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EQUILIBRIUM MOISTURE CONTENT OF WOOD AT DIFFERENT TEMPERATURE/MOISTURE CONDITIONS IN THE CLADDING OF WOODEN CONSTRUCTIONS AND IN THE RELATION TO THEIR RELIABILITY AND SERVICE LIFE

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Abstract

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One of the natural properties of wood and wood-based materials is their soaking capacity (hygroscopicity). The moisture content of wood and building constructions of wood and wood based materials significantly influences the service life and reliability of these constructions and buildings. The equilibrium weight moisture content of built-in wood corresponding to temperature/moisture conditions inside the cladding has therefore a decisive influence on the basic requirements placed on building constructions. The wood in wooden frame cladding changes its moisture content depending on temperature and moisture conditions of the environment it is built into. The water vapor condensation doesn't necessarily have to occur right in the wooden framework of the cladding for the equilibrium moisture content to rise over the level permissible for the reliable function of a given construction. In spite of the fact that the common heat-technical assessment cannot be considered fully capable of detecting the effects of these factors on the functional reliability of wood-based constructions and buildings, an extension has been proposed of the present method of design an assessment of building constructions according to the ČSN 73 0540 standard regarding the interpretation of equilibrium moisture content in relation to the temperature/moisture conditions and their time behavior inside a construction.

equilibrium weight moisture content of wood, temperature and humidity of environment, reliability, service life, basic requirements placed on building constructions.

As part of the MSM 6215648902 research project we have been long studying the temperature/moisture conditions in the cladding of buildings with their main framework made of wood. The equilibrium weight moisture content of wood built into the cladding influences certain **basic requirements** cited in the annex 1NV No. 163/2002 Coll. as amended by NV No. 312/2005 Coll. respectively, No. 190/2005 Coll., subsequently amended. With today's trend towards increasing heat-insulation parameters of cladding intended to reduce the energy consumption needed for heating, it is important to take into account that building construction is, at the same time, also to comply in a reliable way with other basic requirements. An increase in heat-insulation properties of those constructions should therefore be conducted with respect to these requirements. When increasing one of the properties relating to the basic requirements, a reduction in the functional reliability of constructions and buildings regarding the basic requirements must not occur. The adequate service life or durability of wooden constructions and buildings must be ensured. (This requirement is set by ETAG 007 Guideline for European Technical Approval see. art. 4.7.1 – Wooden Frame Assemblies.) From the point of view of durability, the design of a wooden frame building assembly must ensure that the materials and parts wear during their expected service life would not significantly influence the behavior of the entire assembly with regard to compliance with basic requirements 1–6. The wear may be caused by physical, biological and chemical agents. This problem also relates to the public notice 268/2009 Coll. on technical requirements on buildings § 9, 10, 16 and 19.

MATERIAL AND METHODS

The design and production of reliable wooden framing requires above all a good knowledge of wood as a construction material that means, primarily the knowledge of its properties depending on an environment it is built in. These can often have an absolutely decisive influence on complying with the basic requirements placed on buildings. Using selected basic requirements, we will demonstrate the influence of equilibrium moisture content of wood built in construction on the latter's service life and reliability.

Basic requirement 1 – Mechanical resistance and stability

A building must be designed and constructed in such a way so that the loads expected to have an effect on it during the construction process and utilization would not lead to:

a) a higher grade of inadmissible deformation
b) a damage to other parts of the building or technical or installed equipment as a result of the main framework's deformation.

The ČSN 73 1702 standard – *Design, Calculation and Assessment of Wooden Constructions of Buildings – Main Guidelines and Guidelines for Civil Engineering* sets three classes of utilization for wooden constructions, characterizing the climatic environment of the building construction during its service life. The system of utilization classes is necessary due to the physical properties of wooden construction materials in order to assign strength values and to calculate the deformation at set deformation conditions. According to the classification of a construction element into one of the utilization classes and also according to the class of load duration, the strength properties of the material are modified by a modification coefficient k_{mod}, which lowers the strength of wood in the function of its rising equilibrium moisture content. In this case the impact of moisture content will not be as important as it would be in the case of assessment of the construction according to its limiting state of usability, when the time-dependent creeping deformations must be taken into account. Here, the initial deformation must be multiplied by $(1+k_{def})$ coefficient, where k_{def} is a coefficient related

I: *Equilibrium moisture content of wooden construction materials (tab. F. 3 – ČSN 73 1702 standard)*

Class of utilization	1	2	3
Wood moisture content	5–15 % [a)]	10–20 % [b)]	12–24 %

[a)] With most softwood types, the medium equilibrium moisture content of **12 %** is not exceeded in the utilization class 1.
[b)] With most softwood types, the medium equilibrium moisture content of **20 %** is not exceeded in the utilization class 2.

