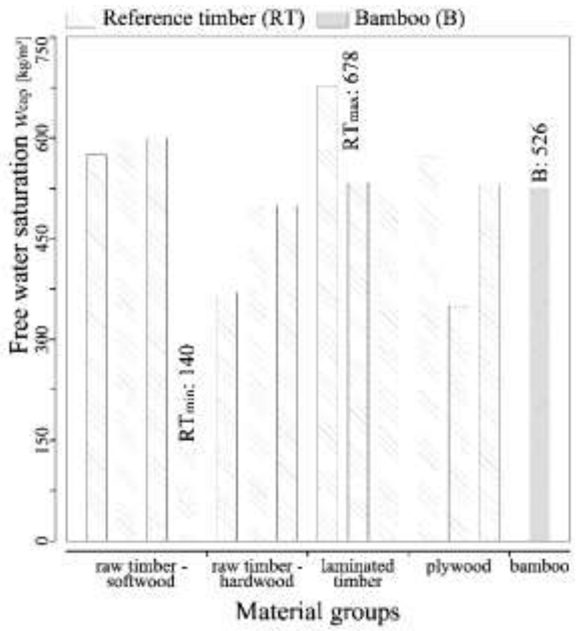
Note:
* the values are the average of adsorption EMC and desorption EMC, while the values in brackets are the adsorption EMC;
** the value corresponds to the temperature range 10 to 30°C, while the value in brackets corresponds to the temperature range –15 to 40°C






Reference timber (RT)
Bamboo (B)
Equilibrium moisture content w50 [kg/m³]
RTmin: 32
RTmax: 70
B: 46.9 (ads.:39.0)
raw timber - softwood
raw timber - hardwood
laminated timber
plywood
bamboo
Material groups


Reference timber (RT)
Bamboo (B)
Equilibrium moisture content w80 [kg/m³]
RTmin: 60
RTmax: 115
B86.5 (ads.:75.4)
raw timber - softwood
raw timber - hardwood
laminated timber
plywood
bamboo
Material groups


Reference timber (RT)
Bamboo (B)
Free water saturation wcap [kg/m³]
RTmin: 140
RTmax: 678
B: 526
raw timber - softwood
raw timber - hardwood
laminated timber
plywood
bamboo
Material groups

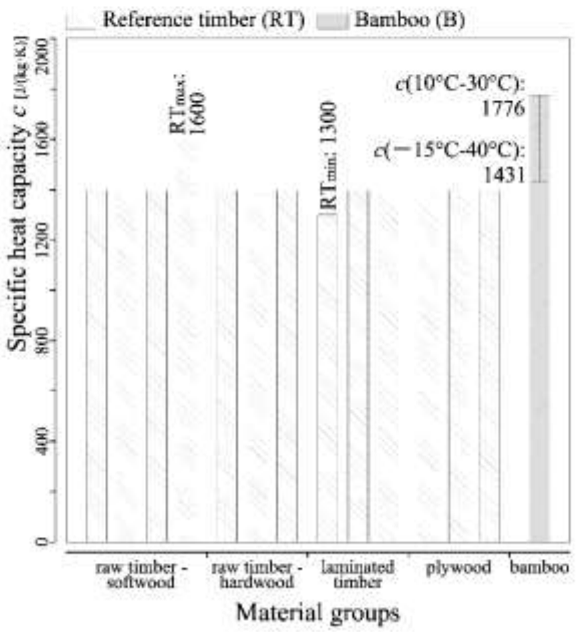


Figure 22:
Comparison between laminated bamboo and reference timber (basic properties, moisture and heat storage-related properties).

6.1.2 Moisture and heat transport-related properties

1) Longitudinal direction
The transport properties of laminated bamboo in longitudinal direction is compared with Spruce and Oak in the same direction. It shows that the moisture transport rate of laminated bamboo is lower than the RT. Take the μ_{50} as an example, the μ_{50} of laminated bamboo is 3.0 and 5.6 times that of the Oak and Spruce, respectively. In contrast, the heat transport rate of laminated bamboo is higher than the RT. The λ_d of laminated bamboo is 0.308 W/(m·K), higher than both the Oak and the Spruce (Table 16, Figure 23).

Table 16:
Comparison between laminated bamboo and reference timber – moisture and heat transport-related properties (longitudinal direction).

Group	Product name	μ_d	μ_{50}	μ_{80}	A	DWS_{80}	λ_d	a_w	
Raw material - softwood	Spruce, longitudinal	4.3	4.3	4.3		5.33E^{-11}	0.23	1.3	IBP
Raw material - hardwood	Oak, longitudinal	8	8	8		1.77E^{-10}	0.3	1.3	IBP
Bamboo, longitudinal		/	24.1	12.3	0.0227	5.40E^{-12}	0.308	1.01	

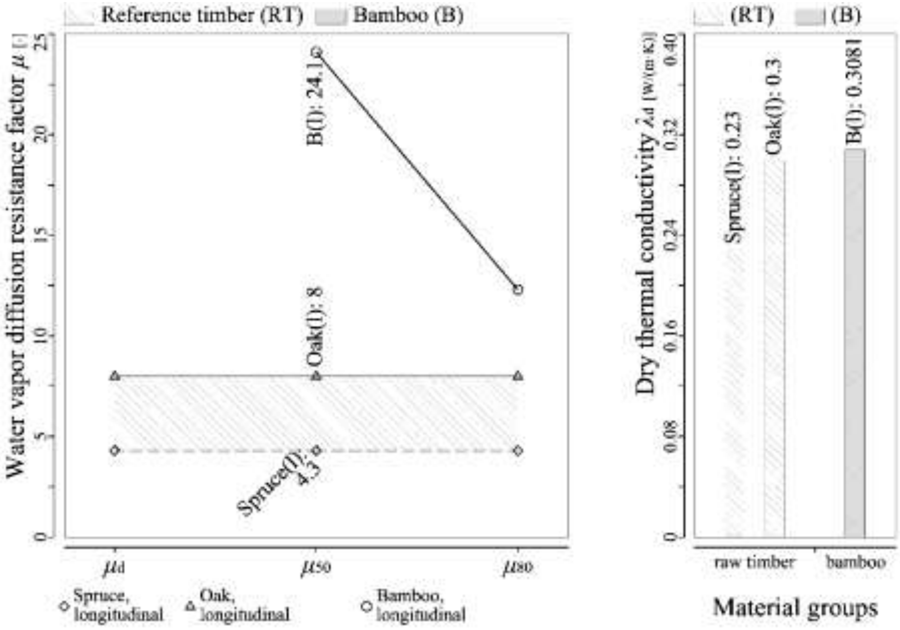


Figure 23:
Comparison between laminated bamboo and reference timber – moisture and heat transport-related properties (longitudinal direction).

2) Radial and tangential directions
The comparison between laminated bamboo and RT in radial and tangential directions shows similar law to the longitudinal direction above. For example, both laminated bamboo in radial and tangential directions have μ_{50} values that are higher than the corresponding max. values of RT, as well as DWS_{80} values that are lower than the min. values of RT. In several sets of the timber parameters, the impact of moisture content on the μ values are not taken into consideration. In these timber products, the μ_{80} values as well as the μ_{50} values are constantly equal to the μ_d values. This results in the μ_{80} values of some timber products exceeding the corresponding values of laminated bamboo but this should be excluded.

It is particularly worth noting that the λ_d values of laminated bamboo in both radial and tangential directions are significantly higher than RT. The λ_d values of laminated bamboo are about 50 % higher than the max. value of RT (Table 17, Figure 24).

Table 17:
Comparison between laminated bamboo and reference timber – moisture and heat transport-related properties (radial and tangential directions).

Group	Product name	μ_d	μ_{50}	μ_{80}	A	DWS_{80}	λ_d	a_w	
Raw material - softwood	Softwood	200	65	25	/	/	0.09	1.3	IBP
	Spruce, radial	130	130	130	/	$1.24E^{-12}$	0.09	1.3	IBP
	Spruce, tangential	83.3	83.3	25	/	/	0.14		LTH
Raw material - hardwood	Hardwood	200	65	17	/	/	0.13	1.3	IBP
	Oak, radial	140	140	140	/	$6.09E^{-12}$	0.13	1.3	IBP

Laminated timber	Stora Enso CLT	500	99.2	11.6	/	/	0.098	2	IBP
	3-ply cross-laminated panel	203	203	203	/	4.00E^{-12}	0.12	1.5	IBP
	Laminated veneer lumber	156	156	156	/	1.00E^{-11}	0.13	1.5	IBP
Plywood	Veneer plywood BFU 100	188	188	188	/	7.00E^{-12}	0.12	1.5	IBP
	Plywood board	700	200	92	/	/	0.1	1.5	IBP
	veneer plywood beech BFU-BU	242	242	242	/	4.00E^{-11}	0.12	1.5	IBP
RT.max		700	242	242		1.77E^{-10}	0.14	2	
RT.min		83.3	65	11.6		1.24E^{-12}	0.09	1.3	
RT.mid		391.7	153.5	126.8		8.91E^{-11}	0.115	1.65	
Bamboo, radial		/	550.9	90	0.0022	9.65E^{-14}	0.2086	0.938	
Bamboo, tangential		/	496.4	53.9	0.0023	1.10E^{-13}	0.2109	1.233	

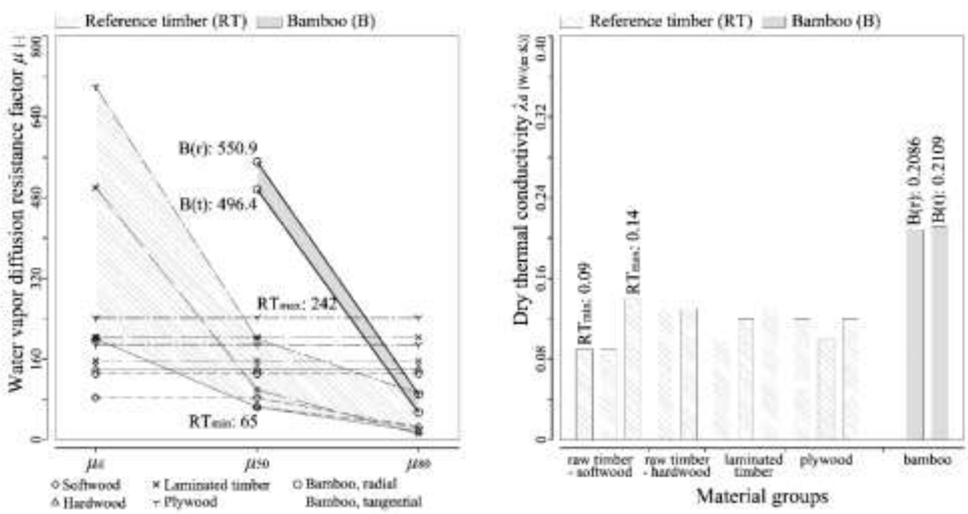


Figure 24:
Comparison between laminated bamboo and reference timber – moisture and heat transport-related properties (radial and tangential directions).

6.2 Bamboo scrimber

The reference timber (RT) for comparison with bamboo scrimber only adopts 13 timber products, provided by Fraunhofer IBP (IBP, Germany), LTH Lund University (LTH, Sweden), and NTNU Norwegian University of Science and Technology (NU, Norway). RT contains a total of four groups, namely the softwood (four kinds), the hardwood (three kinds), the plywood (three kinds), and the hard wood fiberboard (three kinds).

6.2.1 Basic properties, moisture and heat storage-related properties

The softwood, hardwood, and plywood products have ρ_d values in a range 400 to 708 kg/m^3, and the wood fiberboard (hard) products have ρ_d values in a range 800 to 959 kg/m^3. The ρ_d of bamboo scrimber is 1,127 kg/m^3, which is much higher than the RT. The given range of Φ among the RT is 0.47 to 0.8, showing no clear difference between different products. The Φ of bamboo scrimber is only 0.12. Even if the Φ is regarded as w_{cap} (0.29), it is still far lower than the min. value of RT (0.47).

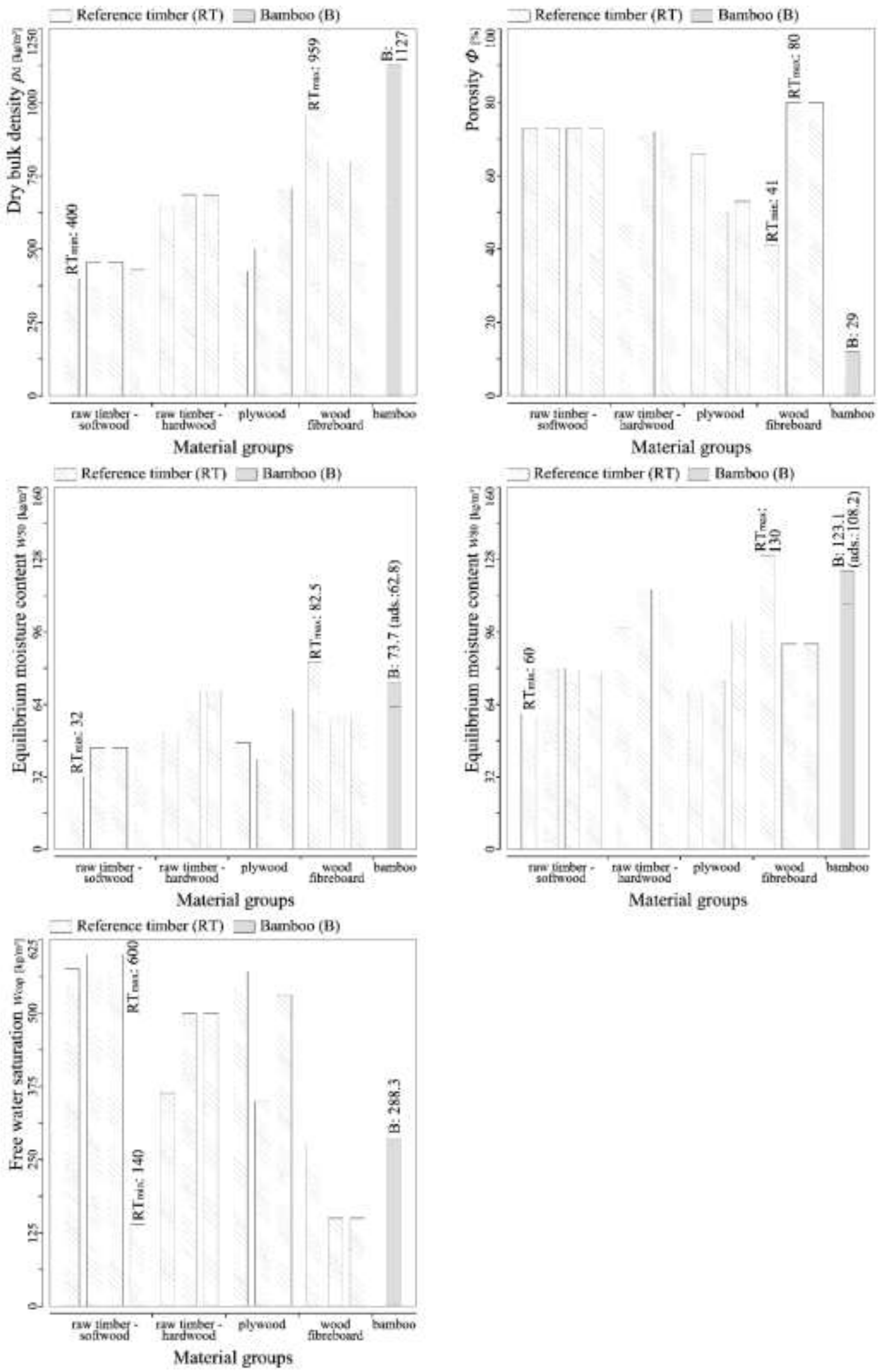
In terms of the equilibrium moisture content, both the w_{50} and w_{80} values of bamboo scrimber fall in the higher area within the RT range. However, the w values of bamboo scrimber are taken by the average of the adsorption and desorption processes, while most of the RT values may be obtained through adsorption process. If the adsorption w is used for comparison, it can be seen that the w_{50} and w_{80} of bamboo scrimber will be lower, and closer to the mid. values of RT. In terms of the w_{cap}, there are large differences among different timber products, ranging from 140 to 600 kg/m³. If converted to the volume ratio, some of them are quite closed to the corresponding Φ, while the others are far lower than their Φ values. This may be caused by different test methods. In the test for w_{cap} of bamboo scrimber, the specimens are immersed in water for about 4.5 months, until the mass no longer changes. This may be far longer the time required by general test methods and it allows the specimens to fully absorb water. However, the resulted w_{cap} of bamboo scrimber is still significantly lower than the mid. value of RT.

As explained in section 5.1.3, the specific heat capacity increases significantly with the temperature. If the c value corresponding to the temperature range 10 to 30 °C is taken, it will be higher than the max. value of RT. However, if the temperature range –15 to 40 °C is considered, the c value of bamboo scrimber falls in the range of RT (Table 18, Figure 25).

Table 18:
Comparison between laminated bamboo and reference timber (basic properties, moisture and heat storage-related properties).

Group	Product name	ρ_d	Φ	w_{50}	w_{80}	w_{cap}	c	Source
Raw material - softwood	Softwood	400	0.73	32	60	575	1400	IBP
	Spruce, longitudinal	455	0.73	45	80	600	1400	IBP
	Spruce, radial	455	0.73	45	80	600	1400	IBP
	Spruce, tangential	430	0.73	47.5	77.5	140	1600	LTH
Raw material - hardwood	Hardwood	650	0.47	52	98	370	1400	IBP
	Oak, longitudinal	685	0.72	70	115	500	1400	IBP
	Oak, radial	685	0.72	70	115	500	1400	IBP
Plywood	Veneer plywood BFU 100	427	0.66	47	70	572	1400	IBP
	Plywood board	500	0.5	40	75	350	1400	IBP
	veneer plywood beech BFU-BU	708	0.53	62	101	530	1400	IBP
Wood fibre-board (hard)	Woodfibreboard, hard	959	0.41	82.5	130	275	1700	LTH
	Wood fibreboard, hard - wind barrier	800	0.8	58.6	90.8	150	1700	NU
	Woodfibre board, hard	800	0.8	58.6	90.8	150	1700	NU
RT.max		959	0.8	82.5	130	600	1700	
RT.min		400	0.41	32	60	140	1400	
RT.mid		679.5	0.605	57.25	95	370	1550	
Bamboo		1127	0.12	73.7 (62.8)*	123.1 (108.2)*	288	1882 (1631)**	

Note:
* the values are the average of adsorption EMC and desorption EMC, while the values in brackets are the adsorption EMC;
** the value corresponds to the temperature range 10 to 30 °C, while the value in brackets corresponds to the temperature range –15 to 40 °C


Reference timber (RT)
Bamboo (B)
Dry bulk density
RTmin: 400
RTmax: 959
B: 1127
Porosity Φ [%]
RTmax: 80
RTmin: 41
B: 29
Equilibrium moisture content
RTmin: 32
RTmax: 82.5
B: 73.7 (ads.:62.8)
RTmin: 60
RTmax: 130
B: 123.1 (ads.:108.2)
Free water saturation
RTmax: 600
RTmin: 140
B: 288.3
raw timber - softwood
raw timber - hardwood
plywood
wood fibreboard
bamboo
Material groups

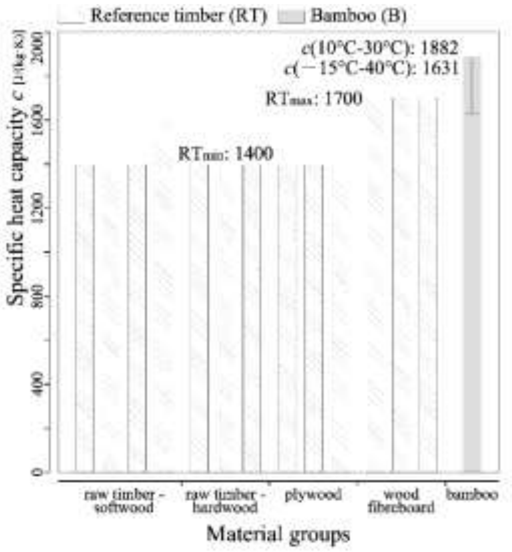


Figure 25:
Comparison between bamboo scrimber and reference timber (basic properties, moisture and heat storage-related properties).

6.2.2 Moisture and heat transport-related properties

1) Longitudinal direction
The transport properties of bamboo scrimber in longitudinal direction is compared with Spruce and Oak in the same direction. It shows that the moisture transport rate of bamboo scrimber is lower than the RT. Take the μ_{50} as an example, the μ_{50} of bamboo scrimber is 8.9 and 16.6 times that of the Oak and Spruce, respectively. In contrast, the heat transport rate of bamboo scrimber is higher than the RT. The λ_d of bamboo scrimber is 0.427 W/(m·K), higher than both the Oak and the Spruce (Table 19, Figure 26).

2) Radial and tangential directions
The comparison between bamboo scrimber and RT in radial and tangential directions shows similar law to the longitudinal direction above. For example, both bamboo scrimber in radial and tangential directions have μ_{50} and μ_{80} values that are much higher than the corresponding max. values of RT, as well as DWS_{80} values that are lower than the min. values of RT. In several sets of the timber parameters, the impact of moisture content on the μ values are not taken into consideration. Therefore, the μ_{50} is used for comparison. The μ_{50} values of bamboo scrimber in radial and tangential directions are 15.7 and 8.1 times that of the max. values of RT, respectively.

Table 19:
Comparison between bamboo scrimber and reference timber – moisture and heat transport-related properties (longitudinal direction).

Group	Product name	μ_d	μ_{50}	μ_{80}	A	DWS_{80}	λ_d	a_w	
Raw material - softwood	Spruce, longitudinal	4.3	4.3	4.3	/	$5.33E^{-11}$	0.23	1.3	IBP
Raw material - hardwood	Oak, longitudinal	8	8	8	/	$1.77E^{-10}$	0.3	1.3	IBP
Bamboo, longitudinal		/	71.3	45.4	0.00167	$2.51E^{-12}$	0.427	1.02	

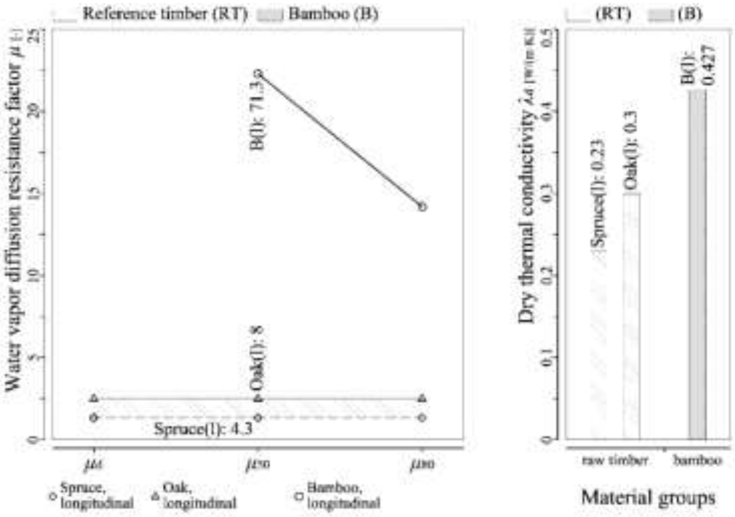


Figure 26:
Comparison between bamboo scrimber and reference timber – moisture and heat transport-related properties (longitudinal direction).

It is particularly worth noting that the λ_d values of bamboo scrimber in both radial and tangential directions are significantly higher than RT. The λ_d values of bamboo scrimber in radial and tangential directions are, respectively, 150 % and 166 % of the max. value of RT (Table 20, Figure 27).

Table 20:
Comparison between bamboo scrimber and reference timber – moisture and heat transport-related properties (radial and tangential directions).

Group	Product name	μ_d	μ_{50}	μ_{80}	A	DWS_{80}	λ_d	a_w	
Raw material - softwood	Softwood	200	65	25	/	/	0.09	1.3	IBP
	Spruce, radial	130	130	130	/	$1.24E^{-12}$	0.09	1.3	IBP
	Spruce, tangential	83.3	83.3	25	/	/	0.14		LTH
Raw material - hardwood	Hardwood	200	65	17	/	/	0.13	1.3	IBP
	Oak, radial	140	140	140	/	$6.09E^{-12}$	0.13	1.3	IBP
Plywood	Veneer plywood BFU 100	188	188	188	/	$7.00E^{-12}$	0.12	1.5	IBP
	Plywood board	700	200	92	/	/	0.1	1.5	IBP
	veneer plywood beech BFU-BU	242	242	242	/	$4.00E^{-11}$	0.12	1.5	IBP
Wood fibreboard (hard)	Wood fibreboard, hard	227	227	114	/	/	0.13	0	LTH
	Wood fibreboard, hard - wind barrier	9	36.1	52.3	/	/	0.18	1.5	NU
	Wood fibreboard, hard	48	48	48	/	/	0.18	1.5	NU
RT.max		700	242	242	/	$4.00E^{-11}$	0.18	1.5	
RT.min		9	36.1	17	/	$1.24E^{-12}$	0.09	0	
RT.mid		354.5	139.05	129.5	/	$2.06E^{-11}$	0.135	0.75	
Bamboo, radial		/	3801.3	1502.8	0.000333	$1.00E^{-13}$	0.270	1.70	
Bamboo, tangential		/	1949.9	857.2	0.000333	$1.00E^{-13}$	0.299	1.72	

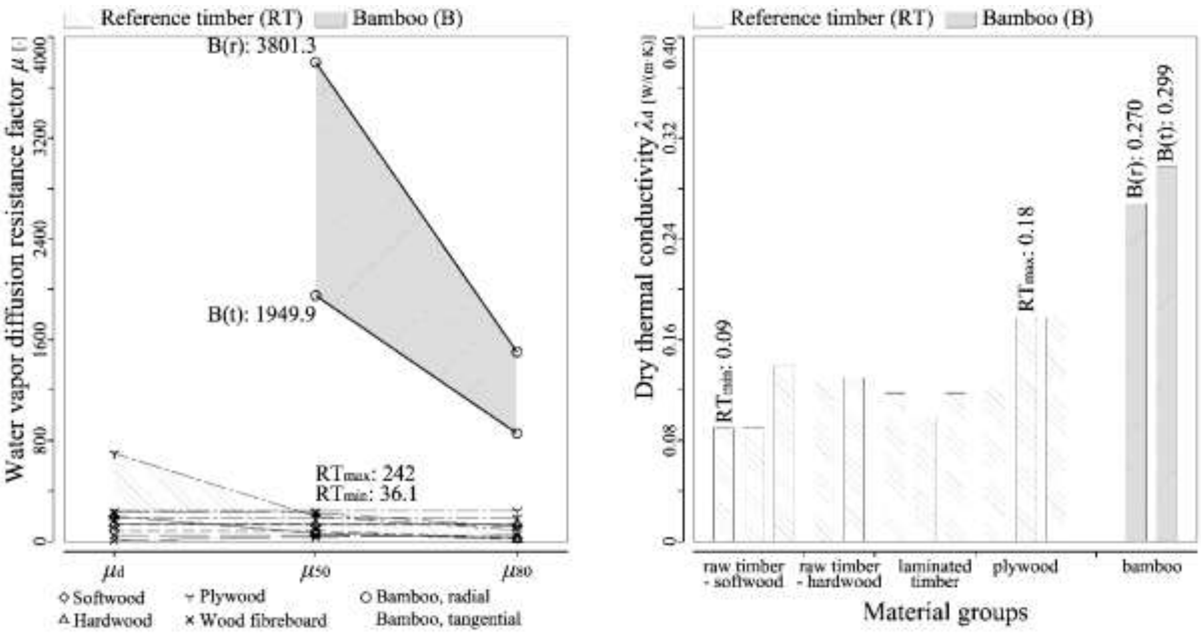


Figure 27:
Comparison between bamboo scrimber and reference timber – moisture and heat transport-related properties (radial and tangential directions).

7 Generation of dataset for WUFI®

Part of the above measured properties parameters can be used directly in WUFI®, such as the dry bulk density, porosity, free water saturation moisture content, capillary water absorption coefficient, specific heat capacity, and thermal conductivity. The rest parameters need to be adjusted or supplemented to support the operation of WUFI® model.

7.1 Laminated bamboo

7.1.1 Generation of the w-RH curve

A complete w-RH curve should contain sufficient moisture content values corresponding to different RH. The starting point (RH = 0%) and the end point (RH = 100%) of the curve corresponds to the dry state and free water saturated state. The generation of the w-RH curve for WUFI® is completed with the support of a procedure, »FitFspFkt2.exe«, developed by the Hygrothermic Department of Fraunhofer IBP. It can generate the curve that best fits the given w values. In this study, the w-RH curve is developed based on both the moisture adsorption and desorption results. In addition to the starting point (w_{RH0} = 0 kg/m^3) and end point (w_{RH1} = w_{cap} = 526 kg/m^3) of the curve, three values ($w_{RH0.5}$ = 46.9 kg/m^3, $w_{RH0.65}$ = 62.5 kg/m^3, $w_{RH0.8}$ = 86.5 kg/m^3) are inserted. The final w-RH curve is generated, shown in the »Mean curve« column in the following table (Table 21, Figure 28).

Table 21:
Generation of the w-RH curve for WUFI®, laminated bamboo.

Procedure	Adsorption curve		Desorption curve		Mean curve	
	RH	*w* [kg/m³]	*RH*	*w* [kg/m³]	*RH*	*w* [kg/m³]
Test result	0.5 0.65 0.8 0.93 0.97 1	39.0 52.7 75.4 112.7 147.3 526	0.5 0.65 0.8	54.9 72.3 97.5	0.5 0.65 0.8	46.9 62.5 86.5
Input	0 0.5 0.65 0.8 0.93 0.97 1	0 39.0 52.7 75.4 112.7 147.3 526	0 0.5 0.65 0.8 1	0 54.9 72.3 97.5 526	0 0.5 0.65 0.8 1	0 46.9 62.5 86.5 526
Output	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.93 0.95 0.99 0.995 0.999 0.9995 0.9999 1	0 25.96 30.44 34.60 38.98 43.99 50.13 58.33 70.78 95.28 109.73 124.56 210.56 252.85 349.15 385.16 448.96 526	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.93 0.95 0.99 0.995 0.999 0.9995 0.9999 1	0 29.78 36.06 42.03 48.45 55.92 65.23 77.85 97.30 135.83 158.31 181.02 300.12 349.21 437.59 462.99 498.88 526	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.93 0.95 0.99 0.995 0.999 0.9995 0.9999 1	0 24.04 29.58 34.93 40.77 47.65 56.36 68.37 87.25 125.79 148.83 172.41 299.07 351.51 443.60 468.94 503.07 526

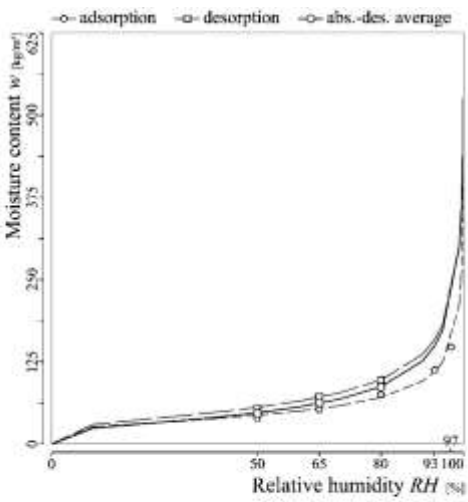


Figure 28:
Generation of the w-RH curve for WUFI®, laminated bamboo.