II: *The values of deformation coefficient k_{def} for wooden materials and their joints at stable and quasi-stable load (tab. F. 2 – ČSN 73 1702 standard)*

	Class of utilization		
	1	2	3
Solid wood [a)] **Glued laminated wood** **Glued wood composed of 2 or 3 lamellae** **Laminated wood [b)]** **Cross-laminated timber**	0.60	0.80	2.00
Plywood boards **Laminated wood [b)]**	0.80	1.00	2.50
OSB boards	1.50	2.25	-
Chipboards with synthetic binder **Wood-cement chipboards** **Fiberboards [d)]** **(type HB.HLA2 ČSN EN 622–2 standard)**	2.25	3.00	4.00
Fiberboards **(type HB.HLA2 ČSN EN 622-3 standard)** **Plaster boards**	3.00	4.00	-

[a)] The value of k_{def} for solid wood, whose moisture content at the moment of installation is near the fiber-saturation point or higher and can subsequently continue its drying once built-in must be increased by 1.0.
[b)] With all veneers in longitudinal orientation.
[c)] With cross-oriented veneers.
[d)] Not allowed for utilization class 3.

to wood moisture content (tab. II). For solid wood and for laminated and plywood elements, it is adequate to consider the decrease in wood strength at the rising moisture content by calculation in class 3; pronounced creeping must, nevertheless, be considered during deformation assessment already in utilization class 2. The wood moisture content has therefore a demonstrably important influence on basic requirement 1.

Basic requirement 3 – Hygiene, health and environment protection

The construction must be designed and built in such a way so that it wouldn't pose a threat to the hygiene or health of its dwellers, mainly due to:

f) Occurrence of moisture in parts of the construction or on the interior surfaces of the building.

The **ČSN** *EN 335 – 2* standards – *Durability of Wood and Wood-based Materials – Definition of Utilization Classes – Part 2: Application to Solid Wood, states in its article no.4 the following:*

4.1 Utilization class 1

In this environment, the moisture content in solid wood reaches such levels, that the risk of mould, wood-coloring or wood-destroying fungi attack stays negligible (this means that the moisture content in any part of the wood in any phase of its service life does not exceed 20%). A wood-borer attack including termites is possible, whereas the frequency and importance of this risk depends on given geographic region.

III: *Values of heat conductivity of wood in relation to its dry-state volume weight and moisture (Řehánek, 2002)*

ρ_s (kgm³)	λ (Wm⁻³K⁻¹) at w_m (%)					
	0	**2**	**5**	**10**	**20**	**30**
300	0.085	0.093	0.105	0.124	0.164	0.204
400	0.101	0.109	0.121	0.141	0.179	0.219
500	0.117	0.126	0.138	0.158	0.198	0.237

4.2 Utilization class 2

In this environment the moisture content in solid wood *occasionally* exceeds 20% in the whole or in parts and therefore allows a wood-destroying fungi attack.

4.3 Utilization class 3

In this environment, it can be expected that the moisture content in solid wood would frequently rise over 20% and the wood will be prone to wood-destroying fungi attack.

Unfortunately, the utilization classes according to ČSN EN 335 – 1 and 2 standards Durability of Wood and Wood-based Materials – Definition of Utilization Classes, do not correspond to the utilization classes according to the ČSN 73 1702 standard. The utilization class 1, according to ČSN EN 335 – 1 and 2 standards (in view of the equilibrium moisture content and risks of mould and wood-destroying fungi attack), roughly corresponds to the utilization class 1 – 2 according to ČSN 73 1702 standard. The utilization class 2, according to ČSN EN 335–1 and 2 standards, corresponds to the utilization classes 2 to 3 according to the ČSN 73 1502 standard. The moisture content in wood has a demonstrably important influence on the basic requirement 3 and also on the durability and service life of the construction.