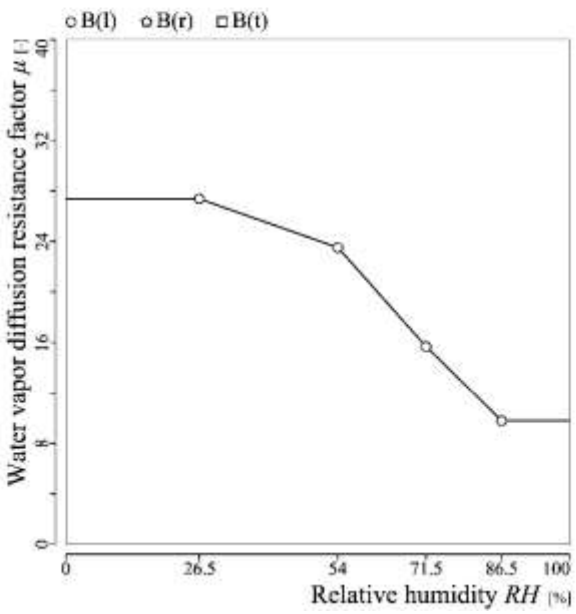
7.1.2 Supplement of the µ-RH curve

A complete µ-RH curve should provide all µ values corresponding to a full range of RH from RH = 0 to RH = 1. But normally it is sufficient to test several µ values as the representatives. In this test, four µ values corresponding to RH = 0.265/0.54/0.715/0.865 are tested. Considering that in practical application, the conditions with RH lower than 0.265 rarely occur, the µ-RH curve segment between RH = 0 and RH = 0.265 is straightened.

In addition, higher RH gradients for testing the µ values corresponding to RH > 0.865 is difficult to create, and will certainly cause mould growth on both sides of the specimens, which may lead to errors to the test results. Therefore, the µ-RH curve segment between RH = 0.865 and RH = 1 is also straightened (Table 22, Figure 29).

Table 22:
Supplement of the µ-RH curve for WUFI®, laminated bamboo.

Procedure	B(l)		B(r)		B(t)	
	RH	*µ* [-]	*RH*	*µ* [-]	*RH*	*µ* [-]
Test result	3%/50% 33%/75% 93%/50% 93%/80%	27.39 23.52 15.67 9.8	3%/50% 33%/75% 93%/50% 93%/80%	1148.67 449.2 139.45 52.18	3%/50% 33%/75% 93%/50% 93%/80%	1392.83 343.78 80.9 33.25
WUFI® dataset	0 0.265 0.54 0.715 0.865 1	27.39 27.39 23.52 15.67 9.8 9.8	0 0.265 0.54 0.715 0.865 1	1148.67 1148.67 449.2 139.45 52.18 52.18	0 0.265 0.54 0.715 0.865 1	1392.83 1392.83 343.78 80.9 33.25 33.25



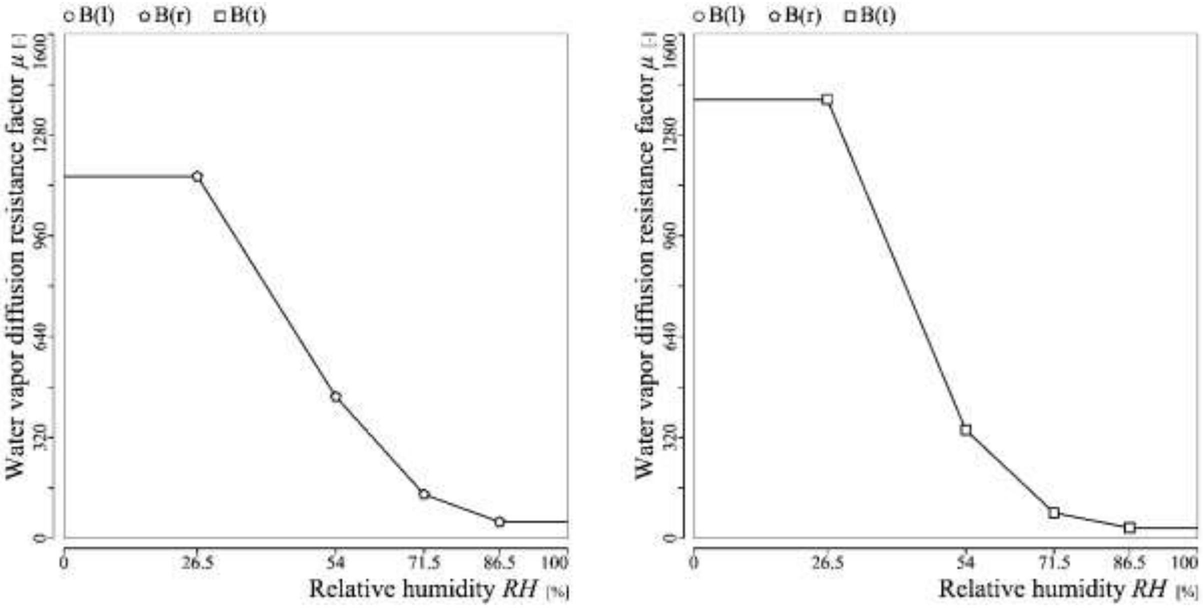


Figure 29:
Supplement of the μ-RH curve for WUFI®, laminated bamboo.

7.1.3 Modification of the DWW-w curve

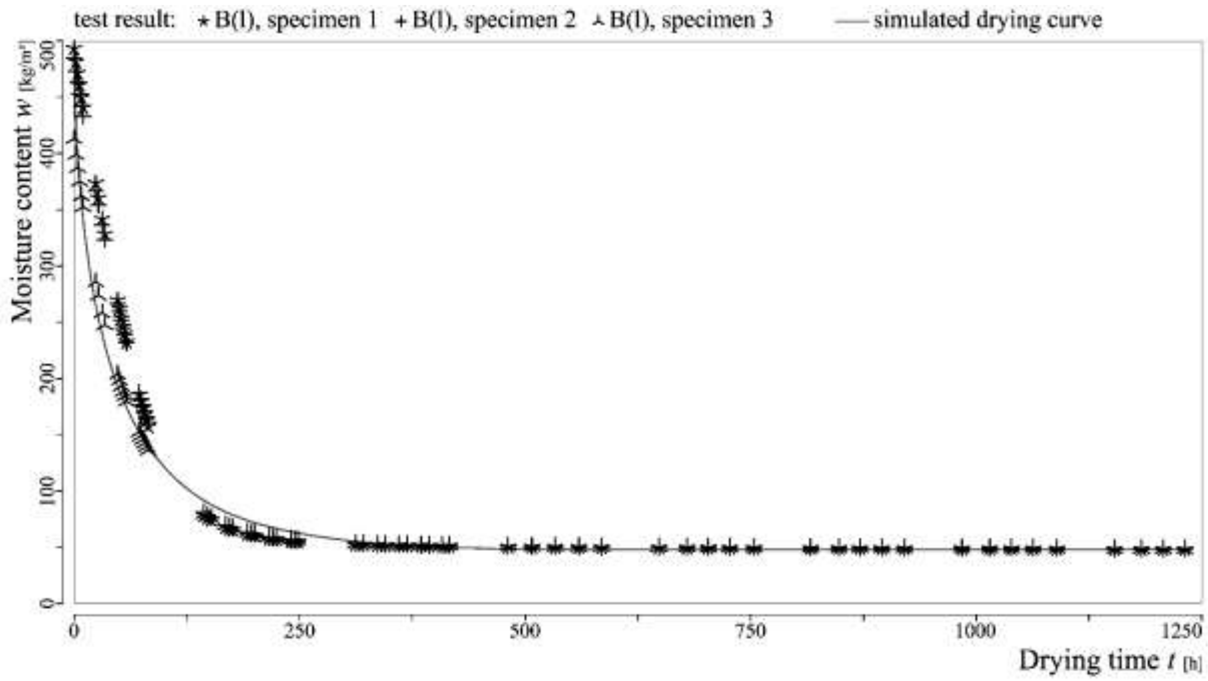
In WUFI®, the DWS-w (liquid transport coefficient, suction) curve can be generated with the tested results of $w_{RH80\%}$ (regarded as the reference water content), w_{cap}, and the A values. The DWW-w (liquid transport coefficient, redistribution) curve can also be generated. But in this study, it needs to be modified in order to achieve a good fitting degree with the measured drying curve.

The modification of DWW-w curve is carried out with the tested results of the dry cup μ value ($\mu_{RH3\%-50\%}$), the wet cup μ value ($\mu_{RH50\%-93\%}$), as well as the measured drying curve. Firstly, simulate the specimens of the drying test with the $\mu_{RH3\%-50\%}$ and the default DWW-w by WUFI®, compare the simulated drying curve with the measured drying curve and adjust the values of $DWW_{wRH80\%}$ and DWW_{wcap} until the simulated drying curve well fits the measured one. Secondly, simulate the $\mu_{RH50\%-93\%}$ value with the $\mu_{RH3\%-50\%}$, the $DWW_{wRH80\%}$ and the DWW_{w-cap} defined above, insert a $DWW_{wRH93\%}$ to the DWW-w curve, adjust $DWW_{wRH93\%}$ until the simulated $\mu_{RH3\%-50\%}$ value is equal to the measured one. Finally, resimulate the drying curve with the above values, and re-adjust the DWW_{wcap} until the simulated drying curve well fits the measured one. (Note: in the second step, the $DWW_{wRH93\%}$ can be adjusted within the range between $DWW_{wRH80\%}$ and DWW_{wcap}, but if the desired $\mu_{RH50\%-93\%}$ cannot be obtained in this range, the value of $DWW_{wRH80\%}$ can be re-adjusted slightly) (Table 23, Figure 30).

Table 23:
Modification of the DWW-w curve for WUFI®, laminated bamboo.

Items	B(l)		B(r)		B(t)	
	w [kg/m^3]	Liquid transport coefficient [m^2/s]	*w* [kg/m^3]	Liquid transport coefficient [m^2/s]	*w* [kg/m^3]	Liquid transport coefficient [m^2/s]
DWS (generated)	0 87.25 526	0 2.22E^{-11} 7.06E^{-9}	0 87.25 526	0 2.03E^{-13} 6.45E^{-11}	0 87.25 526	0 2.35E^{-13} 7.48E^{-11}
DWW (generated)	0 87.25 526	0 2.22E^{-11} 7.06E^{-10}	0 87.25 526	0 2.03E^{-13} 6.45E^{-12}	0 87.25 526	0 2.35E^{-13} 7.48E^{-12}
DWW (modified)	0 87.25 148.83 526	0 2.1E^{-10} 2.2E^{-10} 2.0E^{-9}	0 47.65 87.25 148.83 526	0 3.2E^{-11} 3.2E^{-11} 6E^{-11} 1.4E^{-10}	0 47.65 87.25 148.83 526	0 5.0E^{-11} 5.0E^{-11} 9E^{-11} 1.4E^{-10}

Note: the A values for B(l), B(r), and B(t) are 0.022667 kg/m^2·s$^{0.5}$, 0.002167 kg/m^2·s$^{0.5}$, and 0.002333 kg/m^2·s$^{0.5}$



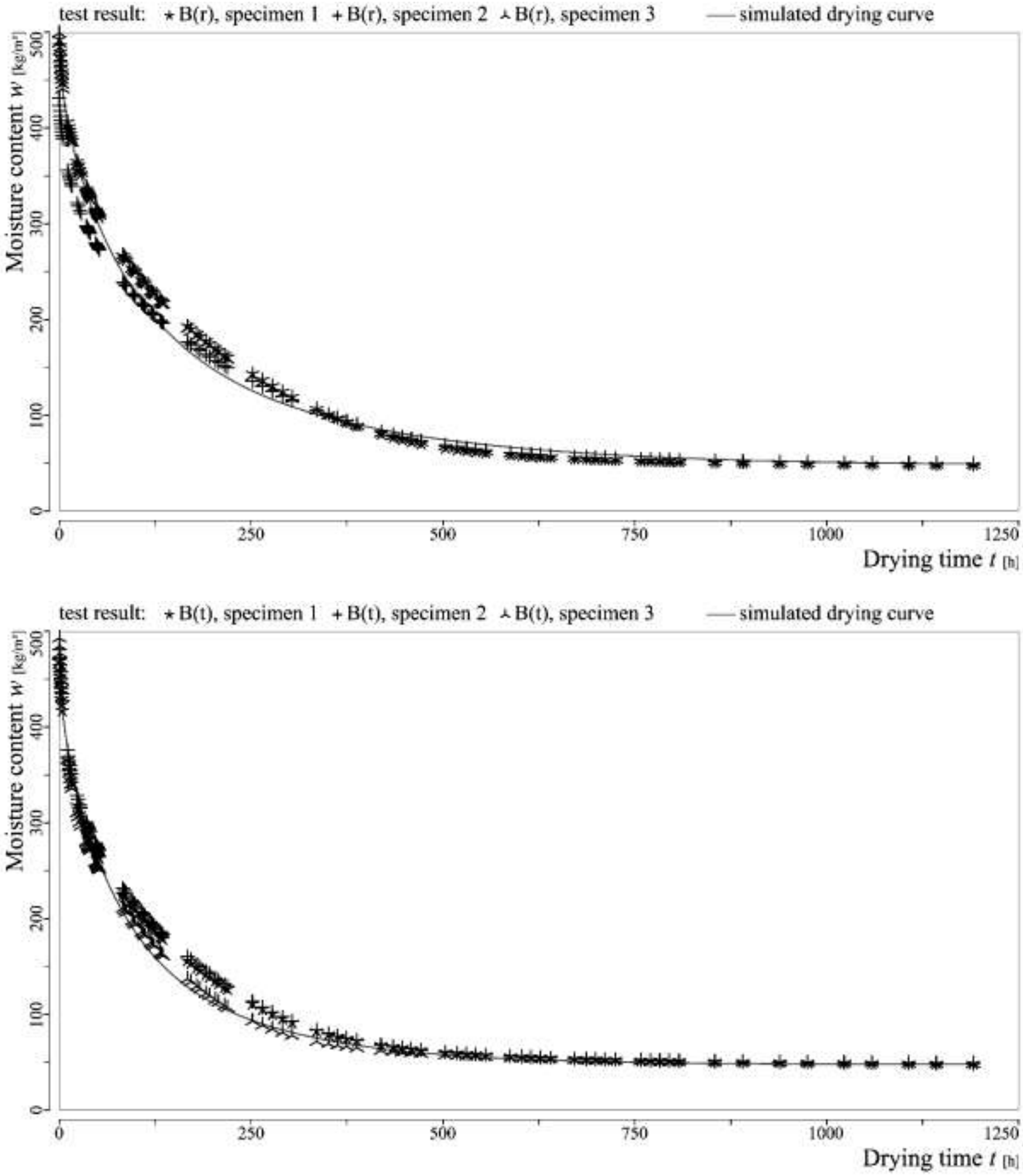


Figure 30:
Measured drying moisture content and the simulated drying curve with modified DWW-w in WUFI®, laminated bamboo.
Note: The measured drying moisture content is calculated by the desorption EMC (RH = 50 %) value.

7.2 Bamboo scrimber

7.2.1 Generation of the w-RH curve

The generation process is same as the corresponding method for laminated bamboo, which has been introduced in section 7.1.1 in detail. The results are shown as follows (Table 24, Figure 31).

Table 24:
Generation of the w-RH curve for WUFI®, bamboo scrimber.

Procedure	Adsorption curve		Desorption curve		Mean curve	
	RH	*w* [kg/m³]	*RH*	*w* [kg/m³]	*RH*	*w* [kg/m³]
Test result	0.5 0.65 0.8 0.93 0.97 1	62.77 80.69 108.19 168.37 244.33 288.28	0.5 0.65 0.8	84.64 107.52 138.06	0.5 0.65 0.8	73.71 94.10 123.12
Input	0 0.5 0.65 0.8 0.93 0.97 1	0 62.77 80.69 108.19 168.37 244.33 288.28	0 0.5 0.65 0.8 1	0 84.64 107.52 138.06 288.28	0 0.5 0.65 0.8 1	0 73.71 94.10 123.12 288.28
Output	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.93 0.95 0.99 0.995 0.999 0.9995 0.9999 1	0 22.29 29.7 37.23 45.74 56 69.12 87.05 113.95 161.02 183.7 203.09 262.1 273.48 284.56 286.26 287.8 288.28	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.93 0.95 0.99 0.995 0.999 0.9995 0.9999 1	0 43.7 53.98 63.61 73.74 85.13 98.67 115.82 139.45 177.25 194.69 209.55 257.84 268.91 281.83 284.31 287.02 288.28	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.93 0.95 0.99 0.995 0.999 0.9995 0.9999 1	0 37.26 46.18 54.61 63.58 73.79 86.11 102.02 124.54 162.18 180.3 196.14 250.67 263.95 279.94 283.1 286.59 288.28

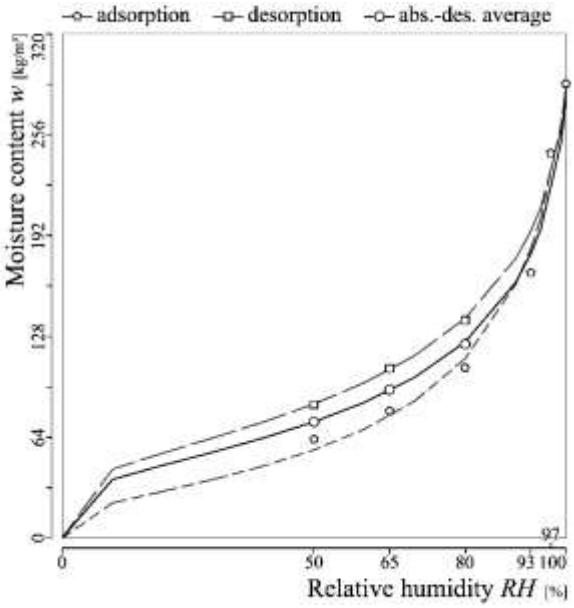


Figure 31:
Generation of the w-RH curve for WUFI®, bamboo scrimber.

7.2.2 Supplement of the μ-RH curve

The generation process is same as the corresponding method for laminated bamboo, which has been introduced in section 7.1.2 in detail. The results are shown as follows (Table 25, Figure 32).

Table 25:
Supplement of the μ-RH curve for WUFI®, bamboo scrimber.

Procedure	B(l)		B(r)		B(t)	
	RH	*μ* [-]	*RH*	*μ* [-]	*RH*	*μ* [-]
Test result	3%/50% 33%/75% 93%/50% 93%/80%	74.2 70.8 57.3 36.4	3%/50% 33%/75% 93%/50% 93%/80%	9245.2 2874.7 1887.9 1208.4	3%/50% 33%/75% 93%/50% 93%/80%	3572.9 1673.7 1015.8 736.0
WUFI® dataset	0 0.265 0.54 0.715 0.865 1	74.2 74.2 70.8 57.3 36.4 36.4	0 0.265 0.54 0.715 0.865 1	9245.2 9245.2 2874.7 1887.9 1208.4 1208.4	0 0.265 0.54 0.715 0.865 1	3572.9 3572.9 1673.7 1015.8 736.0 736.0

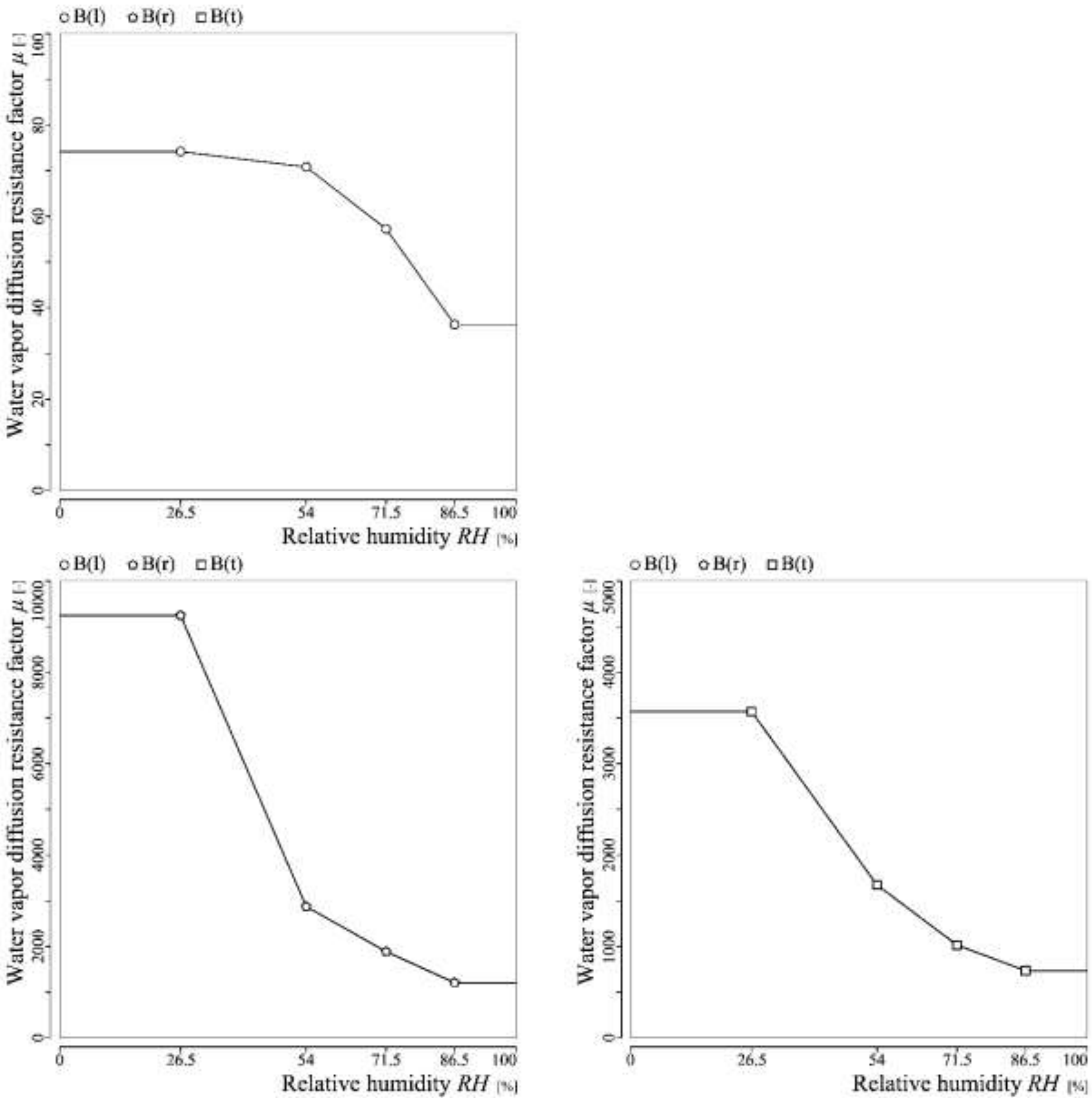


Figure 32:
Supplement of the μ-RH curve for WUFI®, bamboo scrimber.

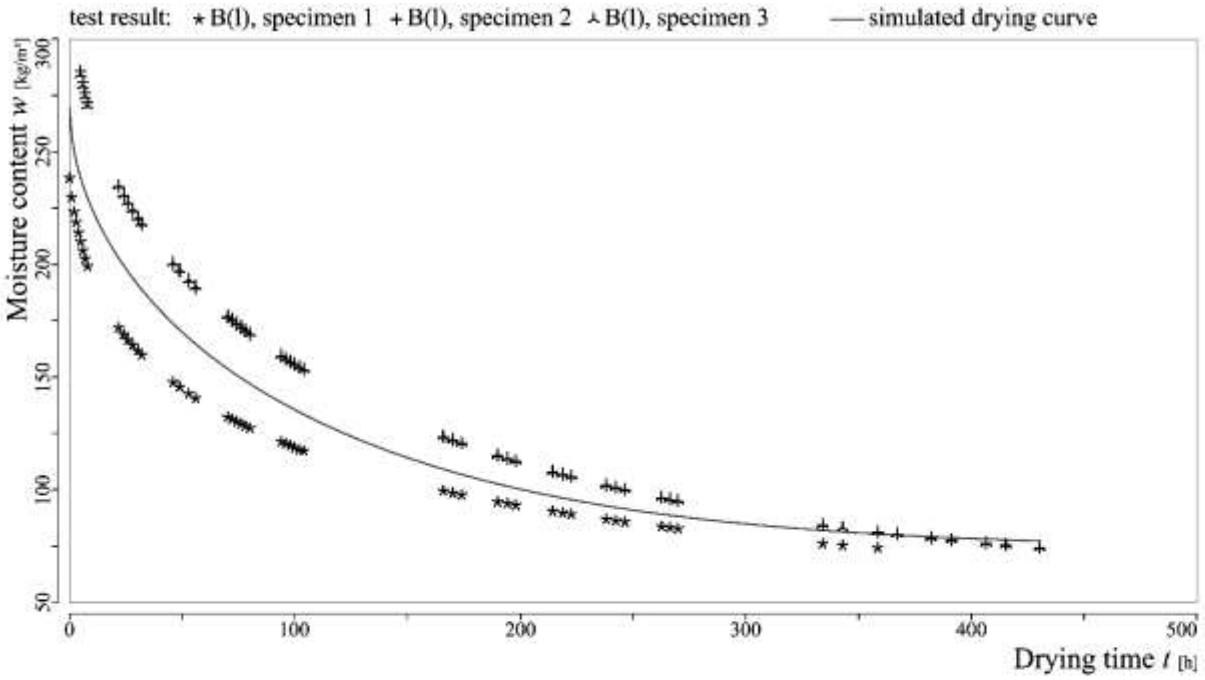
7.2.3 Modification of the DWW-w curve

The generation process is same as the corresponding method for laminated bamboo, which has been introduced in section 7.1.3 in detail. The results are shown as follows (Table 26, Figure 33).

Table 26:
Modification of the DWW-w curve for WUFI®, bamboo scrimber.

Items	B(l)		B(r)		B(t)	
	w [kg/m³]	Liquid transport coefficient [m²/s]	*w* [kg/m³]	Liquid transport coefficient [m²/s]	*w* [kg/m³]	Liquid transport coefficient [m²/s]
DWS (generated)	0 124.5 288.3	0 $2.51E^{-12}$ $1.27E^{-10}$	0 124.5 288.3	0 $1.0E^{-13}$ $5.07E^{-12}$	0 124.5 288.3	0 $1.0E^{-13}$ $5.07E^{-12}$
DWW (generated)	0 124.5 288.3	0 $2.51E^{-12}$ $1.27E^{-11}$	0 124.5 288.3	0 $1.0E^{-13}$ $5.07E^{-13}$	0 124.5 288.3	0 $1.0E^{-13}$ $5.07E^{-13}$
DWW (modified)	0 73.9 124.5 180.3 288.3	0 $1.0E^{-10}$ $1.0E^{-10}$ $1.4E^{-10}$ $1.0E^{-9}$	0 73.9 124.5 180.3 288.3	0 $1.4E^{-11}$ $1.4E^{-11}$ $1.6E^{-11}$ $1.0E^{-10}$	0 73.9 124.5 180.3 288.3	0 $2.2E^{-11}$ $2.2E^{-11}$ $2.6E^{-11}$ $2.6E^{-10}$

Note: the A values for B(l), B(r) and B(t) are 0.001667 kg/m²·s^0.5, 0.000333 kg/m²·s^0.5, and 0.000333 kg/m²·s^0.5



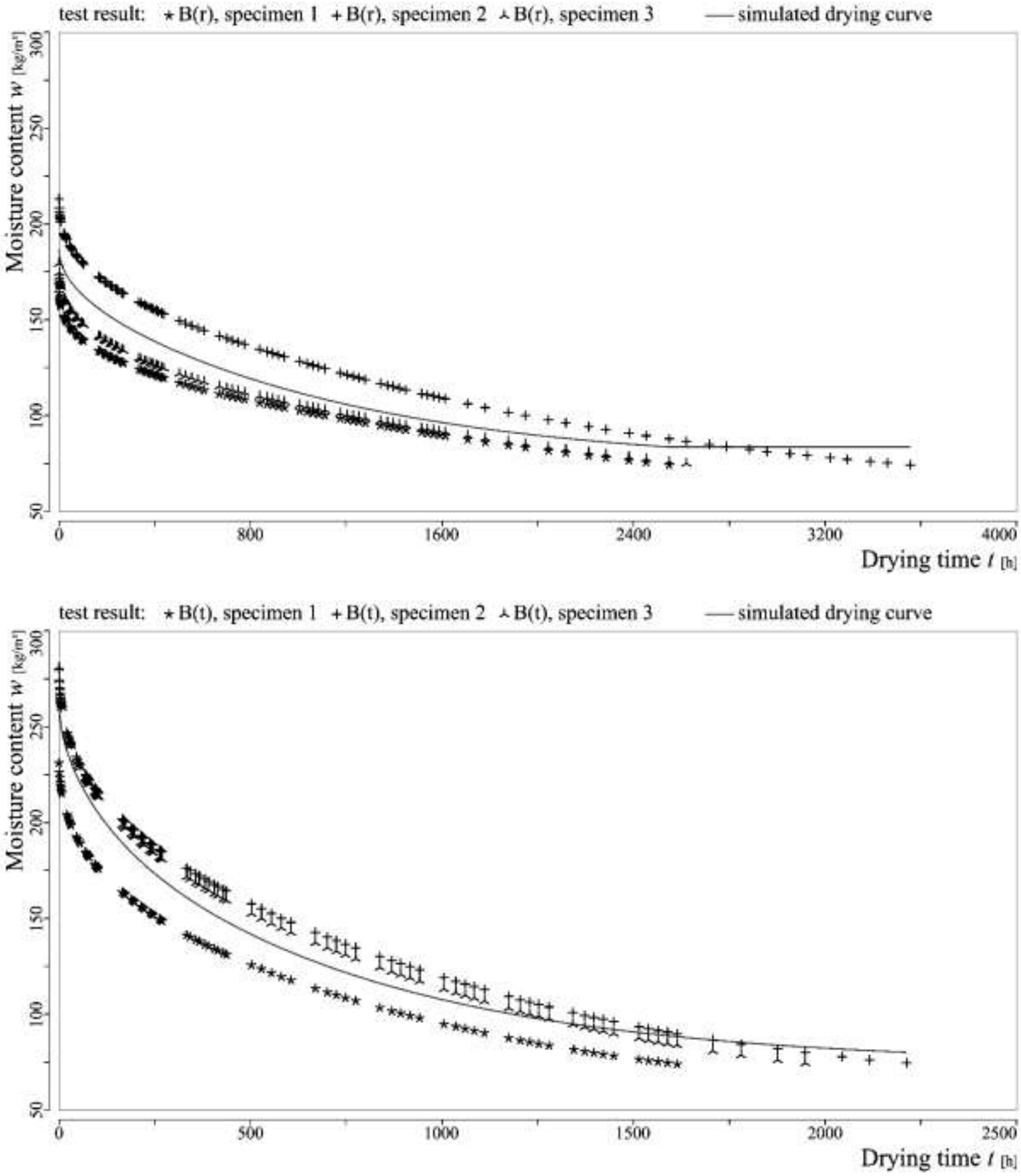


Figure 33:
Measured drying moisture content and the simulated drying curve with modified DWW-w in WUFI®, bamboo scrimber.
Note: the measured drying moisture content is calculated by the dry mass of the specimens before water immersion.