Basic requirement 6 – Energy saving and protection of heat

A building and its heating, cooling and ventilation equipment must be designed and built in such a way so that the service energy consumption would be low with regard to the climatic conditions of the place and the requirements of its users.

Over the past 50 years, spruce wood has been used almost exclusively for the construction of cladding. The heat-technical standard ČSN 73 0540 doesn't differentiate between different types of softwood, but declares the least favorable value of the heat transfer coefficient. The characteristic value of heat conductivity for softwood in the ČSN 73 0540-3 standard corresponds to the heat conductivity of larch. In view of the heat technology it would be suitable to distinguish between wood types or use the design heat values contained in ČSN EN 12524 standard Construction Materials and Products – Heat – Moisture Properties – Table Design Values, where the values are organized according to volume weight of wood. The table III. shows that the wood moisture content influences on its heat conductivity and has therefore a demonstrably important influence on the basic requirement 6.

Contemporary method of construction assessment according to the ČSN 73 0540 standard

Obligation to assess the construction from the point of view of vapor condensation and moisture propagation in constructions is basically set by the **ČSN 73 0540-2 standard art. 6. 1**. The condensation inside the construction is not admitted for a construction where the condensed vapor inside it could pose a threat to its required function. $\mathbf{M_{c,a} = 0}$

For a construction where the condensed vapor does not pose a threat to its function, there is a limitation requirement of the annual volume of water

IV: *Water vapor diffusion under design conditions and moisture balance according to ČSN 730540 standard*

INTEPRETATION OF RESULTS ACCORDING TO ČSN 730540–2 (2007) STANDARDS

III. Requirements on moisture propagation in constructions (arts. 6.1 and 6.2 in ČSN 730540-2 standard)

Requirements:

1. Condensation of water vapor must not pose a threat to the function of a construction.
2. Annual volume of condensate must be lower than the annual evaporation capacity.
3. Annual volume of condensate Mc,a must be lower than **0.1 kg/m².year**, or **3%** of area weight of material (the lower of the values).

Limit for max. volume of condensate derived from min. area weight of material within the condensation zone is: **0.616 kg/m².year** (Isover Orsil Uni).
Next, a limit for the maximum volume of condensate will be used: **0.072 kg/m².year**

Calculated values: The condensation occurs at exterior design condensation temperature.
Annual volume of condensed water vapor **Mc,a = 0.0624 kg/m².year**
Annual volume of condensed water vapor **Mev,a = 0.6165 kg/m².year**

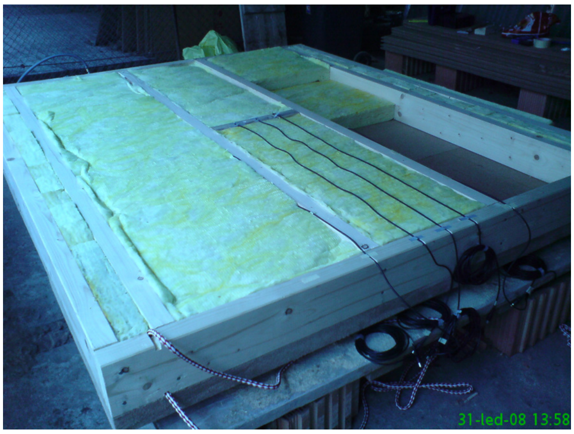
The interpretation of 1st requirement must be carried out by the designer.
Mc,a < Mev,a … 2. THE REQUIREMENT IS ACCOMPLISHED.
Mc,a < Mc,N … 3. THE REQUIREMENT IS ACCOMPLISHED.

vapor condensed inside the construction that must comply with the following condition:

$$M_{c,a} \leq M_{c,N}$$

The decision on whether the vapor condensation inside a construction does or does not pose a threat to its required function is left to the designer. The corresponding ČSN standard doesn't contain any further detailed procedures for his qualified decision (see IV).