8 Mould growth phenomenon on specimens and the potential impact

8.1 Discussion on the potential impact

Mould growth occurs on the surfaces of specimens in three groups of the sorption test (adsorption process in RH = 80 %/93 %/97 %), and two groups of the water vapor transmission test (wet cups with salt solution corresponding to RH = 93 %).

1) Impact on the adsorption w-RH curve
   Mould growth occurs in the adsorption test in RH = 80 %/93 %/97 %. For the specimen groups in RH = 80 %, the mould growth is relatively slight, so that the impact should be negligible. For the groups in RH = 93 % and 97 %, mould starts to grow about two weeks after the specimens are moved into the climate chamber for curing. During the test, it is found that the masses of the specimens decrease to varying degrees after reaching the highest values, which may be caused by the degradation of nutrients caused by mould growth. Although the peak values of the specimen curves are used to calculate the moisture content, there may still be part of mass loss, resulting in lower test results, because the highest value appears later than the time when the mould starts to grow.

2) Impact on the μ values
   Mould growth happens during the water vapor transmission test of the RH gradients 93 % to 50 % and 93 % to 80 %. It occurs on the lower surfaces that are exposed to the air of high humidity (RH = 93 %) created by the saturated salt solution below. The mycelia spread to almost the entire surface of the specimens, and even to the edges of the experimental cups. Some mycelia peel off and drop on the surface of the salt solution below. However, based on this information, it is not yet possible to judge its impact on the test results (Figure 34).

mould growth on the lower surface of the specimens

mycelium stuck to the cup edges

Figure 34:
Photos of mould growth during the water vapor transmission test of the RH gradient 93 % to 50 %, laminated bamboo.

8.2 Record of the mould index

In order to record the mould growth rate in different RH gradients, the VTT model is adopted. The »Mould Index« of VTT model include 7 grades, including 6 grades describing the growth intensities. However, the observation for grade 1 and grade 2 is only possible by microscope. Therefore, in this study, only the grade 3 to 6 is preliminary recorded (Table 27, Figure 35).

This record cannot yet provide complete and sufficiently accurate MI parameters. It shows that both laminated bamboo and bamboo scrimber can be classed to »very sensitive« in the VTT model [27]. In addition, it is worth mentioning that in the groups T = 23 °C and RH = 80 %, mould growth occurs in the laminated bamboo specimen groups in all three directions, as well as the bamboo scrimber groups in the longitudinal direction. It indicates that the internationally used critical RH value (80 %) is not applicable to laminated bamboo and bamboo scrimber.

Table 27:
Mould index for experiments and modeling (VTT model).

Index	Description of the growth rate
0	No growth
1	Small amounts of mould on surface (microscope), initial stages of local growth
2	Several local mould growth colonies on surface (microscope)
3	Visual findings of mould on surface, < 10 % coverage, or < 50 % coverage of mould (microscope)
4	Visual findings of mould on surface, 10 % - 50 % coverage, or > 50 % coverage of mould (microscope)
5	Plenty of growth on surface, > 50 % coverage (visual)
6	Heavy and tight growth, coverage about 100 %

specimens (size: 5×5×1.35 cm), with four sides and bottom surface sealed

wax for sealing the specimens

Figure 35:
Photos of the specimens for mould index record.

8.2.1 Laminated bamboo

Mould indices for laminated bamboo are recorded as follows (Table 28).

Table 28:
Preliminary record of the mould index for bamboo in different RH gradients, laminated bamboo.

Mould Index		0	1	2	3	4	5	6
T=23°C, *RH*=80%	B(l),1	 2020-11-13	no record		 2020-12-18	 2020-12-25	 2021-01-08	 2021-01-26
	B(l),2	 2020-11-13			 2020-12-22	 2020-12-29	 2021-01-15	 2021-02-05
	B(l),3	 2020-11-13			 2020-12-18	 2020-12-25	 2021-01-05	 2021-01-19
	B(r),1	 2020-11-13			 2020-12-25	 2021-01-08	 2021-01-22	/
	B(r),2	 2020-11-13			 2020-12-25	 2021-01-08	 2021-01-26	/
	B(r),3	 2020-11-13			 2020-12-22	 2021-01-01	 2021-01-12	/

	B(t),1	 2020-11-13		 2020-12-22	 2021-01-01	 2021-01-12	/
	B(t),2	 2020-11-13		 2020-12-22	 2021-01-01	 2021-01-19	/
	B(t),3	 2020-11-13		 2020-12-25	 2021-01-05	 2021-01-26	/
T=23°C, RH=93%	B(l),1	 2020-11-20	no record	 2020-12-03	 2020-12-07	 2020-12-09	 2020-12-15
	B(l),2	 2020-11-20		 2020-12-01	 2020-12-07	 2020-12-08	 2020-12-14
	B(l),3	 2020-11-20		 2020-12-04	 2020-12-08	 2020-12-09	 2020-12-14
	B(r),1	 2020-11-20		 2020-11-27	 2020-11-30	 2020-12-03	 2020-12-15
	B(r),2	 2020-11-20		 2020-11-27	 2020-11-30	 2020-12-03	 2020-12-15

	B(r),3	 2020-11-20		 2020-11-30	 2020-12-03	 2020-12-8	 2020-12-29
	B(t),1	 2020-11-20		 2020-11-30	 2020-12-03	 2020-12-8	 2020-12-21
	B(t),2	 2020-11-20		 2020-11-30	 2020-12-02	 2020-12-08	 2020-12-21
	B(t),3	 2020-11-20		 2020-11-30	 2020-12-03	 2020-12-7	 2020-12-18
T=23°C, *RH*=97%	B(l),1	 2020-11-20	no record	 2020-11-30	 2020-12-03	 2020-12-07	 2020-12-09
	B(l),2	 2020-11-20		 2020-11-30	 2020-12-03	 2020-12-07	 2020-12-09
	B(l),3	 2020-11-20		 2020-12-02	 2020-12-04	 2020-12-08	 2020-12-10
	B(r),1	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-02	 2020-12-12

	B(r),2	 2020-11-20		 2020-11-27	 2020-11-30	 2020-12-04	 2020-12-16
	B(r),3	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-02	 2020-12-11
	B(t),1	 2020-11-20		 2020-11-27	 2020-12-01	 2020-12-04	 2020-12-13
	B(t),2	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-03	 2020-12-13
	B(t),3	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-02	 2020-12-12

8.2.2 Bamboo scrimber

Mould indices for bamboo scrimber are recorded as follows (Table 29).

Table 29:
Preliminary record of the mould index for bamboo in different RH gradients, bamboo scrimber.

Mould Index		0	1	2	3	4	5	6
T=23°C, *RH*=80%	B(l),1	 2020-11-13	no record		 2020-12-22	 2021-01-01	 2021-01-19	 2021-02-19

	B(l),2	 2020-11-13		 2020-12-22	 2021-01-01	 2021-01-15	 2021-02-12
	B(l),3	 2020-11-13		 2020-12-25	 2021-01-04	 2021-01-26	 2021-02-26
	B(r),1	 2020-11-13		/	/	/	/
	B(r),2	 2020-11-13		/	/	/	/
	B(r),3	 2020-11-13		/	/	/	/
	B(t),1	 2020-11-13		/	/	/	/
	B(t),2	 2020-11-13		/	/	/	/
	B(t),3	 2020-11-13		/	/	/	/

	B(l),1	 2020-11-20		 2020-12-01	 2020-12-03	 2020-12-07	 2020-12-17
	B(l),2	 2020-11-20		 2020-12-01	 2020-12-03	 2020-12-07	 2020-12-15
	B(l),3	 2020-11-20		 2020-11-30	 2020-12-02	 2020-12-07	 2020-12-15
T=23°C, *RH*=93%	B(r),1	 2020-11-20	no record	 2020-11-30	 2020-12-03	 2020-12-10	 2020-12-23
	B(r),2	 2020-11-20		 2020-11-30	 2020-12-04	 2020-12-14	 2021-01-07
	B(r),3	 2020-11-20		 2020-11-30	 2020-12-03	 2020-12-09	 2021-01-12
	B(t),1	 2020-11-20		 2020-11-30	 2020-12-04	 2020-12-11	 2021-01-04
	B(t),2	 2020-11-20		 2020-11-30	 2020-12-02	 2020-12-10	 2020-12-28

	B(t),3	 2020-11-20		 2020-11-30	 2020-12-02	 2020-12-08	 2020-12-23
T=23°C, *RH*=97%	B(l),1	 2020-11-20	no record	 2020-11-27	 2020-11-30	 2020-12-02	 2020-12-08
	B(l),2	 2020-11-20		 2020-11-27	 2020-11-30	 2020-12-02	 2020-12-07
	B(l),3	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-02	 2020-12-07
	B(r),1	 2020-11-20		 2020-11-25	 2020-12-01	 2020-12-07	 2020-12-18
	B(r),2	 2020-11-20		 2020-11-26	 2020-12-01	 2020-12-07	 2020-12-21
	B(r),3	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-04	 2020-12-18
	B(t),1	 2020-11-20		 2020-11-25	 2020-12-01	 2020-12-07	 2020-12-21

	B(t),2	 2020-11-20		 2020-11-26	 2020-11-30	 2020-12-04	 2020-12-18
	B(t),3	 2020-11-20		 2020-11-25	 2020-11-30	 2020-12-03	 2020-12-16

9 Conclusion

In this study, nine laboratory test items have been carried out on two bamboo-based panel products, namely laminated bamboo and bamboo scrimber. Both products include variants in longitudinal, radial and tangential directions. The test items include the bulk density, true density and porosity test for basic properties; sorption test, water immersion test, capillary absorption test, water vapor transmission test and drying test for hygric properties; as well as thermal analysis and thermal conductivity test for thermal properties. These provide necessary material parameters for describing the heat and moisture transfer characteristics of these bamboo products.

The heat and moisture transport-related properties parameters of the bamboo specimens in different directions are compared, showing that both the heat and moisture transport rate in radial and tangential directions are far lower than that in longitudinal direction. In general, both the heat and moisture transport rate in radial direction is lower than that in tangential direction. For example, in the laminated bamboo groups, the $\mu_{RH33\%-75\%}$ value in radial direction is 30.7 % larger than that in tangential direction, and the $\mu_{RH33\%-75\%}$ values in radial and tangential directions are, respectively, 19.1 and 14.6 times that in longitudinal direction. The λ_d value in radial direction is slightly lower than that in tangential direction, and both are about 68 % of the value in longitudinal direction.

The comparison between bamboo and the corresponding reference timber (RT) shows that, in terms of the basic properties (ρ_d and Φ), laminated bamboo is closer to hardwood and far different from softwood. In terms of hygric and thermal properties, both laminated bamboo and bamboo scrimber have generally lower moisture storage and transport properties, and higher heat storage and transport properties than RT. In many cases, the properties parameters of bamboo scrimber exceed the value range of RT. For example, the μ_{50} values of bamboo scrimber in radial and tangential directions are 15.7 and 8.1 times that of the max. values of RT, respectively, while the λ_d values of bamboo scrimber in radial and tangential directions are, respectively, 150 % and 166 % of the max. value of RT.

In addition, the study also carried out preliminary mould index (MI) records. The test environment is T = 23 °C, and RH = 80 %, 93 %, and 97 %. The surface MI of the limated bamboo and bamboo scrimber in longitudinal, radial and tangential directions is preliminarily obtained. However, limited to experimental conditions, such as the lack of a microscope for observing the initial stages of spore germination and mycelia growth, this test cannot yet provide complete and sufficiently accurate MI parameters. The record shows that both laminated bamboo and bamboo scrimber can be classed to »very sensitive« in the VTT model. In addition, it is worth mentioning that in the groups T = 23 °C and RH = 80 %, mould growth occurs in the laminated bamboo specimen groups in all three directions, as well as the bamboo scrimber groups in the longitudinal direction. It indicates that the internationally used critical RH value (80 %) is not applicable to laminated bamboo and bamboo scrimber. It is necessary to carry out further tests on the mould growth properties of bamboo products in future work.

9.1 Recommended reading

In the early stage, the authors carried out tests on the hygrothermal properties of different bamboo products, as well as the hygrothermal performance simulations of bamboo building components, and also comparisons with reference timber and timber constructions. However, these discussions only focus on a one dimension of the bamboo products.

These studies are mainly published in the following literatures:

Book
Zujian HUANG. Application of Bamboo in Building Envelope, Springer International Publishing, 304 pages, ISSN: 1865-3529, eBook ISBN: 978-3-030-12032-0, Hardcover ISBN: 978-3-030-12031-3, 2019.

This book offers a comprehensive overview of the use of bamboo in building industry. It systematically demonstrates bamboo's utility in terms of its properties, describing the material properties of typical industrial bamboo products, and discussing their performance evaluation and optimization as building components and in the creation of building envelopes. The book also includes examples of the high-value utilization of bamboo forest resources. Further, it examines how building performance may be affected by conditions such as climate. Including insights from material science, construction design, building physics and building climatology, the book also provides data obtained from technology and market status investigation, laboratory test and the computer simulation. This book appeals to scientists and professionals, as it introduces and tests various bamboo products, demonstrating the advantages and disadvantages for each one. The book is also a valuable resource for civil engineers and students interested in this unique plant material and its application in the building industry.

Journal paper

Huang Z, Sun Y*, Musso F. Experimental study on bamboo hygrothermal properties and the impact of bamboo-based panel process. Construction & Building Materials, 2017,155: 1112-1125.

To obtain bamboos' material parameters and clarify the modification impact of bamboo-based panel (BBP) process, nine test items are carried out on six typical bamboos for hygrothermal properties, based on the building envelope heat and moisture process model. Results show that macroscopically gaseous water and heat storage properties show insignificant correlation with basic properties. Both moisture and thermal transport properties show stronger correlation with open porosity than with bulk density and are affected by moisture content to varying degree. Comparison between five BBPs and flattened raw bamboo show that the BBP process improves homogeneity and broadens the material properties spectrum. The transport properties are changed greater than storage properties in terms of both hygric and thermal aspects.

Huang Z, Sun Y*, Musso F. Assessment of bamboo application in building envelope by comparison with reference timber. Construction & Building Materials, 2017,156: 844-860.

For obtaining material parameters of typical bamboos, assessing the performance of bamboo in building envelope, timber units were set as reference model, accordingly bamboo units of the same construction and space size as evaluation model, by which the performances in aspects of material, building component and enclosed space unit were compared. Results showed that bamboo units had strengths on heat storage and vapor resistance but weakness on heat transport performance, which varied with climate condition, building function and construction type. Bamboo showed disadvantages in severe cold and cold zones, and advantages in full bamboo/timber constructions in hot and temperate regions.

Huang Z, Sun Y*, Musso F. Hygrothermal Performance Optimization on Bamboo Building Envelope in Hot-Humid Climate Region. Construction & Building Materials, 2019,202: 223-245.

Bamboo forest distributes largely in Hot-Humid climate regions, where the local application of bamboo in building industry possesses multiple potentials such as high-value utilization of bamboo resources and improvement of building sustainability. To support the application of bamboo in building envelope, the paper carried out study on the bamboo construction design optimization in Hot-Humid climate region. For bamboo as a hygroscopic material, the coupled heat and moisture process model was adopted for the hygrothermal performance study of bamboo construction. With four groups of meteorological data from two representative cities in the Hot-Humid climate region of North America as external conditions, exterior walls were constructed in WUFI® Plus and the coupled heat and moisture process simulation was performed. Based on the statistical analyses of a large sample of simulation results, scientific laws for promoting the parameter optimization were generated, for which the simulation results were grouped to the indicators on three level, including annual exterior walls hygrothermal performance, indoor hygrothermal environment and HVAC demand. Factor impact analyses were carried out to investigate the effect of the partition boards, thermal insulation infill and air layer arrangement. Hygrothermal performance design optimization suggestions were generated, in terms of material and construction parameters optimization, which would support the climate adaptive design of bamboo building envelope in Hot-Humid climate region.

Huang Z, Sun Y*, Musso F. Hygrothermal performance of natural bamboo fiber and bamboo charcoal as local construction infills in building envelope. Construction & Building Materials, 2018,177: 342-357.

Natural bamboo fiber (BF) and bamboo charcoal (BC) resources are available in tropical and subtropical regions in which bamboo forests are widely distributed and exhibit the potential to act as sustainable local building materials. In this study, a hygrothermal properties test and a building component and enclosed space simulation were performed to determine the adaptability of applying BF and BC as construction infills in building envelopes with local climate and building conditions. Hygrothermal properties test results indicated that the relation between BF hygrothermal properties and ambient relative humidity could be generally defined with exponential equations. Both the moisture storage and transport properties of the BC increased when compared with those of uncarbonized bamboo panels. Hygrothermal performance simulation results indicated that the BC arranged in the upstream side of the moisture flow improved the hygric performance of the BF layer, weakened the moisture and heat flow through exterior walls, improved the indoor hygrothermal environment, and reduced the HVAC demand. The application of BF and BC as local building materials was beneficial for both bamboo resources utilization and the building physical performance improvements in the bamboo producing area.

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A.1 Annex 1 Experimental records (laminated bamboo)

Note: Sample A, longitudinal; Sample B, radial; Sample C, tangential.

A.1.1 Bulk density test:

Sample	Volume	Dry weight	Dry bulk density	Dry bulk density average	Dry bulk density deviation
	[cm³]	[g]	[g/cm³]	[g/cm³]	[g/cm³]
A_01	75.05	47.69	0.635	0.621	+/- 0.028
A_02	75.16	48.73	0.648		
A_03	76.31	50.09	0.656		
A_04	76.09	48.39	0.636		
A_05	75.73	47.42	0.626		
A_06	76.22	49.19	0.645		
B_01	75.21	45.98	0.611		
B_02	75.00	45.64	0.609		
B_03	75.22	46.31	0.616		
B_04	75.15	47.04	0.626		
B_05	75.07	45.71	0.609		
B_06	75.15	46.00	0.612		
C_01	74.92	45.11	0.602		
C_02	74.89	44.92	0.600		
C_03	74.90	45.83	0.612		
C_04	74.53	46.72	0.627		
C_05	75.33	45.75	0.607		
C_06	75.01	45.58	0.608		

A.1.2 True density test

Equipment:

Micromeritics®, AccuPyc II 1340 V3.00

Analysis Gas	Helium
Sample Mass	2.8210 g
Temperature	22.55 °C
Expansion Volume	8.4487 cm³
Cell Volume	11.1871 cm³
Number of Purges	10

Equilib. Rate	0.005 psig/min
Analysis Start	08.07.2020 8:33:34
Analysis End	08.07.2020 15:36:40
Reported	08.07.2020 15:36:40
Chamber Insert	None
Sample	I202_A25

Summary report:

Sample Volume	
Average	2.0354 cm³
Deviation	0.0513 cm³

Sample Density	
Average	1.3862 g/cm³
Deviation	0.0346 g/cm³

Source recorded data:

Cycle	Volume (cm³)	P2 Pressure Deviation (psig)	Density (g/cm³)	Volume Deviation (cm³)	Temperature (°C)	Porosity* (%)
1	2.0238	-0.020	1.3939	-0.0116	22.02	28.26
2	2.0222	-0.004	1.3950	-0.0132	22.23	28.31
3	1.9968	0.002	1.4128	-0.0387	22.35	29.22

4	2.0557	-0.005	1.3723	0.0202	22.53	27.13
5	2.0194	-0.004	1.3969	-0.0160	22.59	28.41
6	2.0353	0.021	1.3861	-0.0002	22.67	27.85
7	2.0273	-0.009	1.3915	-0.0081	22.74	28.14
8	2.0090	0.023	1.4042	-0.0264	22.77	28.78
9	2.0994	-0.034	1.3437	0.0640	22.78	25.58
10	2.0655	0.030	1.3658	0.0300	22.79	26.78
Average	2.0354		1.3862			
Deviation	0.0513		0.0346			
*Calculated from envelope density						

A.1.3 Sorption test

Summary report:

Adsorption

	Group (*x*)	A		B		C	
Condition	Specimen number	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]
23°C/50%	I202_*x*26	6.23	6.17	6.31	6.38	6.31	6.28
	I202_*x*27	6.20		6.43		6.26	
	I202_*x*28	6.07		6.39		6.29	
23°C/65%	I202_*x*13	8.29	8.32	8.46	8.46	8.74	8.70
	I202_*x*14	8.34		8.44		8.66	
	I202_*x*15	8.33		8.49		8.70	
23°C/80%	I202_*x*16	12.09	12.05	11.57	11.78	12.82	12.61
	I202_*x*17	11.66		12.16		12.81	
	I202_*x*18	12.39		11.61		12.22	
23°C/93%	I202_*x*19	18.43	17.89	18.00	17.75	18.43	18.79
	I202_*x*20	17.71		16.59		18.84	
	I202_*x*21	17.52		18.65		19.08	
23°C/97%	I202_*x*22	24.83	24.05	23.03	23.31	25.16	23.82
	I202_*x*23	23.62		24.51		23.53	
	I202_*x*24	23.69		22.39		22.76	

Desorption

	Group (*x*)	A		B		C	
Climate condition	Specimen number	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]
23°C/50%	I202_*x*26D	9.22	9.10	8.91	8.84	8.52	8.59
	I202_*x*27D	8.99		8.79		8.65	
	I202_*x*28D	9.10		8.80		8.61	
23°C/65%	I202_*x*13D	12.09	12.05	11.66	11.55	11.38	11.32
	I202_*x*14D	12.06		11.44		11.24	
	I202_*x*15D	11.99		11.54		11.33	
23°C/80%	I202_*x*16D	15.98	15.93	15.76	15.60	15.89	15.58
	I202_*x*17D	15.88		15.38		15.30	
	I202_*x*18D	15.92		15.66		15.54	

Source recorded data:
Adsorption

Climate condition	Specimen number	Glass empty	Glass dry specimen	Glass + wet specimen	Dry mass (before adsorption)	Wet mass	Moisture mass	MC	MC average
[°C/%]		[g]	[g]	[g]	[g]	[g]	[g]	[M.-%]	[M.-%]
23°C/50%	I202_A26	0	-	-	20.428	21.700	1.272	6.23	6.17
	I202_A27	0	-	-	17.052	18.110	1.058	6.20	
	I202_A28	0	-	-	18.355	19.470	1.115	6.07	
23°C/65%	I202_A13	73.490	92.790	94.390	19.300	20.900	1.600	8.29	8.32
	I202_A14	75.160	95.430	97.120	20.270	21.960	1.690	8.34	
	I202_A15	70.720	92.670	94.499	21.950	23.779	1.829	8.33	
23°C/80%	I202_A16	70.930	92.270	94.850	21.340	23.920	2.580	12.09	12.05
	I202_A17	76.440	97.020	99.420	20.580	22.980	2.400	11.66	
	I202_A18	76.280	96.940	99.500	20.660	23.220	2.560	12.39	
23°C/93%	I202_A19	88.740	109.300	113.090	20.560	24.350	3.790	18.43	17.89
	I202_A20	93.110	113.610	117.240	20.500	24.130	3.630	17.71	
	I202_A21	85.700	104.480	107.770	18.780	22.070	3.290	17.52	
23°C/97%	I202_A22	103.690	123.140	127.970	19.450	24.280	4.830	24.83	24.05
	I202_A23	91.560	110.740	115.270	19.180	23.710	4.530	23.62	
	I202_A24	93.410	112.320	116.800	18.910	23.390	4.480	23.69	
23°C/50%	I202_B26	0	-	-	20.035	21.300	1.265	6.31	6.38
	I202_B27	0	-	-	21.461	22.840	1.379	6.43	
	I202_B28	0	-	-	21.102	22.450	1.348	6.39	
23°C/65%	I202_B13	74.560	94.670	96.372	20.110	21.812	1.702	8.46	8.46
	I202_B14	76.200	96.780	98.517	20.580	22.317	1.737	8.44	
	I202_B15	71.810	91.250	92.900	19.440	21.090	1.650	8.49	
23°C/80%	I202_B16	71.040	89.970	92.160	18.930	21.120	2.190	11.57	11.78

	I202_B17	72.710	92.110	94.470	19.400	21.760	2.360	12.16	
	I202_B18	68.780	88.410	90.690	19.630	21.910	2.280	11.61	
23°C/93%	I202_B19	91.550	110.720	114.170	19.170	22.620	3.450	18.00	17.75
	I202_B20	85.060	104.470	107.690	19.410	22.630	3.220	16.59	
	I202_B21	92.100	110.220	113.600	18.120	21.500	3.380	18.65	
23°C/97%	I202_B22	92.530	110.770	114.970	18.240	22.440	4.200	23.03	23.31
	I202_B23	83.090	103.980	109.100	20.890	26.010	5.120	24.51	
	I202_B24	79.550	97.730	101.800	18.180	22.250	4.070	22.39	
23°C/50%	I202_C26	0	-	-	20.554	21.850	1.296	6.31	6.28
	I202_C27	0	-	-	19.123	20.320	1.197	6.26	
	I202_C28	0	-	-	20.021	21.280	1.259	6.29	
23°C/65%	I202_C13	70.460	89.050	90.674	18.590	20.214	1.624	8.74	8.70
	I202_C14	73.740	93.770	95.504	20.030	21.764	1.734	8.66	
	I202_C15	73.310	91.710	93.310	18.400	20.000	1.600	8.70	
23°C/80%	I202_C16	75.020	94.060	96.500	19.040	21.480	2.440	12.82	12.61
	I202_C17	71.950	90.920	93.350	18.970	21.400	2.430	12.81	
	I202_C18	76.330	95.320	97.640	18.990	21.310	2.320	12.22	
23°C/93%	I202_C19	97.250	115.480	118.840	18.230	21.590	3.360	18.43	18.79
	I202_C20	89.900	109.800	113.550	19.900	23.650	3.750	18.84	
	I202_C21	89.240	107.370	110.830	18.130	21.590	3.460	19.08	
23°C/97%	I202_C22	86.510	104.710	109.290	18.200	22.780	4.580	25.16	23.82
	I202_C23	87.330	106.710	111.270	19.380	23.940	4.560	23.53	
	I202_C24	87.310	105.500	109.640	18.190	22.330	4.140	22.76	

Desorption

Climate condition	Specimen number	Glass empty	Dry mass (before de-sorption)	Wet mass after satu-ration	Dry mass (after de-sorption)	Wet mass	Moisture mass	MC	MC aver-age
[°C/%]		[g]	[g]	[g]	[g]	[g]	[g]	[M.-%]	[M.-%]
23°C/50%	I202_A26D	*0*	18.828	36.130	17.580	19.200	1.620	9.22	9.10
	I202_A27D	*0*	20.981	38.252	19.524	21.280	1.756	8.99	
	I202_A28D	*0*	19.761	34.654	18.662	20.360	1.698	9.10	
23°C/65%	I202_A13D	*0*	18.716	34.768	17.472	19.584	2.112	12.09	12.05
	I202_A14D	*0*	19.055	35.021	17.568	19.687	2.119	12.06	
	I202_A15D	*0*	20.687	36.596	19.288	21.601	2.313	11.99	
23°C/80%	I202_A16D	*0*	21.624	39.286	20.375	23.630	3.255	15.98	15.93
	I202_A17D	*0*	22.591	40.434	20.901	24.220	3.319	15.88	
	I202_A18D	*0*	19.677	37.156	18.461	21.400	2.939	15.92	
23°C/50%	I202_B26D	*0*	19.300	33.791	18.501	20.150	1.649	8.91	8.84
	I202_B27D	*0*	20.336	34.061	19.560	21.280	1.720	8.79	
	I202_B28D	*0*	19.652	33.943	18.796	20.450	1.654	8.80	
23°C/65%	I202_B13D	*0*	22.602	37.068	21.851	24.399	2.548	11.66	11.55
	I202_B14D	*0*	19.806	33.770	19.110	21.296	2.186	11.44	

	I202_B15D	*0*	20.388	34.478	19.579	21.839	2.260	11.54	
23°C/80%	I202_B16D	*0*	20.092	34.321	19.281	22.320	3.039	15.76	15.60
	I202_B17D	*0*	21.255	35.701	20.524	23.680	3.156	15.38	
	I202_B18D	*0*	20.446	34.490	19.609	22.680	3.071	15.66	
23°C/50%	I202_C26D	*0*	20.019	34.197	19.435	21.090	1.655	8.52	8.59
	I202_C27D	*0*	20.861	33.927	20.212	21.960	1.748	8.65	
	I202_C28D	*0*	20.523	35.337	19.833	21.540	1.707	8.61	
23°C/65%	I202_C13D	*0*	17.843	34.073	17.150	19.102	1.952	11.38	11.32
	I202_C14D	*0*	21.835	35.220	21.253	23.642	2.389	11.24	
	I202_C15D	*0*	20.141	34.985	19.475	21.681	2.206	11.33	
23°C/80%	I202_C16D	*0*	21.341	36.398	20.338	23.570	3.232	15.89	15.58
	I202_C17D	*0*	21.167	34.758	20.520	23.660	3.140	15.30	
	I202_C18D	*0*	21.463	35.948	20.659	23.870	3.211	15.54	

A.1.4 Water immersion test

Summary report:

Specimen number	*u*	*w*	Dimension change*			Volume expansion rate	Corrected *w*
	[%]	[kg/m^3]	width	length	thickness	[%]	[kg/m^3]
I202_A1	90.71	563.30	103.57%	102.69%	100.23%	107.03	526.32
I202_A2			104.29%	103.20%	100.23%		
I202_A3			103.70%	102.61%	100.19%		
I202_B1	81.76	507.75	103.38%	100.28%	103.35%	106.97	474.69
I202_B2			103.21%	100.20%	103.14%		
I202_B3			103.29%	100.28%	103.41%		
I202_C1	91.43	567.76	102.99%	100.25%	105.46%	108.99	520.94
I202_C2			102.86%	100.35%	105.57%		
I202_C3			102.82%	100.31%	105.79%		

*Note: For sample A, the width, length and thickness dimension change directions correspond to the tangential, radial and longitudinal directions, respectively; For sample B, the width, length and thickness dimension change directions correspond to the tangential, longitudinal and radial directions, respectively; For sample C, the width, length and thickness dimension change directions correspond to the radial, longitudinal and tangential directions, respectively

Source recorded data:

Specimen number	dry mass	mass	u	width	length	thickness
	[g]	[g]	[%]	[mm]	[mm]	[mm]
I202_A1	191.465		0.00	98.829	99.083	29.884
I202_A2	192.958		0.00	98.861	99.331	29.978
I202_A3	192.07		0.00	98.708	99.15	29.873
I202_B1	195.753		0.00	98.767	99.71	29.901
I202_B2	191.375		0.00	98.788	99.736	29.92
I202_B3	196.492		0.00	98.861	99.647	29.912
I202_C1	184.749		0.00	98.844	99.709	29.731
I202_C2	184.792		0.00	98.831	99.686	29.717
I202_C3	180.156		0.00	98.83	99.707	29.714
I202_A1		366.439	91.39	102.355	101.748	29.952
I202_A2		367.383	90.40	103.105	102.513	30.047