In the majority of the cases of the common building praxis, the designers consider every construction as complying that meets the requirements **2.** and **3.** The requirements **2.** and **3.** are, nevertheless, complementary to accomplishing the requirement **1.**



1: *Sample of cladding equipped with built in moisture sensors*

2: *Placing of the sample in the air conditioned chambers of CBE Prague*

RESULTS

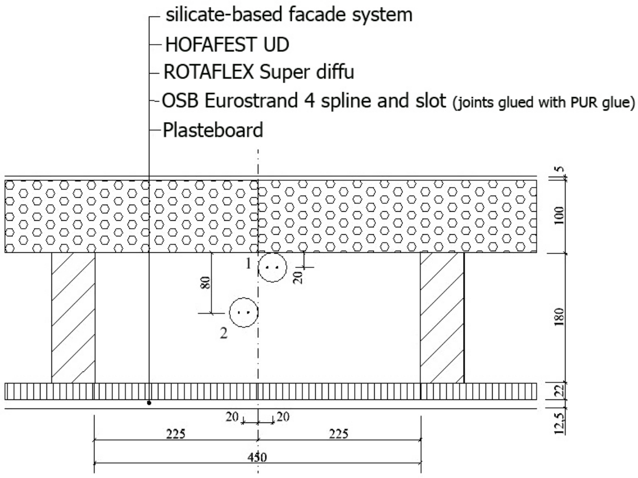
Measuring the equilibrium moisture content of the wooden frameworks of cladding

The measurement of equilibrium moisture content in diffusion-open cladding constructions (fig. 1, 3, 4) was carried out in air conditioned chambers of the accredited test laboratory of the Center of Building Engineering in Prague. (fig. 2). The central intertie of the sample (dimensions 2100 × 2500 mm) was first equipped with wood moisture sensors with temperature compensation WS-16T that were then connected via shielded cables to the Elbez MS3+ data hub.

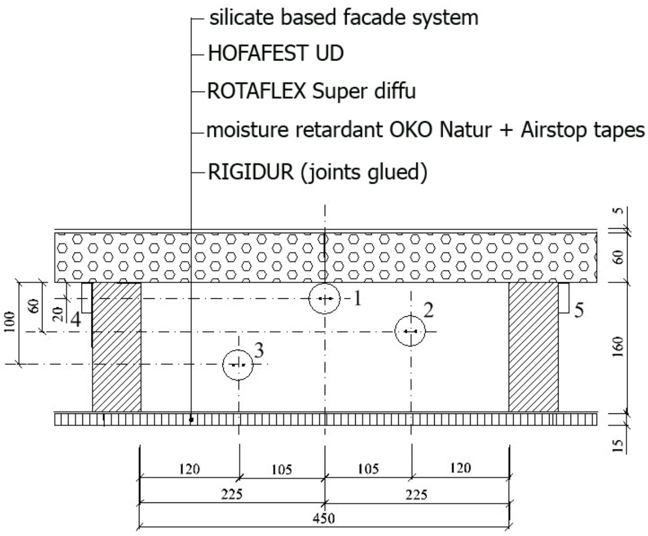
The test samples were subsequently exposed during a period of 14 days to the temperature conditions typical for the habitable rooms in winter. Marginal conditions of measurement including the measured values see Tabs. IX and X.

The measurements were taken at two types of diffusion-open constructions of cladding. Composition and distribution of sensors see figs. 3 and 4.

From the measured values of equilibrium moisture content of wood in wooden framework, it is evident that at both of these diffusion-open constructions, the softwood equilibrium moisture content of 20% will not be exceeded even under very unfavorable conditions.



3: *Sample of a Diffuwall® system cladding, characteristic sector with the distribution of sensors*



4: *Sample of a Rigips - diffuwall®, system cladding, characteristic sector with the distribution of sensors*

V: *Marginal conditions and measured equilibrium moisture contents of wood in the Diffuwall system®*

MEASUREMENT PROTOCOL – STATISTIC VALUES
Center name: Elbez
Ser. No.: 0603113
Type: MS3+
File: C:\Program Files\Comet\MSPlus\Data\Elbez\2007-01-23-CSI.msx
Interval: from 2nd January 2007 12:26:27 till 23rd January 2007 8:07:50