I202_A3		365.588	90.34	102.357	101.742	29.93
I202_B1		353.224	80.44	102.107	99.985	30.902
I202_B2		350.26	83.02	101.955	99.938	30.858
I202_B3		357.268	81.82	102.112	99.927	30.932
I202_C1		352.65	90.88	101.803	99.963	31.353
I202_C2		351.185	90.04	101.655	100.032	31.372
I202_C3		348.341	93.36	101.618	100.012	31.435

A.1.5 Capillary absorption test

Summary report:

Specimen number	W-Wert [kg/(m² √h)]	W-Wert average [kg/(m² √h)]	W-wert deviation [kg/(m² √h)]
I202_A7W	1.31	1.36	+/- 0.05
I202_A8W	1.41		
I202_A9W	1.37		
I202_B7W	0.13	0.13	+/- 0.01
I202_B8W	0.13		
I202_B9W	0.11		
I202_C7W	0.15	0.14	+/- 0.01
I202_C8W	0.13		
I202_C9W	0.15		

Source recorded data:

Date	I202_A7W		I202_A8W		I202_A9W	
	Time	Mass [g]	Time	Mass [g]	Time	Mass [g]
08.06.2020	10.00.02	220.4	10.00.11	217.7	10.00.20	215.0
08.06.2020	10.01.16	222.3	10.01.28	219.6	10.01.42	216.9
08.06.2020	10.05.24	224.7	10.06.05	221.2	10.06.26	218.6
08.06.2020	10.10.04	225.7	10.10.30	222.2	10.10.53	219.6
08.06.2020	10.15.08	226.6	10.15.32	223.1	10.15.56	220.4
08.06.2020	10.20.03	227.3	10.20.28	223.7	10.20.53	221.0
08.06.2020	10.30.02	228.5	10.30.26	224.7	10.30.50	222.0
08.06.2020	10.45.01	230.1	10.45.32	226.0	10.45.57	223.2
08.06.2020	11.00.02	231.6	11.00.33	227.0	11.01.02	224.3
08.06.2020	12.00.08	236.6	12.00.36	230.7	12.01.02	227.9
08.06.2020	13.00.07	240.8	13.00.36	234.6	13.01.08	231.7
08.06.2020	14.00.09	244.7	14.00.43	238.1	14.01.17	235.2
08.06.2020	15.00.06	248.0	15.00.35	241.3	15.01.06	238.4
08.06.2020	16.00.05	250.8	16.00.42	244.2	16.01.12	241.3
08.06.2020	17.00.04	253.2	17.00.36	246.9	17.01.00	243.9
09.06.2020	10.00.07	270.7	10.00.35	272.5	10.01.03	268.8

Date	I202_B7W		I202_B8W		I202_B9W	
	Time	Mass [g]	Time	Mass [g]	Time	Mass [g]
08.06.2020	10.03.01	220.7	10.03.18	217.3	10.03.28	221.2
08.06.2020	10.04.12	220.8	10.04.39	217.5	10.05.05	221.3
08.06.2020	10.08.04	220.9	10.08.28	217.6	10.08.51	221.4
08.06.2020	10.13.04	221.0	10.13.28	217.7	10.13.52	221.4
08.06.2020	10.18.01	221.1	10.18.25	217.8	10.18.48	221.5

08.06.2020	10.23.03	221.2	10.23.27	217.8	10.23.51	221.6
08.06.2020	10.33.07	221.3	10.33.34	218.0	10.34.03	221.8
08.06.2020	10.48.20	221.5	10.48.43	218.1	10.49.07	221.9
08.06.2020	11.03.03	221.6	11.03.28	218.2	11.03.57	222.0
08.06.2020	12.03.02	222.0	12.03.27	218.6	12.03.55	222.3
08.06.2020	13.03.04	222.3	13.03.33	218.9	13.04.05	222.6
08.06.2020	14.03.07	222.5	14.03.34	219.1	14.05.38	222.7
08.06.2020	15.03.04	222.8	15.04.14	219.4	15.05.16	222.9
08.06.2020	16.03.02	223.0	16.03.27	219.6	16.03.51	223.1
08.06.2020	17.03.01	223.2	17.03.24	219.8	17.03.49	223.3
09.06.2020	10.03.04	225.8	10.03.32	222.4	10.04.01	225.4

Date	I202_C7W		I202_C8W		I202_C9W	
	Time	Mass [g]	Time	Mass [g]	Time	Mass [g]
9.6.2020	10.10.01	213.3	10.10.15	210.6	10.10.28	208.5
9.6.2020	10.11.05	213.6	10.11.25	210.8	10.11.43	208.7
9.6.2020	10.15.11	213.7	10.15.30	210.9	10.15.48	208.9
9.6.2020	10.20.03	213.8	10.20.23	211.0	10.20.45	209.0
9.6.2020	10.25.02	213.9	10.25.23	211.1	10.25.56	209.1
9.6.2020	10.30.04	214.0	10.30.26	211.2	10.30.46	209.2
9.6.2020	10.40.01	214.1	10.40.25	211.3	10.40.48	209.3
9.6.2020	10.55.03	214.3	10.55.28	211.4	10.55.48	209.4
9.6.2020	11.10.07	214.4	11.10.32	211.5	11.10.55	209.6
9.6.2020	12.10.03	214.8	12.10.28	211.9	12.10.49	210.0
9.6.2020	13.10.05	215.2	13.10.42	212.1	13.11.08	210.4
9.6.2020	14.10.07	215.5	14.10.31	212.4	14.10.59	210.6
9.6.2020	15.10.04	215.7	15.10.31	212.7	15.10.59	210.8
9.6.2020	16.09.59	215.9	16.10.21	213.0	16.10.49	211.1
9.6.2020	17.10.02	216.1	17.10.29	213.2	17.10.53	211.3
10.6.2020	10.10.08	219.0	10.10.45	215.7	10.11.17	214.1

Specimen information:

Probe	I202_A7W		I202_A8W		I202_A9W	
Saugfläche	0.0078 m²	78.32 cm²	0.0079 m²	79.21 cm²	0.0080 m²	80.10 cm²
Volumen	0.000301 m³	301.33 cm³	0.000300 m³	300.06 cm³	0.000299 m³	298.89 cm³
Trockenmasse	0.208 kg	207.530 g	0.207 kg	206.530 g	0.204 kg	204.300 g
Rohdichte	688.712 kg/m³	0.689 g/cm³	688.296 kg/m³	0.688 g/cm³	683.530 kg/m³	0.684 g/cm³
Anfangsmasse	0.220 kg	220.400 g	0.218 kg	217.700 g	0.215 kg	215.000 g
Endmasse	0.271 kg	270.700 g	0.273 kg	272.500 g	0.269 kg	268.800 g
Delta-Masse	0.050 kg	50.300 g	0.055 kg	54.800 g	0.054 kg	53.800 g
Anfangszeit	08.06.2020 10:00:02		08.06.2020 10:00:11		08.06.2020 10:00:20	
Endzeit	09.06.2020 10:00:07		09.06.2020 10:00:35		09.06.2020 10:01:03	
√Delta-Zeit	4.899√h		4.900√h		4.900√h	
Länge ohne Paraffin: mit Paraffin :	100.16 mm 88.00 mm		100.04 mm 89.00 mm		99.95 mm 89.00 mm	
Breite ohne Paraffin: mit Paraffin :	100.35 mm 89.00 mm		100.08 mm 89.00 mm		100.08 mm 90.00 mm	
Dicke	29.98 mm		29.97 mm		29.88 mm	

Probe	I202_B7W		I202_B8W		I202_B9W	
Saugfläche	0.0078 m²	78.32 cm²	0.0077 m²	77.44 cm²	0.0079 m²	79.21 cm²
Volumen	0.000303 m³	302.57 cm³	0.000303 m³	302.79 cm³	0.000302 m³	301.87 cm³
Trockenmasse	0.211 kg	211.260 g	0.208 kg	207.870 g	0.211 kg	211.400 g
Rohdichte	698.226 kg/m³	0.698 g/cm³	686.515 kg/m³	0.687 g/cm³	700.310 kg/m³	0.700 g/cm³
Anfangsmasse	0.221 kg	220.700 g	0.217 kg	217.300 g	0.221 kg	221.200 g
Endmasse	0.226 kg	225.800 g	0.222 kg	222.400 g	0.225 kg	225.400 g
Delta-Masse	0.005 kg	5.100 g	0.005 kg	5.100 g	0.004 kg	4.200 g
Anfangszeit	08.06.2020 10:03:01		08.06.2020 10:03:18		08.06.2020 10:03:28	
Endzeit	09.06.2020 10:03:04		09.06.2020 10:03:32		09.06.2020 10:04:01	
√Delta-Zeit	4.899√h		4.899√h		4.900√h	
Länge ohne Paraffin: mit Paraffin :	100.03 mm 89.00 mm		100.18 mm 88.00 mm		100.14 mm 89.00 mm	
Breite ohne Paraffin: mit Paraffin :	99.86 mm 88.00 mm		99.85 mm 88.00 mm		99.75 mm 89.00 mm	
Dicke	30.29 mm		30.27 mm		30.22 mm	

Probe	I202_C7W		I202_C8W		I202_C9W	
Saugfläche	0.0077 m²	77.44 cm²	0.0077 m²	77.44 cm²	0.0077 m²	76.56 cm²
Volumen	0.000301 m³	301.08 cm³	0.000301 m³	301.02 cm³	0.000302 m³	301.62 cm³
Trockenmasse	0.205 kg	205.240 g	0.202 kg	201.680 g	0.200 kg	200.050 g
Rohdichte	681.684 kg/m³	0.682 g/cm³	669.994 kg/m³	0.670 g/cm³	663.254 kg/m³	0.663 g/cm³
Anfangsmasse	0.213 kg	213.300 g	0.211 kg	210.600 g	0.208 kg	208.500 g
Endmasse	0.219 kg	219.000 g	0.216 kg	215.700 g	0.214 kg	214.100 g
Delta-Masse	0.006 kg	5.700 g	0.005 kg	5.100 g	0.006 kg	5.600 g
Anfangszeit	09.06.2020 10:10:01		09.06.2020 10:10:15		09.06.2020 10:10:28	
Endzeit	10.06.2020 10:10:08		10.06.2020 10:10:45		10.06.2020 10:11:17	
√Delta-Zeit	4.899√h		4.900√h		4.900√h	
Länge ohne Paraffin: mit Paraffin :	99.99 mm 88.00 mm		100.00 mm 88.00 mm		100.04 mm 88.00 mm	
Breite ohne Paraffin: mit Paraffin :	99.87 mm 88.00 mm		99.84 mm 88.00 mm		99.90 mm 87.00 mm	
Dicke	30.15 mm		30.15 mm		30.18 mm	

A.1.6 Water vapor transmission test

"Messergebnisse der einzelnen Proben", local $\delta_a = 2.12072E^{-10}$ kg/(m·s·Pa)

Condition	Specimen number.	μ [-]			δ [kg/(m·s·Pa)]		
		value	average	deviation	value	average	deviation
23°C - 3%/50%	I202_A1T	25.84	27.39	+/- 2.31	8.206E-12	7.776E-12	+/- 5.748E-13
	I202_A2T	30.05			7.056E-12		
	I202_A3T	26.29			8.065E-12		
23°C - 33%/75%	I202_A31	23.43	23.52	+/- 0.42	9.050E-12	9.018E-12	+/- 1.580E-13
	I202_A32	23.15			9.160E-12		
	I202_A33	23.98			8.844E-12		
23°C - 93%/50%	I202_A4F	15.56	15.67	+/- 0.16	1.363E-11	1.353E-11	+/- 1.247E-13
	I202_A5F	15.85			1.338E-11		

	I202_A6F	15.61			1.358E-11		
23°C - 93%/80%	I202_A34	8.81	9.80	+/- 0.75	2.407E-11	2.177E-11	+/- 1.750E-12
	I202_A35	10.31			2.057E-11		
	I202_A36	10.27			2.066E-11		
23°C - 3%/50%	I202_B1T	1227.43	1148.67	+/- 148.93	1.728E-13	1.869E-13	+/- 2.315E-14
	I202_B2T	976.89			2.171E-13		
	I202_B3T	1241.69			1.708E-13		
23°C - 33%/75%	I202_B31	371.57	449.20	+/- 77.29	5.708E-13	4.818E-13	+/- 8.385E-14
	I202_B32	449.89			4.714E-13		
	I202_B33	526.15			4.031E-13		
23°C - 93%/50%	I202_B4F	155.54	139.45	+/- 28.97	1.364E-12	1.572E-12	+/- 3.241E-13
	I202_B5F	106.01			2.001E-12		
	I202_B6F	156.82			1.352E-12		
23°C - 93%/80%	I202_B34	49.98	52.18	+/- 2.99	4.243E-12	4.075E-12	+/- 2.265E-13
	I202_B35	50.61			4.191E-12		
	I202_B36	55.96			3.790E-12		
23°C - 3%/50%	I202_C1T	979.26	1392.83	+/- 358.20	2.165E-13	1.606E-13	+/- 4.219E-14
	I202_C2T	1604.54			1.322E-13		
	I202_C3T	1594.69			1.330E-13		
23°C - 33%/75%	I202_C31	355.32	343.78	+/- 12.35	5.968E-13	6.174E-13	+/- 2.230E-14
	I202_C32	345.40			6.140E-13		
	I202_C33	330.62			6.414E-13		
23°C - 93%/50%	I202_C4F	84.07	80.90	+/- 5.05	2.522E-12	2.628E-12	+/- 1.512E-13
	I202_C5F	75.07			2.825E-12		
	I202_C6F	83.56			2.538E-12		
23°C - 93%/80%	I202_C34	34.63	33.25	+/- 1.06	6.123E-12	6.382E-12	+/- 1.990E-13
	I202_C35	32.52			6.521E-12		
	I202_C36	32.61			6.503E-12		

A.1.7 Drying test:

Point	I202_A10X		I202_A11X		I202_A12X	
	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]
1	14.14%	46.38	14.61%	47.04	14.32%	33.61
2	13.76%	16.49	14.20%	18.08	13.98%	14.89
3	13.44%	17.95	13.84%	19.94	13.69%	15.96
4	12.40%	15.25	12.71%	16.49	12.69%	14.89
5	12.16%	10.64	12.47%	10.64	12.47%	9.57
6	12.00%	8.64	12.28%	10.64	12.30%	9.31
7	11.38%	8.48	11.62%	9.14	11.68%	8.64
8	11.25%	7.31	11.47%	7.98	11.53%	7.98
9	11.14%	5.98	11.37%	5.98	11.41%	6.65
10	10.79%	4.82	10.96%	5.65	11.04%	5.15
11	10.72%	3.99	10.87%	4.65	10.95%	5.32

12	10.65%	3.99	10.80%	3.99	10.87%	3.99
13	10.42%	3.16	10.55%	3.49	10.61%	3.66
14	10.37%	2.66	10.49%	3.32	10.56%	2.66
15	10.32%	2.66	10.45%	1.99	10.52%	2.66
16	9.92%	1.37	9.99%	1.58	10.05%	1.62
17					10.01%	0.89
18					9.95%	0.89

Point	I202_B10X		I202_B11X		I202_B12X	
	Moisture content	Mass change rate [g/m^{2}d]	Moisture content	Mass change rate [g/m^{2}d]	Moisture content	Mass change rate [g/m^{2}d]
1	14.22%	4.77	14.63%	4.39	14.36%	4.14
2	13.63%	4.12	14.09%	3.95	13.83%	3.52
3	13.26%	3.43	13.73%	3.43	13.48%	3.10
4	12.89%	3.32	13.38%	3.32	13.13%	2.99
5	12.54%	3.08	13.03%	3.19	12.80%	2.77
6	11.84%	2.41	12.30%	2.62	12.10%	2.29
7	11.57%	1.95	12.01%	2.14	11.82%	1.89
8	11.38%	1.70	11.80%	1.99	11.63%	1.66
9	11.22%	1.44	11.61%	1.77	11.44%	1.66
10	11.04%	1.53	11.41%	1.74	11.25%	1.53
11	10.67%	1.25	11.00%	1.50	10.87%	1.25
12	10.53%	1.06	10.84%	1.15	10.70%	1.15
13	10.43%	0.89	10.73%	1.11	10.60%	0.89
14	10.32%	1.00	10.62%	1.00	10.50%	0.89
15	10.25%	0.59	10.51%	0.98	10.39%	0.79
16	10.04%	0.73	10.27%	0.86	10.19%	0.69
17	9.97%	0.51	10.19%	0.60	10.10%	0.60
18	9.97%	0.51	10.12%	0.66	10.04%	0.55
19			10.06%	0.55	9.97%	0.55
20			9.99%	0.57		

Point	I202_C10X		I202_C11X		I202_C12X	
	Moisture content	Mass change rate [g/m^{2}d]	Moisture content	Mass change rate [g/m^{2}d]	Moisture content	Mass change rate [g/m^{2}d]
1	14.27%	4.99	14.47%	5.24	14.58%	5.32
2	13.71%	4.12	13.86%	4.37	13.99%	4.70
3	13.33%	3.55	13.45%	3.88	13.50%	4.15
4	12.97%	3.58	13.07%	3.70	12.49%	3.28
5	12.62%	2.95	12.70%	3.05	12.12%	2.49
6	11.90%	2.57	11.95%	2.66	11.87%	2.22
7	11.61%	2.14	11.64%	2.23	11.65%	1.97
8	11.41%	1.88	11.44%	1.88	11.41%	1.87
9	11.24%	1.66	11.26%	1.66	10.97%	1.48
10	11.06%	1.60	11.07%	1.70	10.79%	1.20
11	10.67%	1.37	10.68%	1.37	10.68%	1.00
12	10.53%	1.03	10.54%	1.03	10.56%	1.00
13	10.43%	1.00	10.44%	0.89	10.43%	1.06
14	10.33%	0.89	10.34%	1.00	10.20%	0.75
15	10.21%	1.13	10.23%	0.92	10.10%	0.69
16	10.00%	0.75	9.99%	0.83	10.03%	0.66
17	9.91%	0.62			9.96%	0.55
18						

A.1.8 Thermal analysis

Equipment:

NETZSCH DSC 214 Polyma DSC21400A-0318-L

Reference	----, 0 mg
Calibration/temperature calibration	applied
Sensitivity	applied
Type of Crucible	Pan Al, closed

Sample holder / thermocouple	DSC 214 Corona sensor / E
Atmosphere	N2, 40.0ml/min / N2, 60.0ml/min
Range	-20°C/3.0(K/min)/40°C
Calibration/measurement range	00/5000 µV

Summary report:

Sample information	
Sample	A1
Sample Mass	2.64 mg
Date/Time	2020/11/12 15:41:28
Test result C_p/(J/(g·K))	
Range: -15°C/3.0(K/min)/40°C	
Max	2.7202
Min	0.1497
Mean	1.4252
Range: 10°C/3.0(K/min)/30°C	
Max	2.2330
Min	1.3233
Mean	1.7548

Sample information	
Sample	A2
Sample Mass	2.90 mg
Date/Time	2020/11/12 16:06:03
Test result C_p/(J/(g·K))	
Range: -15°C/3.0(K/min)/40°C	
Max	2.9252
Min	0.0095
Mean	1.4360
Range: 10°C/3.0(K/min)/30°C	
Max	2.3279
Min	1.3257
Mean	1.7977

Source recorded data:

A1

Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))
-20.0	-0.0840		-5.0	0.0447	0.6594	10.0	0.0988	1.5522	25.0	0.1385	1.9939
-19.9	-0.0860		-4.9	0.0451	0.5979	10.1	0.0987	1.4343	25.1	0.1389	1.8855
-19.8	-0.0837		-4.8	0.0455	0.6119	10.2	0.0985	1.4266	25.2	0.1394	1.8317
-19.7	-0.0803		-4.7	0.0459	0.6570	10.3	0.0984	1.4074	25.3	0.1398	2.0427
-19.6	-0.0762		-4.6	0.0463	0.7183	10.4	0.0982	1.3573	25.4	0.1403	2.1302
-19.5	-0.0717		-4.5	0.0467	0.7229	10.5	0.0980	1.3233	25.5	0.1407	2.0446
-19.4	-0.0671		-4.4	0.0472	0.7325	10.6	0.0979	1.3415	25.6	0.1412	2.0039
-19.3	-0.0624		-4.3	0.0476	0.7609	10.7	0.0977	1.4005	25.7	0.1416	1.9947
-19.2	-0.0576		-4.2	0.0480	0.7205	10.8	0.0976	1.3964	25.8	0.1420	1.9518
-19.1	-0.0529		-4.1	0.0484	0.7196	10.9	0.0975	1.3815	25.9	0.1424	1.9332
-19.0	-0.0482		-4.0	0.0488	0.7607	11.0	0.0975	1.4071	26.0	0.1428	1.9145
-18.9	-0.0436		-3.9	0.0492	0.7669	11.1	0.0975	1.4159	26.1	0.1432	1.9754
-18.8	-0.0393		-3.8	0.0496	0.7684	11.2	0.0976	1.3614	26.2	0.1436	2.0371
-18.7	-0.0351		-3.7	0.0499	0.7868	11.3	0.0977	1.3977	26.3	0.1440	2.0522
-18.6	-0.0312		-3.6	0.0502	0.7606	11.4	0.0978	1.4016	26.4	0.1443	2.0690
-18.5	-0.0275		-3.5	0.0505	0.7646	11.5	0.0980	1.3679	26.5	0.1447	2.0614
-18.4	-0.0241		-3.4	0.0507	0.7699	11.6	0.0982	1.3670	26.6	0.1450	2.0346
-18.3	-0.0210		-3.3	0.0510	0.7885	11.7	0.0985	1.3739	26.7	0.1454	2.0215
-18.2	-0.0182		-3.2	0.0512	0.7810	11.8	0.0988	1.3939	26.8	0.1457	2.0101
-18.1	-0.0157		-3.1	0.0515	0.7572	11.9	0.0991	1.4008	26.9	0.1461	2.0154

-18.0	-0.0135		-3.0	0.0517	0.7622	12.0	0.0994	1.4351	27.0	0.1464	2.0394
-17.9	-0.0116		-2.9	0.0520	0.7674	12.1	0.0998	1.4452	27.1	0.1468	2.0490
-17.8	-0.0100		-2.8	0.0522	0.8108	12.2	0.1001	1.4464	27.2	0.1471	2.0462
-17.7	-0.0085		-2.7	0.0525	0.7574	12.3	0.1005	1.4294	27.3	0.1475	1.9802
-17.6	-0.0072		-2.6	0.0527	0.8218	12.4	0.1009	1.4539	27.4	0.1478	1.9538
-17.5	-0.0061		-2.5	0.0530	0.8517	12.5	0.1013	1.4769	27.5	0.1481	2.1027
-17.4	-0.0052		-2.4	0.0533	0.7969	12.6	0.1016	1.4772	27.6	0.1485	2.1836
-17.3	-0.0043		-2.3	0.0536	0.6974	12.7	0.1020	1.4982	27.7	0.1488	2.1449
-17.2	-0.0036		-2.2	0.0539	0.7043	12.8	0.1023	1.4720	27.8	0.1490	2.0885
-17.1	-0.0029		-2.1	0.0543	0.8494	12.9	0.1027	1.3409	27.9	0.1493	2.0968
-17.0	-0.0023		-2.0	0.0546	0.8632	13.0	0.1031	1.3368	28.0	0.1495	2.1122
-16.9	-0.0017		-1.9	0.0549	0.8141	13.1	0.1034	1.4913	28.1	0.1497	2.0757
-16.8	-0.0012		-1.8	0.0553	0.8622	13.2	0.1038	1.5985	28.2	0.1499	2.0465
-16.7	-0.0007		-1.7	0.0556	0.8810	13.3	0.1041	1.6052	28.3	0.1501	2.0422
-16.6	-0.0002		-1.6	0.0560	0.8569	13.4	0.1045	1.5523	28.4	0.1503	2.0405
-16.5	0.0003		-1.5	0.0563	0.8333	13.5	0.1048	1.4770	28.5	0.1505	2.1291
-16.4	0.0008		-1.4	0.0567	0.7637	13.6	0.1052	1.5230	28.6	0.1507	2.2330
-16.3	0.0012		-1.3	0.0570	0.7455	13.7	0.1056	1.5650	28.7	0.1509	2.0308
-16.2	0.0017		-1.2	0.0573	0.8430	13.8	0.1059	1.5223	28.8	0.1512	2.0929
-16.1	0.0021		-1.1	0.0576	0.9127	13.9	0.1063	1.4504	28.9	0.1514	2.1850
-16.0	0.0025		-1.0	0.0579	0.9027	14.0	0.1067	1.4887	29.0	0.1517	2.0533
-15.9	0.0029		-0.9	0.0582	0.9178	14.1	0.1071	1.5118	29.1	0.1520	1.9943
-15.8	0.0033		-0.8	0.0585	0.8882	14.2	0.1075	1.4952	29.2	0.1524	2.0800
-15.7	0.0037		-0.7	0.0588	0.8862	14.3	0.1079	1.5292	29.3	0.1528	2.1195
-15.6	0.0041		-0.6	0.0591	0.9008	14.4	0.1083	1.5659	29.4	0.1532	2.1215
-15.5	0.0045		-0.5	0.0594	0.8733	14.5	0.1087	1.5197	29.5	0.1537	2.0737
-15.4	0.0049		-0.4	0.0597	0.8882	14.6	0.1091	1.4970	29.6	0.1541	2.0896
-15.3	0.0053		-0.3	0.0600	0.8838	14.7	0.1095	1.6040	29.7	0.1546	2.1289
-15.2	0.0057		-0.2	0.0604	0.9083	14.8	0.1099	1.6273	29.8	0.1550	2.1616
-15.1	0.0061		-0.1	0.0607	0.9136	14.9	0.1103	1.6064	29.9	0.1555	2.2024
-15.0	0.0065	0.1497	0.0	0.0611	0.8832	15.0	0.1106	1.6117	30.0	0.1559	2.2390
-14.9	0.0069	0.1497	0.1	0.0615	0.8787	15.1	0.1110	1.5845	30.1	0.1563	2.2839
-14.8	0.0074	0.1497	0.2	0.0619	0.9178	15.2	0.1114	1.5362	30.2	0.1567	2.2419
-14.7	0.0079	0.1497	0.3	0.0623	0.9031	15.3	0.1118	1.5400	30.3	0.1570	2.1912
-14.6	0.0084	0.1497	0.4	0.0627	0.8305	15.4	0.1122	1.5247	30.4	0.1573	2.1947
-14.5	0.0089	0.1497	0.5	0.0631	0.8807	15.5	0.1125	1.5752	30.5	0.1576	2.1575
-14.4	0.0094	0.1781	0.6	0.0635	0.9724	15.6	0.1129	1.6588	30.6	0.1578	2.0699
-14.3	0.0099	0.1960	0.7	0.0639	1.0226	15.7	0.1132	1.6566	30.7	0.1581	2.1437
-14.2	0.0105	0.2142	0.8	0.0643	1.0202	15.8	0.1135	1.6608	30.8	0.1583	2.1768
-14.1	0.0109	0.2231	0.9	0.0647	1.0137	15.9	0.1138	1.6601	30.9	0.1585	2.2567
-14.0	0.0114	0.2341	1.0	0.0651	1.0198	16.0	0.1141	1.6437	31.0	0.1588	2.2346
-13.9	0.0119	0.2120	1.1	0.0655	0.9887	16.1	0.1144	1.6952	31.1	0.1590	2.2121
-13.8	0.0123	0.1791	1.2	0.0658	0.9228	16.2	0.1147	1.6027	31.2	0.1592	2.2288
-13.7	0.0127	0.2117	1.3	0.0662	0.9301	16.3	0.1150	1.5668	31.3	0.1595	2.1617
-13.6	0.0130	0.2358	1.4	0.0665	0.9431	16.4	0.1153	1.8217	31.4	0.1597	2.1737
-13.5	0.0134	0.2903	1.5	0.0669	0.9460	16.5	0.1156	1.6428	31.5	0.1600	2.2808
-13.4	0.0137	0.2590	1.6	0.0672	0.9799	16.6	0.1159	1.4680	31.6	0.1602	2.3085
-13.3	0.0141	0.2069	1.7	0.0675	0.9755	16.7	0.1162	1.5987	31.7	0.1605	2.3017
-13.2	0.0144	0.1629	1.8	0.0679	1.0126	16.8	0.1166	1.6908	31.8	0.1608	2.2337
-13.1	0.0148	0.1614	1.9	0.0682	1.0211	16.9	0.1170	1.5308	31.9	0.1610	2.2271
-13.0	0.0151	0.1757	2.0	0.0685	1.0475	17.0	0.1174	1.5495	32.0	0.1612	2.2770
-12.9	0.0155	0.1933	2.1	0.0689	1.0502	17.1	0.1178	1.6775	32.1	0.1615	2.2778
-12.8	0.0159	0.2389	2.2	0.0692	1.0443	17.2	0.1182	1.7398	32.2	0.1617	2.3280
-12.7	0.0163	0.2846	2.3	0.0696	1.0226	17.3	0.1185	1.7673	32.3	0.1620	2.2979
-12.6	0.0167	0.2702	2.4	0.0700	1.0100	17.4	0.1189	1.7622	32.4	0.1622	2.2894
-12.5	0.0172	0.2581	2.5	0.0703	0.9985	17.5	0.1192	1.7667	32.5	0.1625	2.1461
-12.4	0.0176	0.2930	2.6	0.0708	1.0170	17.6	0.1194	1.7247	32.6	0.1627	2.1655
-12.3	0.0181	0.3375	2.7	0.0712	0.9945	17.7	0.1196	1.7240	32.7	0.1630	2.2607
-12.2	0.0185	0.3196	2.8	0.0716	1.0169	17.8	0.1198	1.7419	32.8	0.1633	2.2305
-12.1	0.0189	0.2911	2.9	0.0721	1.0836	17.9	0.1200	1.6948	32.9	0.1636	2.2447
-12.0	0.0193	0.3116	3.0	0.0726	1.0687	18.0	0.1201	1.6474	33.0	0.1640	2.2733
-11.9	0.0197	0.3689	3.1	0.0731	1.0537	18.1	0.1202	1.6898	33.1	0.1644	2.2809
-11.8	0.0201	0.3187	3.2	0.0737	1.0716	18.2	0.1203	1.6786	33.2	0.1647	2.3093
-11.7	0.0205	0.3179	3.3	0.0742	1.1037	18.3	0.1205	1.6661	33.3	0.1651	2.3097
-11.6	0.0208	0.2964	3.4	0.0747	1.0854	18.4	0.1207	1.6744	33.4	0.1654	2.2901