Channel	Minimum	Maximum	Average	Decisive variation	No. of samples
Ch. 1 Vlhk.D [%]	4.8	10.6	6.1	1.8	456
Ch. 2 Vlhk.D [%]	6.0	15.6	7.4	1.9	456
Ch. 12 T_in [°C]	18.4	21.2	20.2	0.5	456
Ch. 13 RH_in [%]	24.9	73.8	49.8	12.7	456
Ch. 14 T_out [°C]	15.6-	30.2	–9.5	12.8	456
Ch. 15 RH_out [%]	21.2	70.6	47.1	9.1	456

Subsequently we will carry out a comparison of measured values of moisture content in the wooden construction against the values determined according to the proposed method from the point of view of **criterion 1** of the ČSN 73 0540 standard.

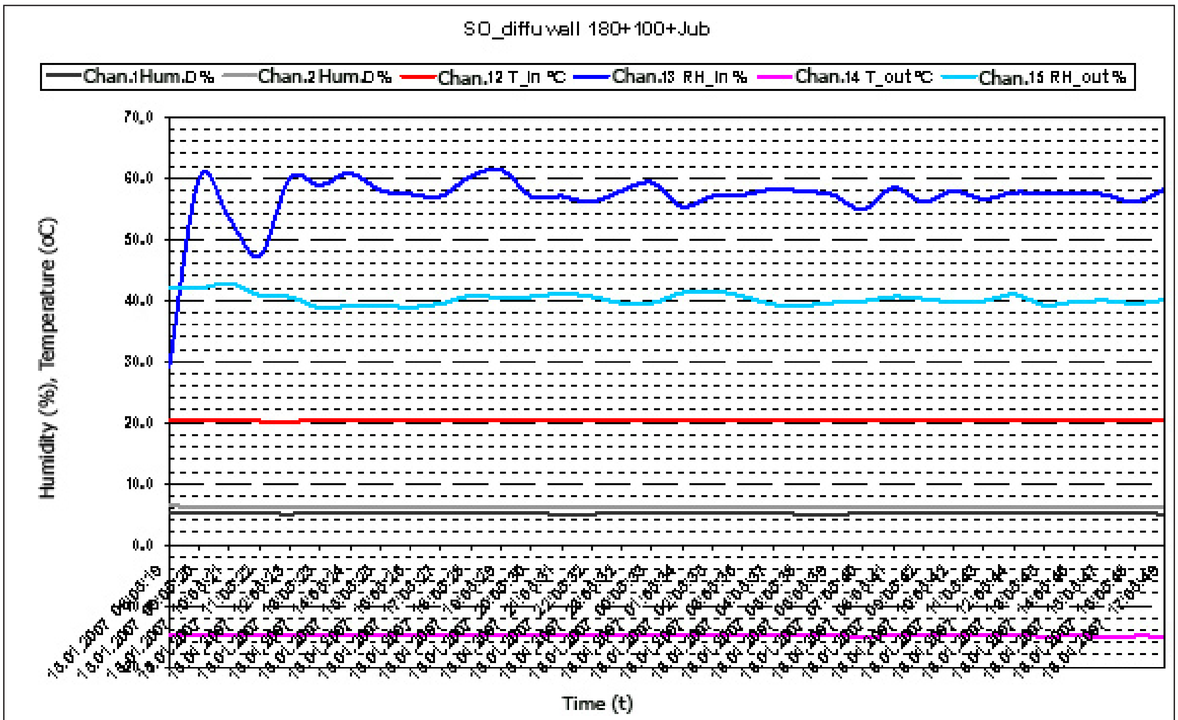
For the purpose of evaluating the **criterion 1**, sequences of approx. 36 – 48 hours were selected from

VI: *Marginal conditions and measured equilibrium moisture contents of wood in the Rigips-diffuwall® system*

MEASUREMENT PROTOCOL – STATISTIC VALUES

Center name: Elbez
Ser. No.: 0603113
Type: MS3+
File: C:\Program Files\Comet\MSPlus\Data\Elbez\2008-03-07-0849 RIGIPS konec.msx
Interval: from 18th February 2008 13:00:22 till 7th March 2008 9:06:50