-11.5	0.0211	0.2987	3.5	0.0753	1.0562	18.5	0.1209	1.6798	33.5	0.1658	2.3125
-11.4	0.0215	0.3572	3.6	0.0758	1.0922	18.6	0.1211	1.6761	33.6	0.1661	2.3397
-11.3	0.0217	0.3432	3.7	0.0763	1.1461	18.7	0.1214	1.6884	33.7	0.1664	2.3464
-11.2	0.0220	0.3458	3.8	0.0768	1.1642	18.8	0.1217	1.7311	33.8	0.1666	2.2868
-11.1	0.0223	0.3588	3.9	0.0774	1.1556	18.9	0.1220	1.7481	33.9	0.1669	2.2564
-11.0	0.0225	0.4552	4.0	0.0779	1.1858	19.0	0.1223	1.7479	34.0	0.1671	2.4596
-10.9	0.0228	0.4752	4.1	0.0784	1.1574	19.1	0.1226	1.7525	34.1	0.1673	2.4342
-10.8	0.0230	0.3683	4.2	0.0790	1.1101	19.2	0.1229	1.7521	34.2	0.1675	2.2774
-10.7	0.0233	0.3366	4.3	0.0796	1.1268	19.3	0.1231	1.7969	34.3	0.1677	2.2908
-10.6	0.0236	0.3136	4.4	0.0802	1.1253	19.4	0.1233	1.8178	34.4	0.1680	2.3320
-10.5	0.0239	0.3312	4.5	0.0808	1.1086	19.5	0.1235	1.7437	34.5	0.1682	2.3144
-10.4	0.0242	0.3203	4.6	0.0814	1.0726	19.6	0.1237	1.6983	34.6	0.1685	2.2691
-10.3	0.0245	0.3502	4.7	0.0820	1.1519	19.7	0.1239	1.7321	34.7	0.1688	2.2745
-10.2	0.0249	0.3376	4.8	0.0827	1.1552	19.8	0.1240	1.7161	34.8	0.1692	2.3004
-10.1	0.0253	0.3518	4.9	0.0834	1.1258	19.9	0.1242	1.8670	34.9	0.1696	2.3686
-10.0	0.0258	0.3677	5.0	0.0840	1.1807	20.0	0.1243	1.8018	35.0	0.1700	2.4396
-9.9	0.0262	0.4147	5.1	0.0847	1.2314	20.1	0.1245	1.6487	35.1	0.1704	2.3214
-9.8	0.0267	0.4739	5.2	0.0853	1.2861	20.2	0.1247	1.6763	35.2	0.1708	2.2639
-9.7	0.0271	0.4934	5.3	0.0859	1.3233	20.3	0.1249	1.7515	35.3	0.1712	2.2785
-9.6	0.0276	0.4832	5.4	0.0865	1.3518	20.4	0.1252	1.7205	35.4	0.1716	2.3470
-9.5	0.0280	0.4902	5.5	0.0870	1.2932	20.5	0.1254	1.7198	35.5	0.1720	2.5876
-9.4	0.0284	0.4563	5.6	0.0875	1.2426	20.6	0.1257	1.7767	35.6	0.1724	2.6540
-9.3	0.0288	0.4394	5.7	0.0880	1.2566	20.7	0.1261	1.7535	35.7	0.1728	2.5397
-9.2	0.0292	0.4458	5.8	0.0885	1.2428	20.8	0.1264	1.6655	35.8	0.1731	2.5772
-9.1	0.0296	0.4477	5.9	0.0889	1.2612	20.9	0.1267	1.7512	35.9	0.1735	2.6465
-9.0	0.0299	0.4950	6.0	0.0893	1.3112	21.0	0.1271	1.8688	36.0	0.1738	2.5479
-8.9	0.0302	0.4577	6.1	0.0896	1.2774	21.1	0.1274	1.9276	36.1	0.1742	2.4307
-8.8	0.0306	0.4498	6.2	0.0900	1.2489	21.2	0.1276	1.8802	36.2	0.1745	2.4113
-8.7	0.0309	0.4689	6.3	0.0903	1.2915	21.3	0.1279	1.8197	36.3	0.1749	2.3697
-8.6	0.0312	0.5081	6.4	0.0906	1.2882	21.4	0.1281	1.8206	36.4	0.1754	2.3136
-8.5	0.0315	0.4939	6.5	0.0909	1.3292	21.5	0.1283	1.7908	36.5	0.1758	2.3206
-8.4	0.0318	0.5066	6.6	0.0912	1.3355	21.6	0.1284	1.7676	36.6	0.1763	2.3878
-8.3	0.0321	0.5142	6.7	0.0915	1.3412	21.7	0.1286	1.7855	36.7	0.1768	2.4062
-8.2	0.0324	0.5256	6.8	0.0919	1.3365	21.8	0.1288	1.7740	36.8	0.1773	2.3862
-8.1	0.0327	0.5309	6.9	0.0922	1.3168	21.9	0.1289	1.7248	36.9	0.1778	2.4055
-8.0	0.0330	0.4963	7.0	0.0925	1.3219	22.0	0.1291	1.7586	37.0	0.1783	2.3921
-7.9	0.0334	0.5116	7.1	0.0928	1.3199	22.1	0.1293	1.8382	37.1	0.1787	2.3301
-7.8	0.0337	0.5239	7.2	0.0931	1.3209	22.2	0.1296	1.8052	37.2	0.1790	2.4540
-7.7	0.0340	0.5007	7.3	0.0934	1.3495	22.3	0.1299	1.7730	37.3	0.1793	2.5736
-7.6	0.0343	0.4911	7.4	0.0938	1.3516	22.4	0.1302	1.8726	37.4	0.1795	2.5641
-7.5	0.0346	0.5279	7.5	0.0940	1.3556	22.5	0.1305	1.9101	37.5	0.1797	2.6064
-7.4	0.0350	0.5590	7.6	0.0943	1.3834	22.6	0.1309	1.8825	37.6	0.1797	2.6254
-7.3	0.0353	0.5770	7.7	0.0946	1.3715	22.7	0.1313	1.8294	37.7	0.1797	2.7202
-7.2	0.0356	0.5712	7.8	0.0948	1.3332	22.8	0.1317	1.8472	37.8	0.1796	2.5778
-7.1	0.0359	0.6234	7.9	0.0951	1.3941	22.9	0.1321	1.8604	37.9	0.1795	2.4174
-7.0	0.0362	0.6370	8.0	0.0953	1.6291	23.0	0.1325	1.8570	38.0	0.1795	2.4255
-6.9	0.0365	0.5674	8.1	0.0955	1.5611	23.1	0.1329	1.9100	38.1	0.1794	2.5253
-6.8	0.0369	0.5734	8.2	0.0957	1.2783	23.2	0.1332	1.8427	38.2	0.1795	2.4319
-6.7	0.0372	0.4515	8.3	0.0960	1.1529	23.3	0.1336	1.6414	38.3	0.1795	2.4012
-6.6	0.0376	0.4150	8.4	0.0962	1.2323	23.4	0.1340	1.7731	38.4	0.1797	2.2511
-6.5	0.0381	0.5950	8.5	0.0964	1.3033	23.5	0.1343	2.0268	38.5	0.1800	2.2265
-6.4	0.0385	0.6515	8.6	0.0967	1.3580	23.6	0.1346	2.0217	38.6	0.1803	2.4171
-6.3	0.0390	0.5810	8.7	0.0969	1.4705	23.7	0.1348	1.8995	38.7	0.1807	2.5533
-6.2	0.0395	0.5924	8.8	0.0972	1.4924	23.8	0.1351	1.9776	38.8	0.1811	2.6301
-6.1	0.0400	0.5823	8.9	0.0974	1.4606	23.9	0.1353	1.9420	38.9	0.1816	2.6757
-6.0	0.0405	0.5848	9.0	0.0977	1.4485	24.0	0.1355	1.8268	39.0	0.1820	2.6529
-5.9	0.0410	0.6588	9.1	0.0980	1.4729	24.1	0.1357	1.8261	39.1	0.1824	2.6529
-5.8	0.0414	0.6953	9.2	0.0982	1.4488	24.2	0.1359	1.8926	39.2	0.1829	2.6529
-5.7	0.0419	0.7018	9.3	0.0984	1.4234	24.3	0.1361	1.9092	39.3	0.1832	2.6529
-5.6	0.0423	0.6679	9.4	0.0986	1.4027	24.4	0.1364	1.8862	39.4	0.1836	2.6529
-5.5	0.0428	0.6293	9.5	0.0987	1.2971	24.5	0.1367	1.9016	39.5	0.1838	2.6529
-5.4	0.0432	0.7305	9.6	0.0988	1.3680	24.6	0.1370	1.9046	39.6	0.1840	
-5.3	0.0436	0.7048	9.7	0.0989	1.3502	24.7	0.1373	1.9259	39.7	0.1840	
-5.2	0.0439	0.6746	9.8	0.0989	1.4140	24.8	0.1377	1.9174	39.8	0.1839	
-5.1	0.0443	0.6560	9.9	0.0989	1.5383	24.9	0.1381	1.9154	39.9	0.1840	

A2

Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))
-20.0	-0.0907		-5.0	0.0430	0.6583	10.0	0.0971	1.5036	25.0	0.1440	2.0364
-19.9	-0.0897		-4.9	0.0434	0.5915	10.1	0.0973	1.4349	25.1	0.1445	1.9517
-19.8	-0.0865		-4.8	0.0439	0.5815	10.2	0.0975	1.3992	25.2	0.1449	1.9452
-19.7	-0.0824		-4.7	0.0444	0.6221	10.3	0.0976	1.3659	25.3	0.1454	2.1220
-19.6	-0.0780		-4.6	0.0449	0.6835	10.4	0.0977	1.3578	25.4	0.1458	2.1767
-19.5	-0.0734		-4.5	0.0454	0.6811	10.5	0.0979	1.3498	25.5	0.1462	2.1222
-19.4	-0.0687		-4.4	0.0460	0.7133	10.6	0.0980	1.3832	25.6	0.1466	2.0914
-19.3	-0.0641		-4.3	0.0465	0.6541	10.7	0.0982	1.3879	25.7	0.1470	2.0649
-19.2	-0.0595		-4.2	0.0471	0.5905	10.8	0.0983	1.3688	25.8	0.1474	2.0456
-19.1	-0.0550		-4.1	0.0476	0.6822	10.9	0.0985	1.3840	25.9	0.1478	2.0212
-19.0	-0.0505		-4.0	0.0481	0.8104	11.0	0.0987	1.4359	26.0	0.1482	2.0233
-18.9	-0.0462		-3.9	0.0486	0.8597	11.1	0.0990	1.4167	26.1	0.1486	2.0663
-18.8	-0.0422		-3.8	0.0490	0.8661	11.2	0.0992	1.4114	26.2	0.1489	2.0903
-18.7	-0.0384		-3.7	0.0494	0.8223	11.3	0.0995	1.4466	26.3	0.1493	2.0668
-18.6	-0.0348		-3.6	0.0498	0.7849	11.4	0.0998	1.4521	26.4	0.1496	2.0742
-18.5	-0.0315		-3.5	0.0501	0.7679	11.5	0.1000	1.4384	26.5	0.1500	2.0777
-18.4	-0.0285		-3.4	0.0504	0.7503	11.6	0.1003	1.4184	26.6	0.1503	2.0830
-18.3	-0.0257		-3.3	0.0507	0.7439	11.7	0.1006	1.4290	26.7	0.1506	2.1215
-18.2	-0.0232		-3.2	0.0509	0.7417	11.8	0.1008	1.4455	26.8	0.1509	2.2731
-18.1	-0.0210		-3.1	0.0512	0.7446	11.9	0.1011	1.4555	26.9	0.1512	2.2814
-18.0	-0.0191		-3.0	0.0514	0.7538	12.0	0.1013	1.4649	27.0	0.1516	2.0265
-17.9	-0.0175		-2.9	0.0517	0.7803	12.1	0.1016	1.4778	27.1	0.1519	1.9364
-17.8	-0.0160		-2.8	0.0520	0.7798	12.2	0.1018	1.4706	27.2	0.1522	2.0551
-17.7	-0.0147		-2.7	0.0523	0.7422	12.3	0.1020	1.4754	27.3	0.1525	2.0763
-17.6	-0.0136		-2.6	0.0526	0.8192	12.4	0.1022	1.4640	27.4	0.1528	2.0572
-17.5	-0.0127		-2.5	0.0529	0.8077	12.5	0.1024	1.5114	27.5	0.1531	2.1443
-17.4	-0.0118		-2.4	0.0533	0.7291	12.6	0.1026	1.4891	27.6	0.1533	2.2737
-17.3	-0.0111		-2.3	0.0537	0.7283	12.7	0.1028	1.4395	27.7	0.1536	2.2535
-17.2	-0.0104		-2.2	0.0540	0.8262	12.8	0.1030	1.4326	27.8	0.1539	2.1415
-17.1	-0.0097		-2.1	0.0544	0.8632	12.9	0.1032	1.3308	27.9	0.1542	2.1103
-17.0	-0.0091		-2.0	0.0548	0.8287	13.0	0.1035	1.3257	28.0	0.1544	2.2799
-16.9	-0.0085		-1.9	0.0552	0.8241	13.1	0.1037	1.4869	28.1	0.1547	2.2152
-16.8	-0.0079		-1.8	0.0556	0.8512	13.2	0.1040	1.6084	28.2	0.1549	2.0580
-16.7	-0.0074		-1.7	0.0559	0.8934	13.3	0.1043	1.6310	28.3	0.1552	2.0503
-16.6	-0.0068		-1.6	0.0563	0.8443	13.4	0.1045	1.5787	28.4	0.1555	2.0968
-16.5	-0.0063		-1.5	0.0566	0.8314	13.5	0.1048	1.5238	28.5	0.1558	2.1128
-16.4	-0.0058		-1.4	0.0569	0.8889	13.6	0.1051	1.5373	28.6	0.1562	2.1375
-16.3	-0.0053		-1.3	0.0572	0.8572	13.7	0.1055	1.5382	28.7	0.1565	2.1647
-16.2	-0.0048		-1.2	0.0575	0.8320	13.8	0.1058	1.4811	28.8	0.1569	2.2213
-16.1	-0.0043		-1.1	0.0578	0.7554	13.9	0.1061	1.4518	28.9	0.1573	2.2448
-16.0	-0.0039		-1.0	0.0581	0.7884	14.0	0.1064	1.4813	29.0	0.1576	2.2025
-15.9	-0.0035		-0.9	0.0584	0.9084	14.1	0.1068	1.4982	29.1	0.1580	2.1753
-15.8	-0.0031		-0.8	0.0587	0.9073	14.2	0.1071	1.4768	29.2	0.1584	2.2082
-15.7	-0.0027		-0.7	0.0590	0.9081	14.3	0.1075	1.5252	29.3	0.1587	2.2402
-15.6	-0.0023		-0.6	0.0594	0.9262	14.4	0.1079	1.5639	29.4	0.1591	2.2321
-15.5	-0.0020		-0.5	0.0597	0.9025	14.5	0.1083	1.5645	29.5	0.1594	2.2126
-15.4	-0.0016		-0.4	0.0601	0.9053	14.6	0.1087	1.5266	29.6	0.1598	2.1894
-15.3	-0.0012		-0.3	0.0605	0.8499	14.7	0.1091	1.5456	29.7	0.1601	2.1743
-15.2	-0.0008		-0.2	0.0609	0.8718	14.8	0.1095	1.5958	29.8	0.1604	2.3279
-15.1	-0.0004		-0.1	0.0613	0.9507	14.9	0.1099	1.5572	29.9	0.1607	2.3142
-15.0	0.0000	0.0432	0.0	0.0617	0.9433	15.0	0.1103	1.5604	30.0	0.1611	2.2130
-14.9	0.0005	0.0432	0.1	0.0621	0.8927	15.1	0.1108	1.5638	30.1	0.1614	2.2265
-14.8	0.0009	0.0432	0.2	0.0626	0.9017	15.2	0.1112	1.5622	30.2	0.1617	2.2122
-14.7	0.0014	0.0432	0.3	0.0630	0.9376	15.3	0.1116	1.5572	30.3	0.1621	2.1412
-14.6	0.0019	0.0432	0.4	0.0634	0.9466	15.4	0.1121	1.5620	30.4	0.1625	2.2018
-14.5	0.0024	0.0432	0.5	0.0639	0.9460	15.5	0.1125	1.5917	30.5	0.1628	2.2179
-14.4	0.0029	0.0657	0.6	0.0643	0.9577	15.6	0.1129	1.6296	30.6	0.1632	2.1821
-14.3	0.0035	0.0970	0.7	0.0647	0.9639	15.7	0.1132	1.6521	30.7	0.1636	2.3009
-14.2	0.0040	0.0683	0.8	0.0651	0.9762	15.8	0.1136	1.6958	30.8	0.1640	2.3459
-14.1	0.0045	0.0795	0.9	0.0655	0.9916	15.9	0.1139	1.6898	30.9	0.1644	2.3182

-14.0	0.0050	0.0784	1.0	0.0660	1.0084	16.0	0.1141	1.6924	31.0	0.1648	2.3322
-13.9	0.0055	0.0095	1.1	0.0664	0.9991	16.1	0.1144	1.6769	31.1	0.1652	2.3539
-13.8	0.0059	0.0641	1.2	0.0667	0.8892	16.2	0.1147	1.6159	31.2	0.1656	2.3512
-13.7	0.0064	0.1315	1.3	0.0671	0.9178	16.3	0.1149	1.5857	31.3	0.1659	2.2189
-13.6	0.0068	0.1366	1.4	0.0675	1.0225	16.4	0.1152	1.6112	31.4	0.1663	2.1965
-13.5	0.0072	0.2505	1.5	0.0678	1.0251	16.5	0.1155	1.6021	31.5	0.1666	2.3926
-13.4	0.0076	0.2476	1.6	0.0681	1.0220	16.6	0.1158	1.6143	31.6	0.1669	2.4630
-13.3	0.0080	0.1692	1.7	0.0684	1.0292	16.7	0.1161	1.6460	31.7	0.1672	2.4041
-13.2	0.0084	0.0911	1.8	0.0686	1.0425	16.8	0.1165	1.6634	31.8	0.1675	2.3250
-13.1	0.0088	0.0557	1.9	0.0688	1.0306	16.9	0.1169	1.5275	31.9	0.1678	2.3245
-13.0	0.0092	0.0757	2.0	0.0690	1.0565	17.0	0.1173	1.5389	32.0	0.1680	2.3825
-12.9	0.0096	0.0916	2.1	0.0691	1.0900	17.1	0.1178	1.6864	32.1	0.1683	2.3805
-12.8	0.0101	0.0523	2.2	0.0692	1.0592	17.2	0.1182	1.7221	32.2	0.1686	2.3907
-12.7	0.0105	0.1401	2.3	0.0693	0.9758	17.3	0.1187	1.6773	32.3	0.1689	2.3678
-12.6	0.0110	0.1720	2.4	0.0693	1.0083	17.4	0.1191	1.7466	32.4	0.1692	2.3783
-12.5	0.0115	0.1782	2.5	0.0694	1.0254	17.5	0.1195	1.7980	32.5	0.1695	2.1919
-12.4	0.0119	0.2297	2.6	0.0694	0.9918	17.6	0.1198	1.7761	32.6	0.1699	2.2401
-12.3	0.0124	0.2350	2.7	0.0695	0.9826	17.7	0.1201	1.7131	32.7	0.1702	2.3936
-12.2	0.0129	0.2175	2.8	0.0695	1.0091	17.8	0.1204	1.7284	32.8	0.1706	2.3533
-12.1	0.0134	0.2400	2.9	0.0696	1.0272	17.9	0.1207	1.6924	32.9	0.1710	2.3709
-12.0	0.0138	0.2561	3.0	0.0697	1.0239	18.0	0.1210	1.6670	33.0	0.1714	2.4201
-11.9	0.0142	0.2706	3.1	0.0698	1.0245	18.1	0.1213	1.7045	33.1	0.1718	2.4401
-11.8	0.0146	0.2542	3.2	0.0700	1.0227	18.2	0.1215	1.7030	33.2	0.1722	2.4410
-11.7	0.0150	0.2783	3.3	0.0701	1.0194	18.3	0.1218	1.6885	33.3	0.1725	2.4103
-11.6	0.0153	0.2386	3.4	0.0703	0.9567	18.4	0.1221	1.7000	33.4	0.1729	2.3680
-11.5	0.0157	0.2261	3.5	0.0705	1.0242	18.5	0.1225	1.7446	33.5	0.1732	2.4164
-11.4	0.0160	0.2279	3.6	0.0708	1.0631	18.6	0.1228	1.6893	33.6	0.1735	2.4329
-11.3	0.0163	0.2350	3.7	0.0710	1.0048	18.7	0.1232	1.6562	33.7	0.1737	2.4176
-11.2	0.0166	0.2281	3.8	0.0713	1.0298	18.8	0.1236	1.7352	33.8	0.1740	2.4253
-11.1	0.0169	0.2094	3.9	0.0716	1.0848	18.9	0.1240	1.8969	33.9	0.1742	2.3954
-11.0	0.0173	0.3144	4.0	0.0719	1.0851	19.0	0.1244	1.8513	34.0	0.1744	2.4261
-10.9	0.0176	0.3687	4.1	0.0722	1.0613	19.1	0.1249	1.7302	34.1	0.1746	2.6245
-10.8	0.0180	0.2869	4.2	0.0725	1.0115	19.2	0.1253	1.7333	34.2	0.1748	2.4291
-10.7	0.0183	0.2626	4.3	0.0729	1.0128	19.3	0.1257	1.7869	34.3	0.1750	2.2552
-10.6	0.0188	0.2623	4.4	0.0733	1.0494	19.4	0.1261	1.8127	34.4	0.1752	2.3111
-10.5	0.0192	0.2811	4.5	0.0737	1.0307	19.5	0.1265	1.7460	34.5	0.1754	2.3630
-10.4	0.0197	0.2779	4.6	0.0742	1.0012	19.6	0.1268	1.7239	34.6	0.1757	2.4381
-10.3	0.0201	0.3272	4.7	0.0746	1.0447	19.7	0.1272	1.7927	34.7	0.1759	2.4886
-10.2	0.0207	0.2763	4.8	0.0751	1.0761	19.8	0.1275	1.8682	34.8	0.1762	2.4594
-10.1	0.0212	0.2847	4.9	0.0756	1.0803	19.9	0.1279	1.8369	34.9	0.1766	2.4706
-10.0	0.0217	0.3032	5.0	0.0761	1.0451	20.0	0.1282	1.8090	35.0	0.1769	2.6214
-9.9	0.0223	0.3513	5.1	0.0766	1.1251	20.1	0.1286	1.7930	35.1	0.1773	2.5583
-9.8	0.0228	0.3970	5.2	0.0772	1.1530	20.2	0.1290	1.8027	35.2	0.1777	2.3506
-9.7	0.0234	0.4076	5.3	0.0777	1.1219	20.3	0.1293	1.7899	35.3	0.1781	2.3151
-9.6	0.0239	0.4138	5.4	0.0783	1.1235	20.4	0.1297	1.8363	35.4	0.1785	2.3849
-9.5	0.0244	0.4085	5.5	0.0788	1.1146	20.5	0.1301	1.8218	35.5	0.1790	2.4142
-9.4	0.0249	0.3973	5.6	0.0794	1.1148	20.6	0.1305	1.8143	35.6	0.1795	2.4486
-9.3	0.0254	0.3984	5.7	0.0799	1.1441	20.7	0.1309	1.8379	35.7	0.1800	2.5604
-9.2	0.0259	0.4116	5.8	0.0805	1.1177	20.8	0.1313	1.7525	35.8	0.1806	2.7393
-9.1	0.0263	0.4305	5.9	0.0810	1.2033	20.9	0.1317	1.7783	35.9	0.1811	2.9252
-9.0	0.0267	0.4335	6.0	0.0815	1.1667	21.0	0.1321	1.8882	36.0	0.1817	2.8208
-8.9	0.0271	0.3974	6.1	0.0820	1.1162	21.1	0.1325	1.9691	36.1	0.1823	2.6151
-8.8	0.0275	0.4252	6.2	0.0825	1.2044	21.2	0.1328	1.9766	36.2	0.1829	2.6029
-8.7	0.0278	0.4467	6.3	0.0830	1.2777	21.3	0.1331	1.9214	36.3	0.1835	2.5308
-8.6	0.0282	0.4405	6.4	0.0834	1.2682	21.4	0.1333	1.8779	36.4	0.1840	2.4328
-8.5	0.0285	0.4326	6.5	0.0839	1.2426	21.5	0.1336	1.8606	36.5	0.1846	2.4389
-8.4	0.0289	0.4724	6.6	0.0843	1.2245	21.6	0.1337	1.8455	36.6	0.1852	2.4484
-8.3	0.0292	0.4653	6.7	0.0847	1.2222	21.7	0.1339	1.8437	36.7	0.1858	2.4751
-8.2	0.0296	0.4673	6.8	0.0851	1.1960	21.8	0.1341	1.8084	36.8	0.1863	2.5557
-8.1	0.0299	0.4888	6.9	0.0855	1.1808	21.9	0.1343	1.8634	36.9	0.1869	2.5628
-8.0	0.0302	0.4606	7.0	0.0859	1.2009	22.0	0.1345	1.8989	37.0	0.1874	2.5467
-7.9	0.0306	0.4411	7.1	0.0863	1.1992	22.1	0.1347	1.9285	37.1	0.1879	2.5314
-7.8	0.0309	0.4892	7.2	0.0867	1.2001	22.2	0.1349	1.9106	37.2	0.1883	2.5802
-7.7	0.0312	0.5165	7.3	0.0870	1.2792	22.3	0.1352	1.8848	37.3	0.1887	2.6388
-7.6	0.0315	0.4892	7.4	0.0874	1.3155	22.4	0.1354	1.8955	37.4	0.1890	2.6560

-7.5	0.0319	0.4742	7.5	0.0878	1.3191	22.5	0.1358	1.9912	37.5	0.1893	2.6915
-7.4	0.0322	0.4838	7.6	0.0882	1.3166	22.6	0.1361	1.8958	37.6	0.1895	2.6635
-7.3	0.0325	0.5291	7.7	0.0886	1.3059	22.7	0.1365	1.8307	37.7	0.1897	2.6396
-7.2	0.0329	0.5251	7.8	0.0889	1.2728	22.8	0.1369	1.8897	37.8	0.1898	2.6467
-7.1	0.0332	0.5635	7.9	0.0893	1.3133	22.9	0.1373	1.9391	37.9	0.1900	2.5976
-7.0	0.0336	0.5772	8.0	0.0896	1.3211	23.0	0.1377	1.9577	38.0	0.1901	2.6318
-6.9	0.0341	0.5133	8.1	0.0899	1.2978	23.1	0.1381	1.9543	38.1	0.1902	2.8950
-6.8	0.0345	0.4404	8.2	0.0903	1.2591	23.2	0.1385	1.9475	38.2	0.1903	2.8294
-6.7	0.0350	0.3822	8.3	0.0906	1.2567	23.3	0.1389	1.8741	38.3	0.1905	2.6379
-6.6	0.0355	0.4214	8.4	0.0910	1.2800	23.4	0.1393	1.9229	38.4	0.1907	2.4791
-6.5	0.0360	0.5739	8.5	0.0914	1.2858	23.5	0.1396	2.0568	38.5	0.1910	2.4090
-6.4	0.0366	0.6451	8.6	0.0918	1.3119	23.6	0.1399	2.0471	38.6	0.1913	2.4936
-6.3	0.0371	0.6045	8.7	0.0922	1.3083	23.7	0.1401	1.9830	38.7	0.1916	2.6203
-6.2	0.0377	0.6216	8.8	0.0926	1.3408	23.8	0.1404	1.9732	38.8	0.1920	2.6805
-6.1	0.0382	0.6031	8.9	0.0930	1.3817	23.9	0.1406	1.9638	38.9	0.1925	2.7380
-6.0	0.0388	0.6432	9.0	0.0934	1.3744	24.0	0.1408	1.9399	39.0	0.1929	2.7569
-5.9	0.0393	0.6656	9.1	0.0939	1.3833	24.1	0.1410	1.9370	39.1	0.1934	2.7569
-5.8	0.0398	0.6501	9.2	0.0943	1.4011	24.2	0.1412	1.9543	39.2	0.1938	2.7569
-5.7	0.0402	0.6109	9.3	0.0948	1.4162	24.3	0.1415	1.9673	39.3	0.1942	2.7569
-5.6	0.0406	0.6171	9.4	0.0952	1.3329	24.4	0.1417	1.9679	39.4	0.1947	2.7569
-5.5	0.0411	0.5419	9.5	0.0956	1.1971	24.5	0.1420	1.9828	39.5	0.1951	2.7569
-5.4	0.0414	0.6421	9.6	0.0960	1.3052	24.6	0.1424	1.9810	39.6	0.1954	
-5.3	0.0418	0.6831	9.7	0.0963	1.3759	24.7	0.1428	2.0067	39.7	0.1956	
-5.2	0.0422	0.6839	9.8	0.0966	1.4122	24.8	0.1431	2.0024	39.8	0.1958	
-5.1	0.0426	0.6925	9.9	0.0969	1.5034	24.9	0.1436	2.0135	39.9	0.1958	

A.1.9 Thermal conductivity test:

Group	Specimen number.	Dry mass [g]	Wet mass [g]	Moisture mass [g]	Moisture content [M.-%]	Thermal conductivity [W/mK]	Value average [W/mK]	Value deviation [W/mK]
original	A1	1236.7	1319.7	83.0	6.71%	0.3441	0.328	+/- 0.021
	A2	1190.3	1271.3	81.0	6.81%	0.3018		
	A3	1242.2	1319.1	76.9	6.19%	0.3395		
dry	A4	1267.2	1267.2	0	0.00%	0.3225	0.308	+/- 0.013
	A5	1232.7	1232.7	0	0.00%	0.3047		
	A6	1234.4	1234.4	0	0.00%	0.2970		
RH=50%	A4	1267.2	1345.35	78.15	6.17%	0.3366	0.322	+/- 0.013
	A5	1232.7	1308.90	76.20	6.18%	0.3176		
	A6	1234.4	1310.50	76.10	6.16%	0.3108		
RH=80%	A1	1236.7	1378.05	141.35	11.43%	0.3564	0.339	+/- 0.022
	A2	1190.3	1324.85	134.55	11.30%	0.3121		
	A3	1242.2	1383.20	141.00	11.35%	0.3499		

Group	Specimen number.	Dry mass [g]	Wet mass [g]	Moisture mass [g]	Moisture content [M.-%]	Thermal conductivity [W/mK]	Value average [W/mK]	Value deviation [W/mK]
original	B1	1211.1	1290.6	79.5	6.56%	0.2271	0.221	+/- 0.006
	B2	1199.7	1277.3	77.6	6.47%	0.2218		
	B3	1168.7	1246.3	77.6	6.64%	0.2155		
dry	B4	1201.9	1201.9	0	0.00%	0.2140	0.209	+/- 0.004

	B5	1179.9	1179.9	0	0.00%	0.2062		
	B6	1220.8	1220.8	0	0.00%	0.2057		
RH=50%	B4	1201.9	1258.35	56.45	4.70%	0.2213	0.216	+/- 0.004
	B5	1179.9	1235.05	55.15	4.67%	0.2131		
	B6	1220.8	1279.80	59.00	4.83%	0.2134		
RH=80%	B1	1211.1	1329.85	118.75	9.81%	0.2327	0.227	+/- 0.006
	B2	1199.7	1315.60	115.90	9.66%	0.2270		
	B3	1168.7	1282.55	113.85	9.74%	0.2207		

Group	Specimen number.	Dry mass [g]	Wet mass [g]	Moisture mass [g]	Moisture content [M.-%]	Thermal conductivity [W/mK]	Value average [W/mK]	Value deviation [W/mK]
original	C1	1269.6	1352.4	82.8	6.52%	0.2313	0.228	+/- 0.004
	C2	1231.3	1313.2	81.9	6.65%	0.2243		
	C3	1250.1	1333.1	83.0	6.64%	0.2285		
dry	C4	1271.0	1269.4	0	0.00%	0.2111	0.211	+/- 0.003
	C5	1258.2	1258.2	0	0.00%	0.2141		
	C6	1239.4	1239.4	0	0.00%	0.2074		
RH=50%	C4	1271.0	1320.15	50.75	3.87%	0.2151	0.217	+/- 0.003
	C5	1258.2	1312.35	54.15	4.30%	0.2204		
	C6	1239.4	1293.65	54.25	4.38%	0.2140		
RH=80%	C1	1269.6	1385.85	116.25	9.16%	0.2346	0.231	+/- 0.005
	C2	1231.3	1347.65	116.35	9.45%	0.2254		
	C3	1250.1	1365.95	115.85	9.27%	0.2323		

A.2 Annex 2 Experimental records (bamboo scrimber)

Note: Sample D, longitudinal; Sample E, radial; Sample F, tangential.