Channel	Minimum	Maximum	Average	Decisive variation	No. of samples
Ch. 1 Vlhk.D [%]	7.6	12.1	7.8	0.3	336
Ch. 2 Vlhk.D [%]	6.6	11.4	7.2	0.4	336
Ch. 3 Vlhk.D [%]	6.0	11.0	6.8	0.5	336
Ch. 4 Vlhk.D [%]	4.6	11.4	5.2	0.4	336
Ch. 5 Vlhk.D [%]	4.5	10.6	47.8	0.3	336
Ch. 12 T_in [°C]	19.5	21.0	20.6	0.1	336
Ch. 13 RH_in [%]	15.4	87.4	67.1	4.4	336
Ch. 14 T_out [°C]	15.1-	22.9	–14.5	3.0	336
Ch. 15 RH_out [%]	14.9	59.5	44.6	2.5	336

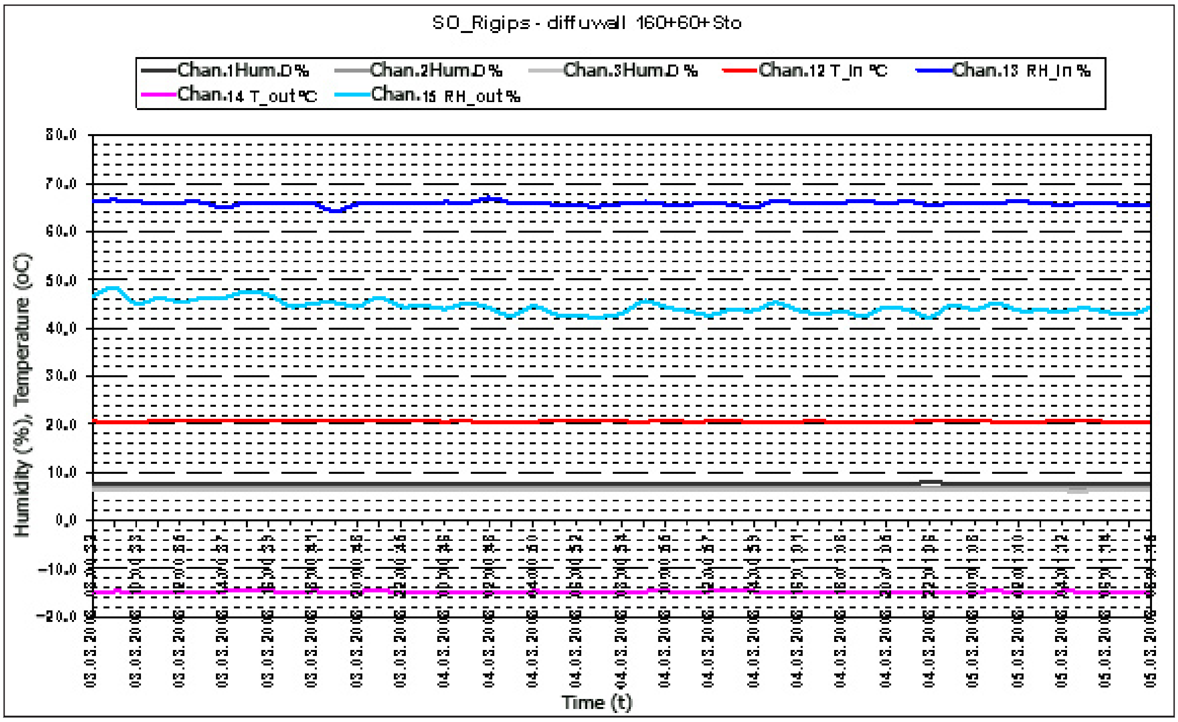


5: *Diffuwall® – development of temperature and humidity – quasi stabilized state*

the set of measurements, that can be considered as quasi-stabilized state of moisture equilibrium of the construction. The values measured in the end of each such quasi-stabilized state were then used for the calculation of temperatures and partial pressures development in the construction according the method of the ČSN 730540 standard (see figs. 5, 6 and tabs. VII and VIII). With the test-sample of Rigips-diffuwall, the sensors 4 and 5 were situated in the so-called compensation zone therefore the values measured by these sensors were eliminated from further evaluation.