A.2.1 Bulk density test

Sample	Volume	Dry weight	Dry bulk density	Dry bulk density average	Dry bulk density deviation
	[cm^3]	[g]	[g/cm^3]	[g/cm^3]	[g/cm^3]
D_01	76.54	89.65	1.171	1.127	+/- 0.067
D_02	76.84	84.45	1.099		
D_03	76.45	83.22	1.089		
D_04	76.76	85.50	1.114		
D_05	76.95	84.50	1.098		
D_06	75.56	83.66	1.107		
E_01	75.11	90.78	1.209		
E_02	76.07	86.64	1.139		
E_03	75.41	88.87	1.178		
E_04	75.33	88.37	1.173		
E_05	75.57	84.85	1.123		
E_06	75.45	81.85	1.085		
F_01	75.18	81.92	1.090		
F_02	74.62	90.92	1.218		
F_03	74.94	82.11	1.096		

F_04	75.12	82.78	1.102		
F_05	75.11	82.46	1.098		
F_06	75.23	82.15	1.092		

A.2.2 True density test

Equipment:

Micromeritics®, AccuPyc II 1340 V3.00

Analysis Gas	Helium
Sample Mass	3.8260 g
Temperature	22.58 °C
Expansion Volume	8.4487 cm^3
Cell Volume	11.1871 cm^3
Number of Purges	10

Equilib. Rate	0.005 psig/min
Analysis Start	09.07.2020 12:53:54
Analysis End	09.07.2020 17:18:11
Reported	09.07.2020 17:18:11
Chamber Insert	None
Sample	I202_D25

Summary report:

Sample Volume	
Average	2.9969 cm^3
Deviation	0.0130 cm^3

Sample Density	
Average	1.2767 g/cm^3
Deviation	0.0055 g/cm^3

Source recorded data:

Cycle	Volume (cm^3)	P2 Pressure Deviation (psig)	Density (g/cm^3)	Volume Deviation (cm^3)	Temperature (°C)	Porosity* (%)
1	3.0032	0.019	1.2740	0.0063	22.48	21.50
2	2.9870	-0.007	1.2809	-0.0099	22.47	21.93
3	3.0135	-0.013	1.2696	0.0166	22.54	21.24
4	3.0152	-0.023	1.2689	0.0183	22.56	21.19
5	3.0056	0.007	1.2730	0.0087	22.59	21.44
6	2.9768	0.020	1.2853	-0.0201	22.61	22.20
7	2.9770	-0.018	1.2852	-0.0199	22.62	22.19
8	2.9902	0.013	1.2795	-0.0067	22.61	21.84
9	3.0001	0.033	1.2753	0.0032	22.64	21.59
10	3.0004	-0.030	1.2752	0.0035	22.66	21.58
Average	2.9969		1.2767			
Deviation	0.0130		0.0055			
*Calculated from envelope density						

A.2.3 Soprtion test

Summary report:

Adsorption

	Group (*x*)	D		E		F	
Condition	Specimen number	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]
23°C/50%	I202_*x*26	5.56	5.57	3.91	3.65	4.62	4.66
	I202_*x*27	5.57		3.56		4.54	

	I202_*x*28	5.56		3.46		4.83	
23°C/65%	I202_*x*13	7.16	7.16	6.59	6.46	6.10	6.14
	I202_*x*14	7.20		6.54		6.26	
	I202_*x*15	7.13		6.25		6.06	
23°C/80%	I202_*x*16	9.54	9.60	9.33	9.08	9.48	9.35
	I202_*x*17	9.86		8.88		9.28	
	I202_*x*18	9.39		9.02		9.30	
23°C/93%	I202_*x*19	14.72	14.94	-	-	-	-
	I202_*x*20	15.02		-		-	
	I202_*x*21	15.08		-		-	
23°C/97%	I202_*x*22	21.67	21.68	-	-	-	-
	I202_*x*23	21.82		-		-	
	I202_*x*24	21.54		-		-	

Desorption

	Group (*x*)	D		E		F	
Climate condition	Specimen number	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]	MC [M.-%]	MC average [M.-%]
23°C/50%	I202_*x*26D	7.48	7.51	6.78	6.87	6.70	6.68
	I202_*x*27D	7.55		6.84		6.65	
	I202_*x*28D	7.51		7.00		6.69	
23°C/65%	I202_*x*13D	9.70	9.54	8.86	8.29	8.29	8.31
	I202_*x*14D	9.45		8.91		8.30	
	I202_*x*15D	9.48		7.08		8.33	
23°C/80%	I202_*x*16D	12.62	12.25	11.05	11.08	10.97	10.81
	I202_*x*17D	12.03		11.01		10.82	
	I202_*x*18D	12.10		11.17		10.64	

Source recorded data:

Adsorption

Climate condition	Specimen number	Glass empty	Glass dry specimen	Glass + wet specimen	Dry mass (before adsorption)	Wet mass	Moisture mass	MC	MC average
[°C/%]		[g]	[g]	[g]	[g]	[g]	[g]	[M.-%]	[M.-%]
23°C/50%	I202_D26	0	-	-	35.875	37.87	1.995	5.56	5.57
	I202_D27	0	-	-	37.482	39.57	2.088	5.57	
	I202_D28	0	-	-	35.874	37.87	1.996	5.56	
23°C/65%	I202_D13	70.940	110.240	113.054	39.300	42.114	2.814	7.16	7.16
	I202_D14	70.690	107.960	110.644	37.270	39.954	2.684	7.20	
	I202_D15	72.860	109.870	112.507	37.010	39.647	2.637	7.13	

23°C/80%	I202_D16	73.410	111.890	115.560	38.480	42.150	3.670	9.54	9.60
	I202_D17	72.510	108.110	111.620	35.600	39.110	3.510	9.86	
	I202_D18	72.200	110.630	114.240	38.430	42.040	3.610	9.39	
23°C/93%	I202_D19	88.230	107.930	110.830	19.700	22.600	2.900	14.72	14.94
	I202_D20	89.310	108.593	111.490	19.283	22.180	2.897	15.02	
	I202_D21	89.370	109.138	112.120	19.768	22.750	2.982	15.08	
23°C/97%	I202_D22	91.270	110.462	114.620	19.192	23.350	4.158	21.67	21.68
	I202_D23	93.900	113.527	117.810	19.627	23.910	4.283	21.82	
	I202_D24	95.800	115.439	119.670	19.639	23.870	4.231	21.54	
23°C/50%	I202_E26	0	-	-	37.003	38.450	1.447	3.91	3.65
	I202_E27	0	-	-	39.522	40.930	1.408	3.56	
	I202_E28	0	-	-	38.226	39.550	1.324	3.46	
23°C/65%	I202_E13	73.080	106.170	108.349	33.090	35.269	2.179	6.59	6.46
	I202_E14	69.650	104.490	106.770	34.840	37.120	2.280	6.54	
	I202_E15	69.930	105.140	107.342	35.210	37.412	2.202	6.25	
23°C/80%	I202_E16	74.090	109.120	112.390	35.030	38.300	3.270	9.33	9.08
	I202_E17	74.970	106.610	109.420	31.640	34.450	2.810	8.88	
	I202_E18	73.220	108.150	111.300	34.930	38.080	3.150	9.02	
23°C/93%	I202_E19	-	-	-	-	-	-	-	-
	I202_E20	-	-	-	-	-	-	-	
	I202_E21	-	-	-	-	-	-	-	
23°C/97%	I202_E22	-	-	-	-	-	-	-	-
	I202_E23	-	-	-	-	-	-	-	
	I202_E24	-	-	-	-	-	-	-	
23°C/50%	I202_F26	0	-	-	35.185	36.810	1.625	4.62	4.66
	I202_F27	0	-	-	35.727	37.350	1.623	4.54	
	I202_F28	0	-	-	29.123	30.530	1.407	4.83	
23°C/65%	I202_F13	70.410	106.100	108.276	35.69	37.866	2.176	6.10	6.14
	I202_F14	74.420	109.530	111.728	35.11	37.308	2.198	6.26	
	I202_F15	69.280	105.540	107.736	36.26	38.456	2.196	6.06	
23°C/80%	I202_F16	71.320	102.960	105.960	31.64	34.640	3.000	9.48	9.35
	I202_F17	75.110	109.700	112.910	34.59	37.800	3.210	9.28	
	I202_F18	69.020	102.350	105.450	33.33	36.430	3.100	9.30	
23°C/93%	I202_F19	-	-	-	-	-	-	-	-
	I202_F20	-	-	-	-	-	-	-	
	I202_F21	-	-	-	-	-	-	-	
23°C/97%	I202_F22	-	-	-	-	-	-	-	-
	I202_F23	-	-	-	-	-	-	-	
	I202_F24	-	-	-	-	-	-	-	

Desorption

Climate condition	Specimen number	Glass empty	Dry mass (before desorption)	Wet mass after saturation	Dry mass (after desorption)	Wet mass	Moisture mass	MC	MC average
[°C/%]		[g]	[g]	[g]	[g]	[g]	[g]	[M.-%]	[M.-%]
23°C/50%	I202_D26D	*0*	32.918	41.434	31.857	34.240	2.383	7.48	7.51
	I202_D27D	*0*	37.262	47.045	36.056	38.780	2.724	7.55	
	I202_D28D	*0*	35.561	43.732	34.388	36.970	2.582	7.51	
23°C/65%	I202_D13D	*0*	37.263	46.845	35.904	39.385	3.481	9.70	9.54
	I202_D14D	*0*	36.193	45.753	35.089	38.405	3.316	9.45	
	I202_D15D	*0*	38.763	47.552	37.534	41.091	3.557	9.48	
23°C/80%	I202_D16D	*0*	38.564	47.890	37.195	41.890	4.695	12.62	12.25
	I202_D17D	*0*	35.757	44.103	34.634	38.800	4.166	12.03	
	I202_D18D	*0*	37.041	45.477	35.844	40.180	4.336	12.10	
23°C/50%	I202_E26D	*0*	40.120	47.296	39.370	42.040	2.670	6.78	6.87
	I202_E27D	*0*	32.638	38.991	32.112	34.310	2.198	6.84	
	I202_E28D	*0*	31.716	38.480	31.281	33.470	2.189	7.00	
23°C/65%	I202_E13D	*0*	35.866	42.624	35.062	38.170	3.108	8.86	8.29
	I202_E14D	*0*	34.148	41.616	33.637	36.634	2.997	8.91	
	I202_E15D	*0*	37.833	41.006	36.773	39.378	2.605	7.08	
23°C/80%	I202_E16D	*0*	37.006	44.069	36.551	40.590	4.039	11.05	11.08
	I202_E17D	*0*	36.648	42.673	35.834	39.780	3.946	11.01	
	I202_E18D	*0*	38.556	45.106	37.879	42.110	4.231	11.17	
23°C/50%	I202_F26D	*0*	32.448	39.549	31.969	34.110	2.141	6.70	6.68
	I202_F27D	*0*	32.314	39.635	31.907	34.030	2.123	6.65	
	I202_F28D	*0*	32.113	39.319	31.661	33.780	2.119	6.69	
23°C/65%	I202_F13D	*0*	32.816	39.473	32.312	34.992	2.680	8.29	8.31
	I202_F14D	*0*	32.083	39.006	31.603	34.225	2.622	8.30	
	I202_F15D	*0*	35.237	42.126	34.662	37.549	2.887	8.33	
23°C/80%	I202_F16D	*0*	32.912	39.934	32.422	35.980	3.558	10.97	10.81
	I202_F17D	*0*	35.801	42.214	35.202	39.010	3.808	10.82	
	I202_F18D	*0*	34.493	41.703	33.930	37.540	3.610	10.64	

A.2.4 Water immersion test

Summary report:

Specimen number	*u*	*w*	Dimension change*			Volume expansion rate	Corrected *w*
	[%]	[kg/m³]	width	length	thickness	[%]	[kg/m³]
I202_D1	28.34	323.49	103.18%	108.34%	100.37%	112.22	288.28
I202_D2			103.14%	108.07%	100.40%		
I202_D3			103.29%	108.46%	100.45%		
I202_E1	25.79	285.53	102.50%	100.36%	106.47%	110.88	257.74
I202_E2			102.59%	100.46%	106.06%		
I202_E3			103.75%	100.33%	109.35%		
I202_F1	28.67	305.50	107.29%	100.34%	103.48%	111.38	274.28
I202_F2			107.31%	100.37%	103.41%		
I202_F3							

*Note: For sample D, the width, length and thickness dimension change directions correspond to the tangential, radial and longitudinal directions, respectively; For sample E, the width, length and thickness dimension change directions correspond to the tangential, longitudinal and radial directions, respectively; For sample F, the width, length and thickness dimension change directions correspond to the radial, longitudinal and tangential directions, respectively

Source recorded data:

	dry mass	mass	u	width	length	thickness
Specimen number	[g]	[g]	[%]	[mm]	[mm]	[mm]
I202_D1	334.745		0.00	98.332	97.429	30.260
I202_D2	323.889		0.00	98.336	97.511	30.136
I202_D3	333.102		0.00	98.276	97.424	30.253
I202_E1	313.632		0.00	98.885	99.892	29.625
I202_E2	313.372		0.00	98.882	99.889	29.627
I202_E3	348.527		0.00	98.875	99.898	29.590
I202_F1	308.714		0.00	98.201	99.926	29.630
I202_F2	310.937		0.00	98.192	99.931	29.631
I202_F3	-		-	-	-	-
I202_D1		426.440	27.39	101.455	105.555	30.373
I202_D2		420.405	29.80	101.425	105.382	30.257
I202_D3		425.839	27.84	101.507	105.670	30.390
I202_E1		398.347	27.01	101.355	100.250	31.543
I202_E2		399.354	27.44	101.445	100.347	31.422
I202_E3		428.401	22.92	102.578	100.225	32.357
I202_F1		398.238	29.00	105.358	100.263	30.660
I202_F2		399.063	28.34	105.367	100.300	30.640
I202_F3		-	-	-	-	-

A.2.5 Capillary absorption test

Summary report:

Specimen number	W-Wert	W-Wert average	W-wert deviation
	[kg/(m² √h)]	[kg/(m² √h)]	[kg/(m² √h)]
I202_D7W	0.11	0.10	+/- 0.01
I202_D8W	0.11		
I202_D9W	0.09		
I202_E7W	0.02	0.02	+/- 0.00
I202_E8W	0.02		
I202_E9W	0.02		
I202_F7W	0.02	0.02	+/- 0.00
I202_F8W	0.02		
I202_F9W	0.02		

Source recorded data:

Date	I202_D7W		I202_D8W		I202_D9W	
	Time	Mass [g]	Time	Mass [g]	Time	Mass [g]
09.06.2020	10.13.02	364.0	10.13.20	357.6	10.13.33	373.2
09.06.2020	10.14.10	364.0	10.14.32	357.7	10.14.50	373.5

09.06.2020	10.18.05	364.1	10.18.28	357.8	10.18.50	373.4
09.06.2020	10.23.05	364.1	10.23.29	357.9	10.23.54	373.5
09.06.2020	10.28.05	364.2	10.28.29	357.9	10.28.52	373.5
09.06.2020	10.33.04	364.2	10.33.29	357.9	10.33.49	373.6
09.06.2020	10.43.04	364.4	10.43.24	358.0	10.43.49	373.6
09.06.2020	10.58.02	364.5	10.58.23	358.1	10.58.45	373.7
09.06.2020	11.13.03	364.5	11.13.29	358.2	11.14.11	373.8
09.06.2020	12.13.00	364.8	12.13.21	358.5	12.13.44	374.0
09.06.2020	13.13.07	365.0	13.13.34	358.7	13.13.59	374.2
09.06.2020	14.13.27	365.2	14.13.55	358.8	14.14.18	374.4
09.06.2020	15.13.03	365.5	15.13.39	359.0	15.14.03	374.5
09.06.2020	16.13.06	365.6	16.13.39	359.2	16.14.06	374.7
09.06.2020	17.13.03	365.8	17.13.34	359.4	17.13.58	374.9
10.06.2020	10.13.24	368.0	10.13.54	361.5	10.14.31	376.6

Date	I202_E7W		I202_E8W		I202_E9W	
	Time	Mass [g]	Time	Mass [g]	Time	Mass [g]
15.06.2020	10.00.01	375.5	10.00.13	381.2	10.00.25	384.1
15.06.2020	10.01.14	375.5	10.01.49	381.4	10.02.06	384.2
15.06.2020	10.05.17	375.6	10.05.37	381.5	10.05.57	384.2
15.06.2020	10.10.04	375.7	10.10.30	381.4	10.11.07	384.2
15.06.2020	10.15.12	375.6	10.15.31	381.4	10.15.50	384.2
15.06.2020	10.20.04	375.6	10.20.27	381.4	10.20.48	384.3
15.06.2020	10.30.04	375.6	10.30.25	381.4	10.31.09	384.3
15.06.2020	10.45.04	375.7	10.45.30	381.4	10.46.14	384.3
15.06.2020	11.00.04	375.7	11.00.33	381.5	11.00.54	384.3
15.06.2020	12.00.07	375.7	12.00.50	381.5	12.01.17	384.3
15.06.2020	13.00.02	375.8	13.00.26	381.6	13.01.22	384.4
15.06.2020	14.00.03	375.8	14.00.55	381.6	14.01.14	384.4
15.06.2020	15.00.05	375.8	15.00.26	381.6	15.00.48	384.4
15.06.2020	16.00.04	375.8	16.00.25	381.6	16.00.49	384.4
15.06.2020	17.00.01	375.9	17.00.24	381.7	17.01.03	384.5
16.06.2020	10.00.03	376.2	10.01.20	382.0	10.03.01	384.8

Date	I202_F7W		I202_F8W		I202_F9W	
	Time	Mass [g]	Time	Mass [g]	Time	Mass [g]
15.06.2020	10.03.04	337.4	10.03.17	337.1	10.03.29	349.7
15.06.2020	10.04.15	337.5	10.04.32	337.2	10.04.50	349.8
15.06.2020	10.08.07	337.5	10.08.29	337.2	10.08.49	349.8
15.06.2020	10.13.06	337.5	10.13.25	337.2	10.13.44	349.8
15.06.2020	10.18.01	337.5	10.18.21	337.3	10.18.42	349.8
15.06.2020	10.23.05	337.5	10.23.28	337.3	10.23.51	349.8
15.06.2020	10.33.00	337.5	10.33.20	337.3	10.33.45	349.9
15.06.2020	10.48.00	337.6	10.48.21	337.3	10.49.03	349.9
15.06.2020	11.03.04	337.6	11.03.26	337.3	11.5.59	349.9
15.06.2020	12.03.00	337.7	12.03.25	337.4	12.03.47	349.9
15.06.2020	13.02.59	337.7	13.03.22	337.4	13.03.46	350.0
15.06.2020	14.03.00	337.7	14.03.22	337.5	14.03.44	350.0
15.06.2020	15.03.02	337.7	15.03.26	337.5	15.03.49	350.0
15.06.2020	16.02.58	337.8	16.03.19	337.5	16.03.44	350.0
15.06.2020	17.02.57	337.8	17.03.18	337.5	17.03.37	350.1
16.06.2020	10.03.40	338.2	10.04.11	337.9	10.04.39	350.4

Specimen information:

Probe	I202_D7W		I202_D8W		I202_D9W	
Saugfläche	0.0077 m²	76.56 cm²	0.0076 m²	75.69 cm²	0.0076 m²	75.69 cm²
Volumen	0.000301 m³	300.77 cm³	0.000298 m³	297.68 cm³	0.000301 m³	300.63 cm³
Trockenmasse	0.357 kg	357.410 g	0.351 kg	350.950 g	0.367 kg	366.880 g
Rohdichte	1188.314 kg/m³	1.188 g/cm³	1178.936 kg/m³	1.179 g/cm³	1220.378 kg/m³	1.220 g/cm³
Anfangsmasse	0.364 kg	364.000 g	0.358 kg	357.600 g	0.373 kg	373.200 g
Endmasse	0.368 kg	368.000 g	0.361 kg	361.500 g	0.377 kg	376.600 g
Delta-Masse	0.004 kg	4.000 g	0.004 kg	3.900 g	0.003 kg	3.400 g
Anfangszeit	09.06.2020 10:13:02		09.06.2020 10:13:20		09.06.2020 10:13:33	
Endzeit	10.06.2020 10:13:24		10.06.2020 10:13:54		10.06.2020 10:14:31	
√Delta-Zeit	4.900√h		4.900√h		4.901√h	
Länge ohne Paraffin: mit Paraffin :	 99.65 mm 87.00 mm		 99.57 mm 87.00 mm		 99.63 mm 87.00 mm	
Breite ohne Paraffin: mit Paraffin :	 99.58 mm 88.00 mm		 99.59 mm 87.00 mm		 99.52 mm 87.00 mm	
Dicke	30.31 mm		30.02 mm		30.32 mm	

Probe	I202_E7W		I202_E8W		I202_E9W	
Saugfläche	0.0077 m²	76.56 cm²	0.0076 m²	75.69 cm²	0.0077 m²	77.44 cm²
Volumen	0.000303 m³	302.96 cm³	0.000304 m³	303.57 cm³	0.000303 m³	303.01 cm³
Trockenmasse	0.368 kg	368.320 g	0.375 kg	375.170 g	0.376 kg	376.120 g
Rohdichte	1215.725 kg/m³	1.216 g/cm³	1235.873 kg/m³	1.236 g/cm³	1241.299 kg/m³	1.241 g/cm³
Anfangsmasse	0.376 kg	375.500 g	0.381 kg	381.200 g	0.384 kg	384.100 g
Endmasse	0.376 kg	376.200 g	0.382 kg	382.000 g	0.385 kg	384.800 g
Delta-Masse	0.001 kg	0.700 g	0.001 kg	0.800 g	0.001 kg	0.700 g
Anfangszeit	15.06.2020 10:00:01		15.06.2020 10:00:13		15.06.2020 10:00:25	
Endzeit	16.06.2020 10:00:03		16.06.2020 10:01:20		16.06.2020 10:03:01	
√Delta-Zeit	4.899√h		4.901√h		4.903√h	
Länge ohne Paraffin: mit Paraffin :	 100.08 mm 87.00 mm		 100.08 mm 87.00 mm		 100.11 mm 88.00 mm	
Breite ohne Paraffin: mit Paraffin :	 100.04 mm 88.00 mm		 100.14 mm 87.00 mm		 100.09 mm 88.00 mm	
Dicke	30.26 mm		30.29 mm		30.24 mm	

Probe	I202_F7W		I202_F8W		I202_F9W	
Saugfläche	0.0077 m²	76.56 cm²	0.0077 m²	76.56 cm²	0.0077 m²	76.56 cm²
Volumen	0.000300 m³	299.76 cm³	0.000299 m³	299.42 cm³	0.000298 m³	298.43 cm³
Trockenmasse	0.327 kg	327.440 g	0.326 kg	326.010 g	0.339 kg	338.530 g
Rohdichte	1092.344 kg/m³	1.092 g/cm³	1088.807 kg/m³	1.089 g/cm³	1134.378 kg/m³	1.134 g/cm³
Anfangsmasse	0.337 kg	337.400 g	0.337 kg	337.100 g	0.350 kg	349.700 g
Endmasse	0.338 kg	338.200 g	0.338 kg	337.900 g	0.350 kg	350.400 g
Delta-Masse	0.001 kg	0.800 g	0.001 kg	0.800 g	0.001 kg	0.700 g
Anfangszeit	15.06.2020 10:03:04		15.06.2020 10:03:17		15.06.2020 10:03:29	
Endzeit	16.06.2020 10:03:40		16.06.2020 10:04:11		16.06.2020 10:04:39	
√Delta-Zeit	4.900√h		4.901√h		4.901√h	
Länge ohne Paraffin: mit Paraffin :	 99.94 mm 88.00 mm		 99.92 mm 88.00 mm		 100.00 mm 88.00 mm	

Breite ohne Paraffin: mit Paraffin :	100.18 mm 87.00 mm	100.12 mm 87.00 mm	100.11 mm 87.00 mm
Dicke	29.94 mm	29.93 mm	29.81 mm

A.2.6 Water vapor transmission test

"Messergebnisse der einzelnen Proben", local δa = 2.12072E-10 kg/(m·s·Pa)

Condition	Specimen number.	μ [-]			δ [kg/(m·s·Pa)]		
		value	average	deviation	value	average	deviation
23°C - 3%/50%	I202_D1T	81.99	74.20	+/- 8.46	2.587E-12	2.884E-12	+/- 3.330E-13
	I202_D2T	65.20			3.253E-12		
	I202_D3T	75.41			2.812E-12		
23°C - 33%/75%	I202_D31	71.34	70.83	+/- 2.75	2.973E-12	2.997E-12	+/- 1.171E-13
	I202_D32	67.83			3.126E-12		
	I202_D33	73.32			2.892E-12		
23°C - 93%/50%	I202_D4F	50.08	57.25	+/- 12.83	4.235E-12	3.817E-12	+/- 6.657E-13
	I202_D5F	49.62			4.274E-12		
	I202_D6F	72.07			2.943E-12		
23°C - 93%/80%	I202_D34	36.51	36.35	+/- 2.00	5.809E-12	5.846E-12	+/- 3.234E-13
	I202_D35	38.27			5.541E-12		
	I202_D36	34.27			6.188E-12		
23°C - 3%/50%	I202_E1T	7215.25	9245.20	+/- 4536.39	2.939E-14	2.632E-14	+/- 1.010E-14
	I202_E2T	6078.27			3.489E-14		
	I202_E3T	14442.07			1.468E-14		
23°C - 33%/75%	I202_E31	2435.71	2392.22	+/- 34.95	8.707E-14	8.867E-14	+/- 1.286E-15
	I202_E32	2365.81			8.964E-14		
	I202_E33	2375.14			8.929E-14		
23°C - 93%/50%	I202_E4F	1325.32	1887.86	+/- 513.01	1.600E-13	1.189E-13	+/- 3.450E-14
	I202_E5F	2329.89			9.102E-14		
	I202_E6F	2008.36			1.056E-13		
23°C - 93%/80%	I202_E34	1399.27	1574.63	+/- 175.36	1.516E-13	1.364E-13	+/- 1.519E-14
	I202_E35	-			-		
	I202_E36	1749.99			1.212E-13		
23°C - 3%/50%	I202_F1T	4017.10	3572.93	+/- 404.06	5.279E-14	5.985E-14	+/- 6.461E-15
	I202_F2T	3474.55			6.104E-14		
	I202_F3T	3227.15			6.571E-14		
23°C - 33%/75%	I202_F31	1564.51	1673.67	+/- 130.80	1.356E-13	1.273E-13	+/- 9.710E-15
	I202_F32	1630.37			1.301E-13		
	I202_F33	1826.12			1.161E-13		
23°C - 93%/50%	I202_F4F	1051.67	1015.79	+/- 134.32	2.017E-13	2.114E-13	+/- 2.832E-14
	I202_F5F	867.17			2.446E-13		
	I202_F6F	1128.53			1.879E-13		

23°C - 93%/80%	I202_F34	789.67	735.96	+/- 207.91	2.686E-13	3.077E-13	+/- 9.594E-14
	I202_F35	917.02			2.313E-13		
	I202_F36	501.19			4.231E-13		

A.2.7 Drying test

Point	I202_D10X		I202_D11X		I202_D12X	
	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]
1	12.47%	27.48	13.56%	22.60	13.62%	19.94
2	11.74%	23.17	10.95%	17.26	10.98%	17.35
3	11.65%	19.94	10.81%	11.17	10.84%	11.70
4	11.55%	21.27	10.69%	12.63	10.71%	12.63
5	11.47%	18.61	10.21%	12.13	10.24%	11.97
6	11.38%	18.61	10.09%	11.97	10.12%	11.97
7	11.30%	18.61	9.99%	9.97	10.01%	10.64
8	10.76%	17.10	9.57%	10.47	9.59%	10.47
9	10.69%	15.96	9.47%	10.64	9.49%	9.97
10	10.61%	17.29	9.38%	9.31	9.40%	9.31
11	10.52%	19.94	9.03%	8.64	9.06%	8.64
12	10.45%	15.96	8.95%	8.64	8.97%	8.64
13	10.41%	9.31	8.86%	8.64	8.89%	7.98
14	8.83%	11.51	8.55%	7.81	8.58%	7.98
15	8.74%	7.98	8.48%	7.31	8.51%	6.65
16	8.67%	7.31	8.41%	6.65	8.45%	5.98
17	8.39%	8.16	7.46%	5.98	7.50%	5.98
18	8.33%	5.85				
19	8.27%	6.65				
20	8.02%	6.81				
21	7.97%	5.98				
22	7.91%	6.65				
23	7.71%	5.48				
24	7.66%	5.98				
25	7.60%	5.98				
26	7.42%	5.15				

Point	I202_E10X		I202_E11X		I202_E12X	
	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]
1	12.33%	3.99	12.26%	1.62	12.32%	3.32
2	11.88%	3.31	12.17%	1.48	12.21%	2.99
3	11.85%	2.66	11.94%	1.52	12.19%	2.66
4	11.83%	1.99	11.84%	1.46	12.17%	2.66
5	11.74%	2.66	11.76%	1.44	12.07%	2.83
6	11.71%	3.32	11.67%	1.44	12.04%	2.66
7	11.69%	2.66	11.59%	1.38	12.02%	2.66
8	11.59%	2.66	11.38%	1.41	11.92%	2.66
9	11.58%	1.99	11.28%	1.29	11.90%	2.66
10	11.55%	2.66	11.20%	1.44	11.88%	2.66
11	11.48%	2.16	11.13%	1.22	11.53%	2.45
12	11.45%	2.66	11.04%	1.43	11.48%	2.36
13	11.43%	2.66	10.85%	1.29	11.41%	2.13
14	11.35%	2.16	10.76%	1.33	11.37%	1.77

15	11.33%	2.66	10.69%	1.22	11.31%	1.95
16	11.32%	1.33	10.62%	1.22	11.26%	2.36
17	11.02%	2.12	10.54%	1.18	11.20%	1.77
18	10.98%	1.77	10.36%	1.24	11.16%	2.07
19	10.92%	1.95	10.27%	1.20	11.10%	1.77
20	10.88%	1.77	10.21%	1.00	11.06%	1.99
21	10.82%	1.77	10.14%	1.33	10.81%	1.72
22	10.79%	1.77	10.06%	1.14	10.70%	1.84
23	10.73%	1.60	9.89%	1.09	10.62%	1.53
24	10.70%	1.77	9.83%	1.06	10.51%	1.74
25	10.64%	1.77	9.77%	1.11	10.43%	1.60
26	10.61%	1.66	9.71%	0.96	10.23%	1.37
27	10.39%	1.55	9.65%	1.02	10.14%	1.29
28	10.30%	1.53	9.42%	1.06	10.07%	1.22
29	10.21%	1.53	9.24%	1.02	10.01%	1.27
30	10.13%	1.43	9.03%	0.94	9.94%	1.18
31	10.05%	1.49	8.87%	0.89	9.77%	1.18
32	9.88%	1.20	8.68%	0.86	9.70%	1.03
33	9.80%	1.03	8.54%	0.85	9.64%	1.11
34	9.75%	1.11	8.35%	0.80	9.58%	1.11
35	9.69%	1.16	8.23%	0.74	9.52%	1.06
36	9.62%	1.08	8.06%	0.75	9.36%	1.12
37	9.47%	1.10	7.94%	0.70	9.30%	0.94
38	9.40%	1.03	7.80%	0.61	9.24%	1.11
39	9.35%	1.00	7.68%	0.70	9.18%	1.00
40	9.29%	1.00	7.54%	0.64	9.12%	1.02
41	9.24%	0.96	7.44%	0.55	8.98%	1.04
42	9.10%	1.00			8.90%	1.06
43	9.03%	0.94			8.86%	0.89
44	8.98%	1.00			8.81%	0.89
45	8.93%	0.89			8.76%	0.89
46	8.88%	1.02			8.62%	0.94
47	8.75%	0.91			8.56%	0.94
48	8.68%	0.98			8.52%	0.78
49	8.63%	0.89			8.46%	1.00
50	8.59%	0.89			8.42%	0.76
51	8.53%	0.89			8.29%	0.89
52	8.41%	0.90			8.24%	0.74
53	8.36%	0.77			8.20%	0.78
54	8.32%	0.78			8.15%	0.96
55	8.27%	0.89			8.11%	0.72
56	8.22%	0.85			7.95%	0.77
57	8.10%	0.81			7.82%	0.76
58	8.05%	0.85			7.67%	0.69
59	8.02%	0.66			7.55%	0.74
60	7.97%	0.85			7.42%	0.64
61	7.93%	0.72				
62	7.77%	0.77				
63	7.65%	0.76				
64	7.50%	0.69				

Point	I202_F10X		I202_F11X		I202_F12X	
	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]	Moisture content	Mass change rate [g/m²d]
1	12.31%	3.90	12.28%	2.66	12.66%	3.30
2	12.24%	3.55	12.12%	2.66	12.18%	2.91
3	12.10%	3.90	11.95%	2.36	11.95%	2.83
4	12.02%	3.55	11.54%	2.53	11.79%	2.66
5	11.89%	3.72	11.35%	2.40	11.63%	2.66
6	11.82%	3.25	11.22%	2.11	11.45%	2.66
7	11.70%	3.55	11.07%	2.33	11.04%	2.53
8	11.63%	3.32	10.92%	2.34	10.85%	2.40
9	11.14%	3.19	10.56%	2.16	10.71%	2.22
10	10.97%	2.86	10.39%	2.14	10.56%	2.44
11	10.78%	3.07	10.27%	1.99	10.41%	2.34
12	10.61%	2.86	10.15%	1.88	10.04%	2.24
13	10.44%	2.77	10.01%	2.15	9.87%	2.14
14	10.07%	2.49	9.69%	1.91	9.75%	1.99
15	9.88%	2.49	9.55%	1.86	9.63%	1.99
16	9.76%	2.22	9.43%	1.88	9.48%	2.25
17	9.63%	2.43	9.33%	1.55	9.16%	1.95
18	9.49%	2.17	9.21%	1.77	9.01%	1.86
19	9.17%	2.15	8.95%	1.63	8.90%	1.88
20	9.02%	2.06	8.82%	1.63	8.79%	1.66
21	8.91%	1.88	8.72%	1.55	8.67%	1.77
22	8.80%	1.99	8.63%	1.44	8.41%	1.67
23	8.69%	1.91	8.53%	1.42	8.28%	1.54
24	8.41%	1.83	8.29%	1.41	8.19%	1.55
25	8.29%	1.63	8.20%	1.38	8.09%	1.55
26	8.20%	1.66	8.12%	1.33	7.98%	1.52
27	8.10%	1.66	8.04%	1.17	7.76%	1.29
28	8.00%	1.64	7.96%	1.13	7.68%	1.38
29	7.77%	1.58	7.68%	1.17	7.59%	1.33
30	7.67%	1.42	7.48%	1.06	7.52%	1.17
31	7.58%	1.44			7.44%	1.13
32	7.50%	1.44				

A.2.8 Thermal analysis

Equipment:

NETZSCH DSC 214 Polyma DSC21400A-0318-L

Reference	----, 0 mg
Calibration/temperature calibration	applied
Sensitivity	applied
Type of Crucible	Pan Al, closed

Sample holder / thermocouple	DSC 214 Corona sensor / E
Atmosphere	N2, 40.0ml/min / N2, 60.0ml/min
Range	-20°C/3.0(K/min)/40°C
Calibration/measurement range	00/5000 µV

Summary report:

Sample information	
Sample	D1
Sample Mass	3.78 mg
Date/Time	2020/11/12 16:30:41
Test result C_p/(J/(g·K))	
Range: -15°C/3.0(K/min)/40°C	
Max	2.3447
Min	0.4852
Mean	1.3873
Range: 10°C/3.0(K/min)/30°C	
Max	2.1033
Min	1.2538
Mean	1.6357

Sample information	
Sample	D2
Sample Mass	3.55 mg
Date/Time	2020/11/12 16:55:17
Test result C_p/(J/(g·K))	
Range: -15°C/3.0(K/min)/40°C	
Max	3.2024
Min	0.8844
Mean	1.8743
Range: 10°C/3.0(K/min)/30°C	
Max	2.5493
Min	1.7320
Mean	2.1284

Source recorded data:

D1

Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))
-20.0	-0.0516		-5.0	0.0577	0.8845	10.0	0.0955	1.4731	25.0	0.1267	1.7996
-19.9	-0.0508		-4.9	0.0579	0.8456	10.1	0.0956	1.3710	25.1	0.1269	1.7357
-19.8	-0.0475		-4.8	0.0582	0.8576	10.2	0.0956	1.3551	25.2	0.1272	1.7200
-19.7	-0.0435		-4.7	0.0585	0.8796	10.3	0.0956	1.3527	25.3	0.1275	1.8433
-19.6	-0.0392		-4.6	0.0588	0.8930	10.4	0.0957	1.3243	25.4	0.1278	1.8948
-19.5	-0.0347		-4.5	0.0591	0.8908	10.5	0.0957	1.3155	25.5	0.1281	1.8408
-19.4	-0.0302		-4.4	0.0594	0.8873	10.6	0.0957	1.3514	25.6	0.1283	1.8142
-19.3	-0.0258		-4.3	0.0596	0.8869	10.7	0.0957	1.3585	25.7	0.1286	1.8225
-19.2	-0.0215		-4.2	0.0599	0.8629	10.8	0.0957	1.3571	25.8	0.1288	1.8159
-19.1	-0.0172		-4.1	0.0602	0.8844	10.9	0.0958	1.3522	25.9	0.1291	1.7836
-19.0	-0.0130		-4.0	0.0605	0.9224	11.0	0.0959	1.3729	26.0	0.1293	1.7742
-18.9	-0.0090		-3.9	0.0607	0.9285	11.1	0.0960	1.3657	26.1	0.1295	1.7880
-18.8	-0.0053		-3.8	0.0610	0.9777	11.2	0.0962	1.3827	26.2	0.1297	1.8161
-18.7	-0.0018		-3.7	0.0612	0.9643	11.3	0.0964	1.3992	26.3	0.1299	1.8407
-18.6	0.0015		-3.6	0.0615	0.9477	11.4	0.0966	1.3749	26.4	0.1301	1.8503
-18.5	0.0045		-3.5	0.0617	0.9505	11.5	0.0968	1.3996	26.5	0.1303	1.8351
-18.4	0.0073		-3.4	0.0619	0.9423	11.6	0.0971	1.3861	26.6	0.1305	1.8057
-18.3	0.0097		-3.3	0.0621	0.9416	11.7	0.0973	1.3853	26.7	0.1307	1.8109
-18.2	0.0119		-3.2	0.0623	0.9289	11.8	0.0976	1.3490	26.8	0.1309	1.7981
-18.1	0.0139		-3.1	0.0625	0.9267	11.9	0.0978	1.3404	26.9	0.1311	1.8101
-18.0	0.0156		-3.0	0.0627	0.9312	12.0	0.0981	1.3989	27.0	0.1313	1.8236
-17.9	0.0170		-2.9	0.0629	0.9464	12.1	0.0983	1.4677	27.1	0.1316	1.8312
-17.8	0.0183		-2.8	0.0631	0.9398	12.2	0.0985	1.4778	27.2	0.1318	1.8474
-17.7	0.0194		-2.7	0.0633	0.9435	12.3	0.0987	1.4684	27.3	0.1320	1.8248
-17.6	0.0204		-2.6	0.0635	0.9838	12.4	0.0989	1.4622	27.4	0.1323	1.7978
-17.5	0.0213		-2.5	0.0638	0.9991	12.5	0.0991	1.4810	27.5	0.1325	1.8456
-17.4	0.0220		-2.4	0.0640	0.9727	12.6	0.0992	1.4379	27.6	0.1328	1.8992
-17.3	0.0227		-2.3	0.0642	0.9021	12.7	0.0994	1.3853	27.7	0.1330	1.8910
-17.2	0.0232		-2.2	0.0644	0.9318	12.8	0.0996	1.3703	27.8	0.1332	1.8622
-17.1	0.0238		-2.1	0.0647	1.0141	12.9	0.0998	1.2538	27.9	0.1335	1.8662
-17.0	0.0242		-2.0	0.0649	1.0029	13.0	0.1000	1.3144	28.0	0.1337	1.8893
-16.9	0.0247		-1.9	0.0652	0.9664	13.1	0.1002	1.3912	28.1	0.1339	1.8716
-16.8	0.0251		-1.8	0.0655	0.9824	13.2	0.1004	1.4758	28.2	0.1341	1.8646
-16.7	0.0255		-1.7	0.0658	0.9918	13.3	0.1006	1.5464	28.3	0.1343	1.8544
-16.6	0.0259		-1.6	0.0661	0.9480	13.4	0.1008	1.5745	28.4	0.1344	1.8470
-16.5	0.0262		-1.5	0.0663	0.9066	13.5	0.1011	1.5391	28.5	0.1346	1.8744
-16.4	0.0266		-1.4	0.0666	0.9560	13.6	0.1013	1.5043	28.6	0.1348	1.8796
-16.3	0.0269		-1.3	0.0669	0.9739	13.7	0.1016	1.4675	28.7	0.1350	1.8458

-16.2	0.0272		-1.2	0.0672	0.9898	13.8	0.1018	1.4551	28.8	0.1352	1.8735
-16.1	0.0275		-1.1	0.0675	0.9904	13.9	0.1020	1.4115	28.9	0.1354	1.8807
-16.0	0.0279		-1.0	0.0677	1.0142	14.0	0.1022	1.4131	29.0	0.1356	1.8703
-15.9	0.0282		-0.9	0.0680	1.0609	14.1	0.1025	1.4324	29.1	0.1359	1.9042
-15.8	0.0285		-0.8	0.0682	1.1052	14.2	0.1027	1.4244	29.2	0.1361	1.9133
-15.7	0.0287		-0.7	0.0684	1.0966	14.3	0.1029	1.4732	29.3	0.1363	1.9091
-15.6	0.0290		-0.6	0.0686	1.0641	14.4	0.1031	1.5063	29.4	0.1365	1.8959
-15.5	0.0293		-0.5	0.0688	1.0299	14.5	0.1033	1.4970	29.5	0.1367	1.8676
-15.4	0.0296		-0.4	0.0690	1.0119	14.6	0.1036	1.4584	29.6	0.1369	1.8764
-15.3	0.0299		-0.3	0.0692	1.0183	14.7	0.1038	1.4354	29.7	0.1371	1.8819
-15.2	0.0301		-0.2	0.0694	1.0201	14.8	0.1040	1.4373	29.8	0.1373	1.9489
-15.1	0.0304		-0.1	0.0696	1.0098	14.9	0.1043	1.4812	29.9	0.1375	2.1033
-15.0	0.0307	0.5081	0.0	0.0698	1.0057	15.0	0.1045	1.5170	30.0	0.1377	1.9853
-14.9	0.0310	0.5081	0.1	0.0700	0.9940	15.1	0.1048	1.4877	30.1	0.1379	1.7647
-14.8	0.0313	0.5081	0.2	0.0703	0.9889	15.2	0.1050	1.5133	30.2	0.1381	1.7489
-14.7	0.0315	0.5081	0.3	0.0705	1.0367	15.3	0.1053	1.5064	30.3	0.1384	1.8493
-14.6	0.0318	0.5081	0.4	0.0708	1.0819	15.4	0.1055	1.4901	30.4	0.1386	1.9193
-14.5	0.0321	0.5081	0.5	0.0711	1.0961	15.5	0.1058	1.5039	30.5	0.1388	1.9018
-14.4	0.0324	0.4852	0.6	0.0713	1.0808	15.6	0.1060	1.4965	30.6	0.1390	1.8560
-14.3	0.0327	0.5219	0.7	0.0716	1.0772	15.7	0.1062	1.5221	30.7	0.1392	1.9665
-14.2	0.0330	0.5626	0.8	0.0719	1.0613	15.8	0.1064	1.5206	30.8	0.1394	2.0113
-14.1	0.0333	0.5544	0.9	0.0723	1.0800	15.9	0.1066	1.5056	30.9	0.1396	2.0149
-14.0	0.0335	0.5445	1.0	0.0726	1.0729	16.0	0.1069	1.6131	31.0	0.1397	2.1001
-13.9	0.0338	0.5642	1.1	0.0729	1.0253	16.1	0.1071	1.6657	31.1	0.1399	2.1242
-13.8	0.0340	0.5699	1.2	0.0732	1.0229	16.2	0.1073	1.5137	31.2	0.1400	2.0472
-13.7	0.0342	0.6123	1.3	0.0735	1.0789	16.3	0.1075	1.4023	31.3	0.1402	1.8134
-13.6	0.0343	0.6066	1.4	0.0738	1.0829	16.4	0.1077	1.4685	31.4	0.1403	1.7038
-13.5	0.0345	0.6054	1.5	0.0741	1.0851	16.5	0.1080	1.4880	31.5	0.1404	1.8349
-13.4	0.0347	0.5535	1.6	0.0743	1.1497	16.6	0.1083	1.4980	31.6	0.1406	1.9553
-13.3	0.0348	0.5275	1.7	0.0746	1.2039	16.7	0.1086	1.5529	31.7	0.1408	1.9882
-13.2	0.0350	0.5126	1.8	0.0748	1.1610	16.8	0.1089	1.5924	31.8	0.1410	1.9718
-13.1	0.0352	0.5109	1.9	0.0750	1.1224	16.9	0.1092	1.5001	31.9	0.1412	1.9976
-13.0	0.0354	0.5196	2.0	0.0751	1.0863	17.0	0.1095	1.4908	32.0	0.1414	2.0370
-12.9	0.0356	0.5331	2.1	0.0753	1.0515	17.1	0.1099	1.5486	32.1	0.1416	2.0293
-12.8	0.0358	0.5500	2.2	0.0754	1.0739	17.2	0.1102	1.6070	32.2	0.1418	2.0373
-12.7	0.0360	0.5809	2.3	0.0755	1.1486	17.3	0.1104	1.6391	32.3	0.1420	2.0729
-12.6	0.0363	0.5824	2.4	0.0756	1.1504	17.4	0.1107	1.6258	32.4	0.1422	2.0358
-12.5	0.0366	0.5816	2.5	0.0757	1.1117	17.5	0.1109	1.6238	32.5	0.1424	1.8737
-12.4	0.0368	0.6126	2.6	0.0758	1.0729	17.6	0.1111	1.6138	32.6	0.1425	1.9068
-12.3	0.0371	0.6112	2.7	0.0759	1.0898	17.7	0.1113	1.5743	32.7	0.1427	1.9948
-12.2	0.0374	0.5999	2.8	0.0760	1.1142	17.8	0.1114	1.5666	32.8	0.1428	1.9777
-12.1	0.0376	0.6047	2.9	0.0761	1.1198	17.9	0.1115	1.5613	32.9	0.1430	1.9870
-12.0	0.0379	0.6122	3.0	0.0762	1.1675	18.0	0.1116	1.5627	33.0	0.1431	2.0149
-11.9	0.0381	0.6323	3.1	0.0764	1.1358	18.1	0.1117	1.5792	33.1	0.1433	1.9576
-11.8	0.0383	0.6062	3.2	0.0765	1.1123	18.2	0.1118	1.5793	33.2	0.1434	1.9734
-11.7	0.0385	0.6186	3.3	0.0767	1.0958	18.3	0.1119	1.5475	33.3	0.1435	2.0046
-11.6	0.0387	0.6106	3.4	0.0768	1.1199	18.4	0.1121	1.5619	33.4	0.1437	1.9857
-11.5	0.0389	0.6099	3.5	0.0770	1.1294	18.5	0.1123	1.6002	33.5	0.1438	1.9841
-11.4	0.0391	0.6052	3.6	0.0772	1.1123	18.6	0.1125	1.5915	33.6	0.1439	1.9933
-11.3	0.0392	0.6135	3.7	0.0774	1.0997	18.7	0.1127	1.5817	33.7	0.1440	2.0157
-11.2	0.0394	0.6213	3.8	0.0777	1.0954	18.8	0.1130	1.5804	33.8	0.1441	1.9898
-11.1	0.0395	0.6031	3.9	0.0779	1.0854	18.9	0.1133	1.5829	33.9	0.1442	2.1000
-11.0	0.0397	0.6715	4.0	0.0782	1.1326	19.0	0.1137	1.6027	34.0	0.1443	2.0587
-10.9	0.0399	0.7100	4.1	0.0785	1.1276	19.1	0.1140	1.6047	34.1	0.1444	1.9685
-10.8	0.0400	0.6464	4.2	0.0788	1.1271	19.2	0.1144	1.6058	34.2	0.1446	1.9485
-10.7	0.0402	0.6152	4.3	0.0791	1.1514	19.3	0.1147	1.6337	34.3	0.1447	1.9879
-10.6	0.0404	0.6112	4.4	0.0794	1.1802	19.4	0.1151	1.6875	34.4	0.1449	2.0038
-10.5	0.0406	0.6171	4.5	0.0797	1.1862	19.5	0.1154	1.6222	34.5	0.1451	1.9797
-10.4	0.0408	0.6233	4.6	0.0800	1.1550	19.6	0.1158	1.5808	34.6	0.1453	1.9714
-10.3	0.0411	0.6384	4.7	0.0803	1.1503	19.7	0.1161	1.6155	34.7	0.1456	2.0035
-10.2	0.0414	0.6080	4.8	0.0806	1.1511	19.8	0.1164	1.6645	34.8	0.1459	2.0024
-10.1	0.0417	0.6240	4.9	0.0809	1.1422	19.9	0.1167	1.6580	34.9	0.1462	2.0453
-10.0	0.0421	0.6355	5.0	0.0812	1.1318	20.0	0.1170	1.6623	35.0	0.1465	2.0941
-9.9	0.0424	0.6813	5.1	0.0815	1.1524	20.1	0.1173	1.6497	35.1	0.1468	2.0085
-9.8	0.0428	0.6797	5.2	0.0818	1.1711	20.2	0.1176	1.6666	35.2	0.1471	1.9644

-9.7	0.0432	0.7163	5.3	0.0821	1.1569	20.3	0.1179	1.6722	35.3	0.1474	1.9742
-9.6	0.0436	0.6748	5.4	0.0824	1.1763	20.4	0.1182	1.6574	35.4	0.1477	2.0121
-9.5	0.0440	0.6467	5.5	0.0827	1.1516	20.5	0.1184	1.6609	35.5	0.1480	2.1852
-9.4	0.0444	0.6702	5.6	0.0831	1.1817	20.6	0.1187	1.6860	35.6	0.1482	2.3169
-9.3	0.0447	0.7284	5.7	0.0834	1.2192	20.7	0.1190	1.6738	35.7	0.1484	2.1810
-9.2	0.0451	0.7229	5.8	0.0838	1.1921	20.8	0.1192	1.6133	35.8	0.1487	2.2082
-9.1	0.0454	0.7248	5.9	0.0841	1.1933	20.9	0.1195	1.6544	35.9	0.1489	2.3447
-9.0	0.0457	0.7503	6.0	0.0845	1.2311	21.0	0.1197	1.7167	36.0	0.1492	2.2237
-8.9	0.0459	0.7839	6.1	0.0848	1.1878	21.1	0.1199	1.7512	36.1	0.1494	2.0025
-8.8	0.0462	0.7716	6.2	0.0851	1.2083	21.2	0.1201	1.7474	36.2	0.1497	1.9607
-8.7	0.0464	0.7413	6.3	0.0854	1.2830	21.3	0.1203	1.7297	36.3	0.1500	1.9573
-8.6	0.0466	0.7266	6.4	0.0857	1.2855	21.4	0.1204	1.6647	36.4	0.1503	1.9867
-8.5	0.0468	0.7015	6.5	0.0859	1.2717	21.5	0.1206	1.6241	36.5	0.1506	2.0449
-8.4	0.0470	0.7344	6.6	0.0862	1.2573	21.6	0.1207	1.6316	36.6	0.1509	2.0569
-8.3	0.0472	0.7344	6.7	0.0864	1.2706	21.7	0.1208	1.6823	36.7	0.1512	2.0772
-8.2	0.0474	0.7158	6.8	0.0867	1.2702	21.8	0.1209	1.7033	36.8	0.1515	2.0859
-8.1	0.0476	0.7474	6.9	0.0869	1.2311	21.9	0.1211	1.7056	36.9	0.1518	2.0958
-8.0	0.0478	0.7402	7.0	0.0872	1.1996	22.0	0.1212	1.7039	37.0	0.1520	2.0645
-7.9	0.0481	0.7363	7.1	0.0875	1.2142	22.1	0.1213	1.7349	37.1	0.1523	2.1749
-7.8	0.0483	0.7367	7.2	0.0877	1.2315	22.2	0.1215	1.7461	37.2	0.1525	2.3145
-7.7	0.0486	0.7271	7.3	0.0880	1.2130	22.3	0.1217	1.7101	37.3	0.1526	2.1906
-7.6	0.0489	0.7210	7.4	0.0883	1.2394	22.4	0.1218	1.7015	37.4	0.1528	1.9444
-7.5	0.0491	0.7725	7.5	0.0886	1.2679	22.5	0.1220	1.7409	37.5	0.1529	1.9729
-7.4	0.0494	0.7659	7.6	0.0889	1.3012	22.6	0.1222	1.7094	37.6	0.1531	2.0583
-7.3	0.0497	0.7927	7.7	0.0892	1.3741	22.7	0.1224	1.7164	37.7	0.1532	2.1292
-7.2	0.0500	0.8131	7.8	0.0895	1.3692	22.8	0.1227	1.8016	37.8	0.1534	2.1450
-7.1	0.0503	0.8252	7.9	0.0897	1.3498	22.9	0.1229	1.7587	37.9	0.1535	2.1237
-7.0	0.0506	0.8200	8.0	0.0900	1.3409	23.0	0.1231	1.6706	38.0	0.1537	2.1103
-6.9	0.0509	0.7969	8.1	0.0902	1.3256	23.1	0.1233	1.6757	38.1	0.1538	2.1626
-6.8	0.0512	0.7708	8.2	0.0904	1.2765	23.2	0.1235	1.6969	38.2	0.1540	2.1567
-6.7	0.0516	0.7470	8.3	0.0906	1.2767	23.3	0.1238	1.6599	38.3	0.1541	2.1621
-6.6	0.0519	0.7486	8.4	0.0908	1.2745	23.4	0.1240	1.7202	38.4	0.1543	2.2042
-6.5	0.0522	0.8270	8.5	0.0911	1.2774	23.5	0.1242	1.8235	38.5	0.1544	2.1892
-6.4	0.0526	0.8604	8.6	0.0913	1.2877	23.6	0.1243	1.8266	38.6	0.1545	2.2078
-6.3	0.0530	0.8341	8.7	0.0915	1.3105	23.7	0.1245	1.7784	38.7	0.1546	2.2117
-6.2	0.0534	0.8407	8.8	0.0918	1.3251	23.8	0.1246	1.7442	38.8	0.1547	2.1977
-6.1	0.0538	0.7869	8.9	0.0921	1.3277	23.9	0.1247	1.7254	38.9	0.1547	2.1750
-6.0	0.0542	0.7756	9.0	0.0925	1.3017	24.0	0.1249	1.6929	39.0	0.1548	2.1259
-5.9	0.0546	0.8160	9.1	0.0928	1.3137	24.1	0.1250	1.7345	39.1	0.1548	2.1259
-5.8	0.0550	0.8569	9.2	0.0932	1.3276	24.2	0.1251	1.7542	39.2	0.1548	2.1259
-5.7	0.0554	0.8599	9.3	0.0936	1.3611	24.3	0.1252	1.7685	39.3	0.1548	2.1259
-5.6	0.0557	0.8532	9.4	0.0939	1.3366	24.4	0.1254	1.7366	39.4	0.1548	2.1259
-5.5	0.0561	0.8438	9.5	0.0943	1.2996	24.5	0.1255	1.8313	39.5	0.1547	2.1259
-5.4	0.0564	0.9292	9.6	0.0946	1.3585	24.6	0.1257	1.8007	39.6	0.1548	
-5.3	0.0568	0.9242	9.7	0.0949	1.3476	24.7	0.1259	1.7211	39.7	0.1548	
-5.2	0.0571	0.8855	9.8	0.0951	1.3994	24.8	0.1261	1.6970	39.8	0.1551	
-5.1	0.0574	0.8897	9.9	0.0953	1.5015	24.9	0.1264	1.7388	39.9	0.1555	

D2

Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))	Temp. (°C)	DSC (mW/mg)	*c* (J/(g·K))
-20.0	-0.0428		-5.0	0.0836	1.2818	10.0	0.1236	1.8246	25.0	0.1656	2.3652
-19.9	-0.0361		-4.9	0.0839	1.2169	10.1	0.1238	1.7834	25.1	0.1659	2.2715
-19.8	-0.0300		-4.8	0.0843	1.2655	10.2	0.1241	1.7696	25.2	0.1663	2.2398
-19.7	-0.0239		-4.7	0.0846	1.3152	10.3	0.1243	1.7320	25.3	0.1666	2.4206
-19.6	-0.0179		-4.6	0.0849	1.3095	10.4	0.1245	1.7449	25.4	0.1670	2.4668
-19.5	-0.0120		-4.5	0.0853	1.2823	10.5	0.1247	1.7395	25.5	0.1673	2.4047
-19.4	-0.0063		-4.4	0.0857	1.2944	10.6	0.1249	1.8356	25.6	0.1677	2.3578
-19.3	-0.0008		-4.3	0.0860	1.2302	10.7	0.1250	1.8645	25.7	0.1680	2.3524
-19.2	0.0044		-4.2	0.0864	1.2053	10.8	0.1252	1.8228	25.8	0.1683	2.3404
-19.1	0.0094		-4.1	0.0868	1.2749	10.9	0.1253	1.7909	25.9	0.1687	2.3254
-19.0	0.0142		-4.0	0.0872	1.3520	11.0	0.1255	1.7936	26.0	0.1690	2.3127
-18.9	0.0187		-3.9	0.0875	1.3707	11.1	0.1256	1.8198	26.1	0.1693	2.3430
-18.8	0.0228		-3.8	0.0878	1.3803	11.2	0.1257	1.8178	26.2	0.1697	2.3760