Subsequently, the course of partial pressures of water vapor and temperatures inside the construction were calculated for these values of temperatures and relative humidities of interior and exterior air according to the method set by the ČSN 73 0540 standard. To such calculated values, the corresponding equilibrium moisture contents of wood were then assigned; see nomogram of equilibrium moisture content of N. N. Tchulicky (Pereligin L. M., 1960).

Highlighted values of wood moisture content correspond to the inner and outer side of the wooden framework and to the distribution of sensors inside the test sample. The other values of wood moisture content are taken on the layer interfaces and in 20mm intervals. **Sensor No. 2** placed in 80 mm distance form the exterior side of wooden frame-



6: *Rigips-diffuwall – development of temperature and humidity – quasi stabilized state*

VII: *Diffuwall 180+100+Jub_ measured values – quasi stabilized state*

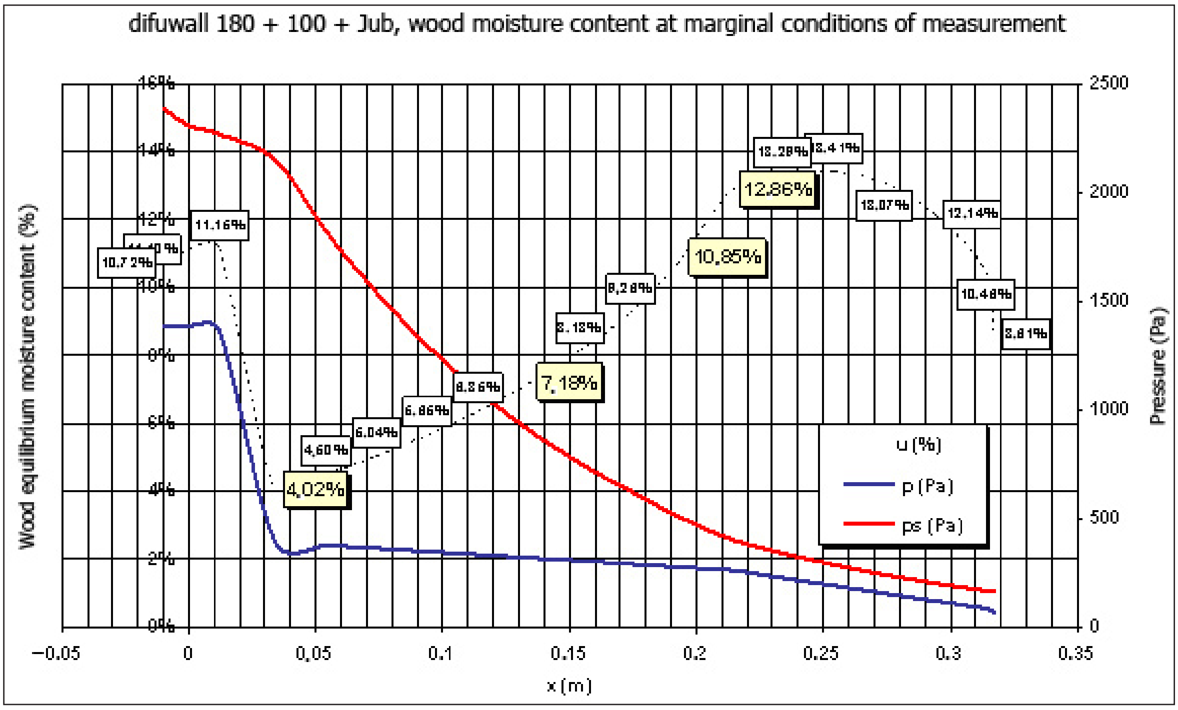
DATE AND TIME	Channel 1 moist. D	Channel 2 moist. D	Channel 12 T_in	Channel 13 RH_in	Channel 14 T_out	Channel 15 RH_out
	%	%	°C	%	°C	%
16.01.2007 17:05:49	5.0	6.2	**20.3**	**58.1**	**–15.0**	**40.1**