-18.7	0.0266		-3.7	0.0881	1.3684	11.3	0.1259	1.8232	26.3	0.1700	2.3912
-18.6	0.0301		-3.6	0.0884	1.3607	11.4	0.1260	1.8153	26.4	0.1703	2.4156
-18.5	0.0333		-3.5	0.0886	1.3684	11.5	0.1262	1.7982	26.5	0.1707	2.4101
-18.4	0.0361		-3.4	0.0889	1.4320	11.6	0.1264	1.7915	26.6	0.1710	2.3970
-18.3	0.0387		-3.3	0.0891	1.4367	11.7	0.1266	1.7524	26.7	0.1714	2.3581
-18.2	0.0409		-3.2	0.0892	1.3822	11.8	0.1268	1.7470	26.8	0.1718	2.3666
-18.1	0.0428		-3.1	0.0894	1.3226	11.9	0.1270	1.7774	26.9	0.1722	2.3958
-18.0	0.0445		-3.0	0.0896	1.2968	12.0	0.1273	1.8019	27.0	0.1726	2.3827
-17.9	0.0460		-2.9	0.0897	1.3112	12.1	0.1275	1.8621	27.1	0.1730	2.3840
-17.8	0.0472		-2.8	0.0899	1.3298	12.2	0.1278	1.8776	27.2	0.1734	2.4077
-17.7	0.0483		-2.7	0.0901	1.3093	12.3	0.1280	1.8870	27.3	0.1738	2.4047
-17.6	0.0492		-2.6	0.0903	1.3485	12.4	0.1283	1.8491	27.4	0.1743	2.4221
-17.5	0.0500		-2.5	0.0905	1.3671	12.5	0.1286	1.8531	27.5	0.1747	2.4537
-17.4	0.0507		-2.4	0.0907	1.3488	12.6	0.1288	1.8454	27.6	0.1750	2.4986
-17.3	0.0513		-2.3	0.0909	1.3190	12.7	0.1291	1.8313	27.7	0.1754	2.4610
-17.2	0.0518		-2.2	0.0912	1.3809	12.8	0.1293	1.8187	27.8	0.1757	2.4306
-17.1	0.0522		-2.1	0.0914	1.4284	12.9	0.1296	1.7446	27.9	0.1760	2.4752
-17.0	0.0526		-2.0	0.0917	1.4075	13.0	0.1298	1.7418	28.0	0.1763	2.5024
-16.9	0.0530		-1.9	0.0919	1.3737	13.1	0.1300	1.8361	28.1	0.1765	2.4898
-16.8	0.0534		-1.8	0.0922	1.4049	13.2	0.1302	2.0109	28.2	0.1767	2.4601
-16.7	0.0537		-1.7	0.0924	1.3988	13.3	0.1305	2.0406	28.3	0.1768	2.4964
-16.6	0.0539		-1.6	0.0927	1.3766	13.4	0.1307	1.9567	28.4	0.1770	2.5209
-16.5	0.0542		-1.5	0.0929	1.3720	13.5	0.1309	1.9244	28.5	0.1772	2.4586
-16.4	0.0545		-1.4	0.0931	1.3566	13.6	0.1311	1.9110	28.6	0.1773	2.4738
-16.3	0.0547		-1.3	0.0933	1.3456	13.7	0.1313	1.8677	28.7	0.1775	2.4696
-16.2	0.0550		-1.2	0.0936	1.3694	13.8	0.1316	1.8424	28.8	0.1777	2.3932
-16.1	0.0552		-1.1	0.0938	1.3631	13.9	0.1318	1.8100	28.9	0.1780	2.4058
-16.0	0.0555		-1.0	0.0940	1.3877	14.0	0.1320	1.8314	29.0	0.1783	2.4273
-15.9	0.0557		-0.9	0.0943	1.4231	14.1	0.1323	1.8746	29.1	0.1786	2.4066
-15.8	0.0559		-0.8	0.0945	1.3605	14.2	0.1326	1.8502	29.2	0.1789	2.4459
-15.7	0.0561		-0.7	0.0948	1.3892	14.3	0.1328	1.8932	29.3	0.1793	2.4931
-15.6	0.0564		-0.6	0.0951	1.4835	14.4	0.1331	1.9197	29.4	0.1797	2.5211
-15.5	0.0566		-0.5	0.0953	1.4560	14.5	0.1334	1.8968	29.5	0.1801	2.5330
-15.4	0.0568		-0.4	0.0956	1.4394	14.6	0.1337	1.8890	29.6	0.1805	2.5283
-15.3	0.0570		-0.3	0.0959	1.4747	14.7	0.1340	1.9149	29.7	0.1809	2.5328
-15.2	0.0572		-0.2	0.0961	1.4736	14.8	0.1343	1.9307	29.8	0.1813	2.5418
-15.1	0.0575		-0.1	0.0963	1.4422	14.9	0.1346	1.9171	29.9	0.1817	2.5493
-15.0	0.0577	0.8844	0.0	0.0965	1.4047	15.0	0.1350	1.9230	30.0	0.1821	2.5449
-14.9	0.0579	0.8844	0.1	0.0967	1.4235	15.1	0.1353	1.9161	30.1	0.1824	2.5625
-14.8	0.0581	0.8844	0.2	0.0969	1.4893	15.2	0.1356	1.9294	30.2	0.1828	2.5353
-14.7	0.0584	0.8844	0.3	0.0970	1.4369	15.3	0.1359	1.9292	30.3	0.1831	2.6004
-14.6	0.0586	0.8844	0.4	0.0970	1.3880	15.4	0.1363	1.9391	30.4	0.1834	2.6192
-14.5	0.0589	0.8844	0.5	0.0971	1.4587	15.5	0.1366	1.9180	30.5	0.1838	2.4375
-14.4	0.0592	0.8903	0.6	0.0971	1.5274	15.6	0.1369	1.9201	30.6	0.1841	2.3649
-14.3	0.0594	0.9967	0.7	0.0971	1.4723	15.7	0.1373	2.0037	30.7	0.1844	2.5130
-14.2	0.0597	1.0252	0.8	0.0970	1.4397	15.8	0.1376	1.9697	30.8	0.1847	2.5945
-14.1	0.0600	1.0029	0.9	0.0970	1.4508	15.9	0.1379	1.9607	30.9	0.1850	2.5790
-14.0	0.0602	1.0062	1.0	0.0969	1.4388	16.0	0.1382	1.9988	31.0	0.1853	2.6072
-13.9	0.0605	1.0094	1.1	0.0969	1.4062	16.1	0.1385	2.0239	31.1	0.1857	2.6434
-13.8	0.0607	0.9663	1.2	0.0968	1.3857	16.2	0.1389	1.9904	31.2	0.1860	2.6322
-13.7	0.0609	0.9836	1.3	0.0967	1.3595	16.3	0.1392	1.9755	31.3	0.1863	2.5117
-13.6	0.0611	1.0006	1.4	0.0967	1.4064	16.4	0.1395	1.9770	31.4	0.1866	2.5654
-13.5	0.0613	1.0176	1.5	0.0967	1.4391	16.5	0.1398	1.9398	31.5	0.1869	2.7499
-13.4	0.0615	0.9798	1.6	0.0966	1.4289	16.6	0.1402	1.9296	31.6	0.1872	2.7066
-13.3	0.0617	0.9664	1.7	0.0966	1.4451	16.7	0.1406	1.9864	31.7	0.1875	2.6323
-13.2	0.0619	0.9533	1.8	0.0966	1.4605	16.8	0.1409	2.0368	31.8	0.1877	2.6075
-13.1	0.0621	0.9737	1.9	0.0966	1.4414	16.9	0.1413	1.9887	31.9	0.1880	2.5775
-13.0	0.0624	0.9895	2.0	0.0966	1.4181	17.0	0.1417	1.9834	32.0	0.1882	2.5912
-12.9	0.0626	0.9396	2.1	0.0966	1.4059	17.1	0.1421	2.0289	32.1	0.1885	2.6613
-12.8	0.0629	0.9373	2.2	0.0966	1.4028	17.2	0.1425	2.0554	32.2	0.1887	2.7330
-12.7	0.0631	1.0404	2.3	0.0967	1.3815	17.3	0.1429	2.0654	32.3	0.1890	2.7114
-12.6	0.0634	1.0668	2.4	0.0968	1.4012	17.4	0.1432	2.0655	32.4	0.1892	2.6513
-12.5	0.0637	1.0397	2.5	0.0969	1.4171	17.5	0.1436	2.0311	32.5	0.1895	2.4782
-12.4	0.0640	1.0493	2.6	0.0971	1.4374	17.6	0.1439	2.0266	32.6	0.1898	2.5183
-12.3	0.0643	1.0428	2.7	0.0972	1.4452	17.7	0.1442	2.0057	32.7	0.1901	2.6428

-12.2	0.0646	1.0261	2.8	0.0975	1.4084	17.8	0.1445	2.0058	32.8	0.1904	2.6489
-12.1	0.0648	1.0039	2.9	0.0977	1.4119	17.9	0.1448	2.0276	32.9	0.1907	2.6757
-12.0	0.0651	1.0254	3.0	0.0980	1.4103	18.0	0.1450	2.0765	33.0	0.1910	2.7218
-11.9	0.0654	1.0515	3.1	0.0984	1.3928	18.1	0.1453	2.1326	33.1	0.1914	2.6927
-11.8	0.0656	1.0241	3.2	0.0987	1.4326	18.2	0.1455	2.1143	33.2	0.1918	2.6543
-11.7	0.0659	0.9884	3.3	0.0990	1.4496	18.3	0.1458	2.0540	33.3	0.1921	2.6177
-11.6	0.0661	1.0018	3.4	0.0994	1.4524	18.4	0.1460	2.0535	33.4	0.1925	2.6534
-11.5	0.0663	1.0607	3.5	0.0998	1.4733	18.5	0.1463	2.0772	33.5	0.1928	2.6551
-11.4	0.0665	1.0597	3.6	0.1002	1.4886	18.6	0.1466	2.0491	33.6	0.1931	2.6530
-11.3	0.0667	1.1208	3.7	0.1006	1.4606	18.7	0.1469	2.0484	33.7	0.1935	2.7025
-11.2	0.0669	1.1316	3.8	0.1010	1.4743	18.8	0.1472	2.0711	33.8	0.1938	2.7347
-11.1	0.0670	1.1032	3.9	0.1014	1.5028	18.9	0.1475	2.0782	33.9	0.1941	2.8007
-11.0	0.0671	1.1352	4.0	0.1018	1.5026	19.0	0.1479	2.0905	34.0	0.1944	2.7288
-10.9	0.0673	1.1281	4.1	0.1023	1.4956	19.1	0.1482	2.0945	34.1	0.1946	2.6782
-10.8	0.0674	1.0726	4.2	0.1027	1.4801	19.2	0.1485	2.0951	34.2	0.1949	2.6514
-10.7	0.0676	1.0236	4.3	0.1032	1.4699	19.3	0.1488	2.1638	34.3	0.1952	2.6897
-10.6	0.0677	1.0171	4.4	0.1037	1.4560	19.4	0.1492	2.1782	34.4	0.1956	2.7003
-10.5	0.0679	1.0292	4.5	0.1042	1.3965	19.5	0.1495	2.0419	34.5	0.1959	2.6917
-10.4	0.0681	1.0256	4.6	0.1047	1.4085	19.6	0.1498	2.0217	34.6	0.1963	2.7012
-10.3	0.0684	1.0583	4.7	0.1052	1.4777	19.7	0.1501	2.1435	34.7	0.1967	2.7259
-10.2	0.0687	1.0328	4.8	0.1057	1.4999	19.8	0.1505	2.2217	34.8	0.1971	2.7478
-10.1	0.0690	1.0277	4.9	0.1061	1.5279	19.9	0.1508	2.0772	34.9	0.1976	2.7831
-10.0	0.0694	1.0707	5.0	0.1066	1.5789	20.0	0.1512	2.0543	35.0	0.1980	2.8084
-9.9	0.0698	1.1194	5.1	0.1071	1.6402	20.1	0.1515	2.1257	35.1	0.1985	2.7057
-9.8	0.0703	1.1398	5.2	0.1075	1.6308	20.2	0.1519	2.1411	35.2	0.1990	2.6231
-9.7	0.0708	1.1197	5.3	0.1079	1.5762	20.3	0.1523	2.1047	35.3	0.1995	2.6412
-9.6	0.0712	1.1237	5.4	0.1083	1.5431	20.4	0.1526	2.1335	35.4	0.1999	2.7427
-9.5	0.0717	1.1089	5.5	0.1087	1.5245	20.5	0.1530	2.1625	35.5	0.2004	2.8606
-9.4	0.0721	1.0908	5.6	0.1091	1.5510	20.6	0.1534	2.1830	35.6	0.2008	2.9269
-9.3	0.0726	1.1340	5.7	0.1095	1.5602	20.7	0.1538	2.1651	35.7	0.2013	2.9546
-9.2	0.0730	1.1553	5.8	0.1099	1.5426	20.8	0.1541	2.1462	35.8	0.2017	3.0794
-9.1	0.0733	1.1722	5.9	0.1103	1.5521	20.9	0.1545	2.2136	35.9	0.2021	3.2024
-9.0	0.0736	1.2179	6.0	0.1107	1.5879	21.0	0.1548	2.2241	36.0	0.2025	3.0890
-8.9	0.0738	1.2165	6.1	0.1111	1.5521	21.1	0.1551	2.2207	36.1	0.2028	2.9031
-8.8	0.0741	1.2010	6.2	0.1114	1.5913	21.2	0.1553	2.2397	36.2	0.2032	2.8082
-8.7	0.0742	1.2018	6.3	0.1118	1.6345	21.3	0.1555	2.2151	36.3	0.2035	2.7218
-8.6	0.0744	1.2280	6.4	0.1122	1.6454	21.4	0.1557	2.2116	36.4	0.2038	2.6548
-8.5	0.0745	1.1701	6.5	0.1126	1.6329	21.5	0.1558	2.1884	36.5	0.2041	2.7041
-8.4	0.0746	1.1474	6.6	0.1130	1.5920	21.6	0.1560	2.1310	36.6	0.2044	2.7316
-8.3	0.0747	1.1557	6.7	0.1134	1.6150	21.7	0.1561	2.1247	36.7	0.2047	2.7209
-8.2	0.0748	1.1573	6.8	0.1137	1.6480	21.8	0.1563	2.1251	36.8	0.2050	2.7819
-8.1	0.0749	1.1478	6.9	0.1141	1.6784	21.9	0.1565	2.1408	36.9	0.2053	2.8045
-8.0	0.0750	1.1470	7.0	0.1145	1.7009	22.0	0.1567	2.1633	37.0	0.2056	2.9461
-7.9	0.0752	1.1555	7.1	0.1148	1.6887	22.1	0.1570	2.2302	37.1	0.2059	3.0701
-7.8	0.0754	1.1507	7.2	0.1151	1.6795	22.2	0.1573	2.2529	37.2	0.2062	2.9315
-7.7	0.0756	1.1289	7.3	0.1155	1.6764	22.3	0.1576	2.2351	37.3	0.2065	2.7470
-7.6	0.0758	1.1394	7.4	0.1158	1.6787	22.4	0.1579	2.2530	37.4	0.2069	2.6784
-7.5	0.0761	1.1464	7.5	0.1161	1.6715	22.5	0.1583	2.2876	37.5	0.2072	2.6789
-7.4	0.0764	1.1801	7.6	0.1164	1.6645	22.6	0.1587	2.2324	37.6	0.2076	2.7616
-7.3	0.0766	1.2087	7.7	0.1167	1.6471	22.7	0.1591	2.1708	37.7	0.2079	2.8764
-7.2	0.0769	1.2325	7.8	0.1170	1.6265	22.8	0.1595	2.2666	37.8	0.2083	2.9674
-7.1	0.0772	1.2604	7.9	0.1173	1.6831	22.9	0.1599	2.2642	37.9	0.2087	2.9701
-7.0	0.0774	1.2557	8.0	0.1176	1.7119	23.0	0.1603	2.2407	38.0	0.2091	2.9463
-6.9	0.0777	1.2141	8.1	0.1179	1.7222	23.1	0.1606	2.2663	38.1	0.2096	2.9658
-6.8	0.0780	1.2202	8.2	0.1181	1.7625	23.2	0.1610	2.2758	38.2	0.2100	2.9662
-6.7	0.0783	1.1859	8.3	0.1184	1.7626	23.3	0.1613	2.2336	38.3	0.2104	2.9169
-6.6	0.0786	1.1806	8.4	0.1186	1.7337	23.4	0.1616	2.2491	38.4	0.2108	2.9954
-6.5	0.0788	1.2298	8.5	0.1189	1.6866	23.5	0.1618	2.3023	38.5	0.2112	3.0146
-6.4	0.0791	1.2398	8.6	0.1191	1.7000	23.6	0.1621	2.3147	38.6	0.2116	2.9953
-6.3	0.0795	1.2277	8.7	0.1194	1.6898	23.7	0.1623	2.2843	38.7	0.2120	2.9771
-6.2	0.0798	1.2482	8.8	0.1197	1.7023	23.8	0.1625	2.2588	38.8	0.2123	2.9669
-6.1	0.0801	1.2196	8.9	0.1199	1.7200	23.9	0.1626	2.2758	38.9	0.2127	2.9303
-6.0	0.0804	1.2032	9.0	0.1202	1.7196	24.0	0.1628	2.2787	39.0	0.2131	2.9239
-5.9	0.0808	1.2497	9.1	0.1206	1.7167	24.1	0.1630	2.2625	39.1	0.2135	2.9239
-5.8	0.0811	1.2584	9.2	0.1209	1.7403	24.2	0.1632	2.2610	39.2	0.2139	2.9239

-5.7	0.0814	1.2193	9.3	0.1212	1.7984	24.3	0.1634	2.2956	39.3	0.2143	2.9239
-5.6	0.0818	1.2223	9.4	0.1216	1.7429	24.4	0.1636	2.2650	39.4	0.2149	2.9239
-5.5	0.0821	1.2300	9.5	0.1219	1.6790	24.5	0.1639	2.2546	39.5	0.2154	2.9239
-5.4	0.0824	1.2975	9.6	0.1223	1.7314	24.6	0.1642	2.3140	39.6	0.2161	
-5.3	0.0827	1.3030	9.7	0.1226	1.7111	24.7	0.1645	2.3606	39.7	0.2169	
-5.2	0.0830	1.2852	9.8	0.1230	1.7411	24.8	0.1648	2.2985	39.8	0.2180	
-5.1	0.0833	1.3028	9.9	0.1233	1.8172	24.9	0.1652	2.3049	39.9	0.2195	

A.2.9 Thermal conductivity test

Group	Specimen number.	Dry mass [g]	Wet mass [g]	Moisture mass [g]	Moisture content [M.-%]	Thermal conductivity [W/mK]	Value average [W/mK]	Value deviation [W/mK]
original	D1	2127.00	2270.60	143.60	6.75%	0.4902	0.488	+/- 0.005
	D2	2165.00	2313.30	148.30	6.85%	0.4916		
	D3	2184.60	2343.80	159.20	7.29%	0.4817		
dry	D4	2160.30	2160.30	0	0.00%	0.4440	0.427	+/- 0.017
	D5	2144.70	2144.70	0	0.00%	0.4290		
	D6	2125.10	2125.10	0	0.00%	0.4094		
RH=50%	D4	2160.30	2271.00	110.70	5.12%	0.4806	0.463	+/- 0.019
	D5	2144.70	2257.80	113.10	5.27%	0.4656		
	D6	2125.10	2238.10	113.00	5.32%	0.4426		
RH=80%	D1	2127.00	2326.85	199.85	9.40%	0.4879	0.493	+/- 0.004
	D2	2165.00	2366.70	201.70	9.32%	0.4942		
	D3	2184.60	2368.70	184.10	8.43%	0.4955		

Group	Specimen number.	Dry mass [g]	Wet mass [g]	Moisture mass [g]	Moisture content [M.-%]	Thermal conductivity [W/mK]	Value average [W/mK]	Value deviation [W/mK]
original	E1	2193.80	2281.50	87.70	4.00%	0.2843	0.287	+/- 0.002
	E2	2221.30	2307.50	86.20	3.88%	0.2878		
	E3	2171.70	2257.40	85.70	3.95%	0.2888		
dry	E4	2258.30	2258.30	0	0.00%	0.2925	0.270	+/- 0.021
	E5	2174.60	2174.60	0	0.00%	0.2659		
	E6	2176.50	2176.50	0	0.00%	0.2503		
RH=50%	E4	2258.30	2283.50	25.20	1.12%	0.2949	0.272	+/- 0.021
	E5	2174.60	2199.80	25.20	1.16%	0.2696		
	E6	2176.50	2199.95	23.45	1.08%	0.2528		
RH=80%	E1	2193.80	2226.60	32.80	1.50%	0.2645	0.271	+/- 0.006
	E2	2221.30	2254.45	33.15	1.49%	0.2713		
	E3	2171.70	2211.25	39.55	1.82%	0.2757		

Group	Specimen number.	Dry mass [g]	Wet mass [g]	Moisture mass [g]	Moisture content [M.-%]	Thermal conductivity [W/mK]	Value average [W/mK]	Value deviation [W/mK]
original	F1	2084.90	2168.60	83.70	4.01%	0.3195	0.313	+/- 0.007
	F2	2033.60	2112.30	78.70	3.87%	0.3125		
	F3	1978.70	2059.80	81.10	4.10%	0.3057		
dry	F4	1931.10	1931.10	0	0.00%	0.2983	0.299	+/- 0.003
	F5	2036.40	2036.40	0	0.00%	0.2971		
	F6	1958.60	1958.60	0	0.00%	0.3030		
RH=50%	F4	1931.10	1962.40	31.30	1.62%	0.3031	0.302	+/- 0.003
	F5	2036.40	2067.20	30.80	1.51%	0.2979		
	F6	1958.60	1990.65	32.05	1.64%	0.3035		
RH=80%	F1	2084.90	2145.70	60.80	2.92%	0.3059	0.304	+/- 0.010
	F2	2033.60	2095.55	61.95	3.05%	0.3123		
	F3	1978.70	2041.15	62.45	3.16%	0.2927		

A.3 Annex 3 Collection of reference timber

Catalog		**Items**	**Representative value**	**Notation**	**Unit**
Basic properties		Bulk density	Dry state	ρ_d	[kg/m^3]
		Porosity	Dry state	Φ	[-]
Hygric properties	Moisture storage	Equilibrium moisture content	Equilibrium moisture content (RH=50%)	w_{50}	kg/m^3
			Equilibrium moisture content (RH=80%)	w_{80}	kg/m^3
			Free water saturation	w_{cap}	kg/m^3
	Moisture transport	Water vapor diffusion resistance factor	Dry state	μ_d	-
			Wet state (RH=50%)	μ_{50}	-
			Wet state (RH=80%)	μ_{80}	-
		Liquid transport rate	Liquid transport coefficient, suction (RH=80%)	DWS_{80}	[m^2/s]
			Water absorption coefficient	A	[kg/m^2·s$^{0.5}$]
Thermal properties	Heat storage	Specific heat capacity	Dry state	c	[J/kgK]
	Heat transport	Thermal conductivity	Dry state	λ_d	[W/mK]
			Moisture-dependent λ supplement	a_w	[%/M.-%]

Source	**Country / region**	**Abbreviation**
Fraunhofer IBP	Germany	IBP
Japan Database	Japan	JD
LTH Lund University	Sweden	LTH
MASEA Database	Germany	MD
North America Database	North America	NA
NTNU Norwegian University of Science and Technology	Norway	NU
University of Technology Vienna	Austria	TUV

Material name	Basic					Hygric					Thermal			Source
	ρ_d	Φ	w_{50}	w_{80}	w_{cap}	μ_d	μ_{50}	μ_{80}	A	DWS_{80}	c	λ_d	a_w	
Raw material - softwood														
Softwood	400	0.73	32	60	575	200	65	25			1400	0.09	1.3	IBP
Spruce, longitudinal	455	0.73	45	80	600	4.3	4.3	4.3		5.33E-11	1400	0.23	1.3	IBP
Spruce, radial	455	0.73	45	80	600	130	130	130		1.24E-12	1400	0.09	1.3	IBP
Spruce, tangential	430	0.73	47.5	77.5	140	83.3	83.3	25			1600	0.14	0	LTH
Spruce	400	0.9	18.1	55.8	845	552	66.5	12.8	0.002	3.35E-14	1880	0.086	0	NA
Scandinavian spruce transverse direction II	390	0.75	34.9	58.3	600	108	62	15		9.06E-13	1600	0.13	1.3	NU
Scandinavian spruce transverse direction	420	0.75	50.4	83.8	600	50	34.7	25.5			1600	0.13	1.3	NU
Spruce (density: 600 kg/m3)	600	0.2	44.17	72.09	121.87	132.62	94.08	48.77		6.64E-11	2000	0.16	0	TUV
KLH Massivholz	423	0.7	27.1	56.1	550	300	123.6	17.8			1500	0.12	1.3	IBP
GFM-Diagonalplatte (glue-free massive wood panel)	450	0.73	33.75	63	575.2	366.2	191.9	17.6			1400	0.13	1.3	IBP
Western Red Cedar	350	0.8	7.79	33.7	450	1963	423.8	133.4	0.001	3.15E-14	1880	0.084	0	NA
Eastern White Cedar	360	0.82	9.45	36.35	750	16515	429	26.6	0.0016	2.42E-14	1880	0.091	0	NA
Eastern White Pine	460	0.81	14.8	47.7	450	4427.4	308.7	41	0.0066	1.7E-12	1880	0.093	0	NA
Southern Yellow Pine	500	0.858	20.1	62.2	300	1734.1	151.9	23.6	0.0014	3.47E-13	1880	0.119	0	NA
Pine transverse direction, density 510	510	0.73	76	125.9	600	50	34.7	25.5		1.94E-12	1600	0.13	1.5	NU
Raw material - hardwood														
Hardwood	650	0.47	52	98	370	200	65	17			1400	0.13	1.3	IBP
Oak, longitudinal	685	0.72	70	115	500	8	8	8		1.77E-10	1400	0.3	1.3	IBP
Oak, radial	685	0.72	70	115	500	140	140	140		6.09E-12	1400	0.13	1.3	IBP
Oak Old	740	0.36	64.6	104	349	223	223	223	0.0016	6.26E-13	1400	0.1522	1.3	MD
Laminated timber														
Stora Enso CLT (cross laminated timber)	410	0.74	38	63	678	500	99.2	11.6			1300	0.098	2	IBP
3-ply cross-laminated panel	454	0.56	53	73	534	203	203	203		4E-12	1400	0.12	1.5	IBP
Laminated veneer lumber	462	0.627	55	76	525	156	156	156		1E-11	1400	0.13	1.5	IBP
Laminate flooring	800	0.42	77.5	117.5	245	2500	2500	625			1600	0.15	0	LTH
Plywood														
Veneer plywood BFU 100	427	0.66	47	70	572	188	188	188		7E-12	1400	0.12	1.5	IBP
Plywood board	500	0.5	40	75	350	700	200	92			1400	0.1	1.5	IBP
veneer plywood beech BFU-BU	708	0.53	62	101	530	242	242	242		4E-11	1400	0.12	1.5	IBP
Plywood	560	0.65	60	96.5	190	274	8.33	5.32			1500	0.13	0	LTH
BFU 100 Plywood	427	0.66	19.3	70	573	188	188	188	0.00216	1.26E-13	1400	0.0883	1.5	MD
Plywood low	400	0.64	25.2	54.8	236	493.1	150.8	29.6	0.0026	2.29E-12	1880	0.068	0	NA
Plywood (USA)	470	0.69	36.5	64.4	550	1078.2	142.5	45.4	0.0042	4.96E-13	1880	0.084	0	NA
Plywood, Exterior-Grade	578	0.96	37.9	71.1	148	782	495.8	70.6			1880	0.0984	1.5	NA
Plywood high	600	0.96	37.8	82.2	354	383.2	117.6	23	0.0026	1.02E-12	1880	0.101	0	NA
Plywood density 410	410	0.5	40.6	64.5	350	210	99.6	33.3			1600	0.13	1.5	NU
Plywood density 600	600	0.5	51	84.7	350	210	143.7	103.9			1600	0.13	1.5	NU
Wood-wool board														
SINIAT PUREBEL SOLO (wood-wool board)	420	0.801	42.7	73.5	396	5.7	5.6	5.5	0.467	1.90E-08	1400	0.0698	0.5	IBP
Wood-wool board	450	0.55	36	68	350	9	8	7.4			1400	0.08	2.5	IBP
Wood fibreboard														
medium density fibreboard #2	508	0.667	49	66	667	15	15	15		1E-12	1400	0.12	1.5	IBP
Medite Vent (MDF)	518	0.88	32.57	61.3	864.5	9.65	9.65	9.65	0.0013	1.4E-14	1700	0.0905	0	IBP
medium density fibreboard #1	528	0.8	50	70	667	12	12	12		1.5E-12	1400	0.1	1.5	IBP
AiF Rigid Underlay Board MDF, RWH	550	0.67	44	82.5	550	13	13	13	0.0075	1.99E-12	1400	0.09	1.5	IBP
AiF Wood-Fiber Board in humid environment MDF, RWH	550	0.67	44	82.5	550	13	13	13	0.0075	1.99E-12	1400	0.09	1.5	IBP
Woodfibreboard, hard	959	0.41	82.5	130	275	227	227	114			1700	0.13	0	LTH
Wood fibre board, hard - wind barrier	800	0.8	58.6	90.8	150	9	36.1	52.3			1700	0.18	1.5	NU
Woodfibre board, hard	800	0.8	58.6	90.8	150	48	48	48			1700	0.18	1.5	NU
Oriented strand board														

Oriented strand board (density 553 kg/m³)	553	0.61	49	76	610	134	134	134		1E-12	1400	0.12	1.5	IBP
Oriented strand board (density 595 kg/m³)	595	0.9	71	95	814	165	165	165		3E-12	1400	0.13	1.5	IBP
AiF OSB 3	600	0.6	48	90	570	267	197	127	0.00333	3.86E-13	1400	0.1	1.5	IBP
Oriented strand board (density 615 kg/m³)	615	0.9	69	92	636	175	175	175		9E-13	1400	0.13	1.5	IBP
AGEPAN OSB/3 PUR, 12mm	616	0.52	49.8	85.6	395	144	144	144		8.8E-12	2100	0.13	1.5	IBP
Smartply VapAirTight (structural OSB panel)	618	0.558	24.7	45.5	542.5	845	610.5	376	0.001	2.3E-14	1500	0.1	0	IBP
esb-Platte elka strong board P5 (OSB)	621	0.57	22.1	79	554	91.58	63.88	36.18	0.002	1.33E-13	2000	0.102	1.5	IBP
Oriented strand board (density 630 kg/m³)	630	0.6	50	95	470	650	401	157.6			1400	0.13	1.5	IBP
AiF OSB 4	650	0.57	52	97.5	541.5	276	227.5	179	0.00333	4.98E-13	1400	0.12	1.5	IBP
AGEPAN OSB/4 PUR, 12mm	679	0.41	46.5	79.3	326	520	520	520		2.7E-12	2100	0.13	1.5	IBP
OSB plate	593	0.84	47.5	76	724	227	227	227	0.002	5.99E-14	1500	0.0964	1.5	JD
OSB 3 (oriented strand board)	595	0.85	60	96	814	165	165	165	0.002	4.85E-14	1400	0.1049	1.5	MD
MSB (Microstrandboard)	664	0.67	56.6	90.5	587	92	92	92	0.00183	1.03E-13	1400	0.108	1.5	MD
Oriented Strand Board low	575	0.8625	30.8	71.3	333.5	1182	187.5	72.3	0.0022	7.24E-13	1880	0.084	0	NA
Oriented Strand Board	650	0.95	44	83.3	470	812.8	169.2	67.6	0.0022	2.83E-13	1880	0.092	0	NA
Oriented Strand Board high	725	0.95	38.9	89.9	420.5	1015.1	161.3	61.8	0.0022	4.55E-13	1880	0.115	0	NA
Chipboard / particleboard														
Chipboard	600	0.5	50	90	400	70	55	45			1400	0.11	1.5	IBP
Particle board V 100	620	0.74	74	110	738	44	44	44		3E-12	1400	0.12	1.5	IBP
Particle board (micro strand board)	664	0.62	56	91	590	92	92	92		5E-12	1400	0.12	1.5	IBP
Particleboard	660	0.59	65	105	200	125	125	62.5			1700	0.14	0	LTH
Chipboard V100 E1F0	620	0.74	32.7	110	520	44	44	44	0.03	5.45E-11	1400	0.111	1.5	MD
Particle board density 550	550	0.5	39.9	62.2	400	50	32.1	21.4			1700	0.14	1.5	NU
Particle board density 610	610	0.5	67	109.2	400	50	32.1	21.4			1700	0.14	1.5	NU
LivingBoard face contiprotect P5 (25mm)	655	0.61	40.7	73.8	579	107	85.1	65	0.0018	8.86E-14	1400	0.12	1.5	IBP
LivingBoard face contiprotect P5 (22mm)	661	0.63	41.2	74.4	595	107	87.2	69	0.0018	8.25E-14	1400	0.12	1.5	IBP
LivingBoard face contiprotect P5 (18mm)	668	0.65	41.5	75.3	617	107	90.3	75	0.0017	6.7E-14	1400	0.12	1.5	IBP
LivingBoard face contiprotect P5 (15mm)	673	0.66	41.8	75.9	633	107	92.9	80	0.0017	6.27E-14	1400	0.12	1.5	IBP
LivingBoard face contiprotect P5 (12mm)	679	0.68	42.2	76.5	649	107	95	84	0.0017	5.89E-14	1400	0.12	1.5	IBP
Other (unknown)														
Composite Wood Sliding	740	0.666	33.8	75.5	347	53.1	44.6	39	0.00072	7.35E-14	1880	0.094	0	NA

List of figures

List of tables