VIII: *Rigips-diffuwall 160+60+Sto_measured values – quasi stabilized state*

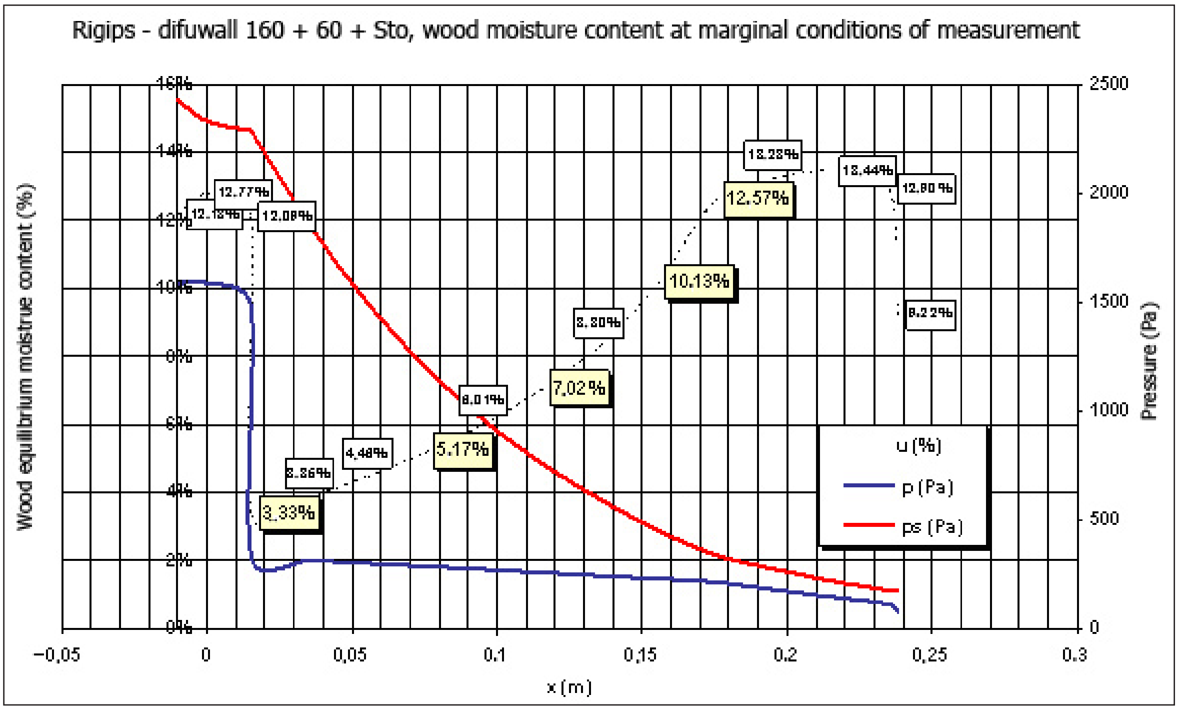
DATE AND TIME	Channel 1 moist. D	Channel 2 moist. D	Channel 3 moist. D	Channel 12 T_in	Channel 13 RH_in	Channel 14 T_out	Channel 15 RH_out
	%	%	%	°C	%	°C	%
05.03.2008 08:01:15	7.9	6.9	6.3	**20.6**	**65.4**	**–14.7**	**44.3**

work measured the wood moisture content of 6.2 %. The wood moisture content value calculated from the relative humidity of air and temperature in a given place is 7.2 %. Approximately in the middle of the wooden framework section, the difference between measured and calculated value reaches 1%. From the point of view of the equilibrium moisture content, the calculated value is on the safe side. **Sensor No. 1** measured approximately half the value of the wood moisture content compared to the calculated one. Because the sensors, including their cables, are placed into the cladding sample weighing approximately 250–300 kg during its production, a failure of sensor or of its connection may occur during the subsequent handling, transport and situating of the sample into the test-chamber. Its repair or replacement is not possible without the destruction of the entire sample. That's why the measured values were eliminated from evaluation.

Sensor No. 2 placed in 60 mm distance form the exterior side of wooden framework measured the wood moisture content of 6.9 %. The wood moisture content value calculated from the relative humidity of air and temperature in a given place is 7.02 %. Approximately in the middle of the wooden framework section, the difference between measured and calculated value is negligible. **Sensor No. 2** measured **the** moisture content of 7.9 %. The calculated moisture content is 10.1%. **Sensor No. 3** measured the moisture content of 6.3% in quasi-stabilized



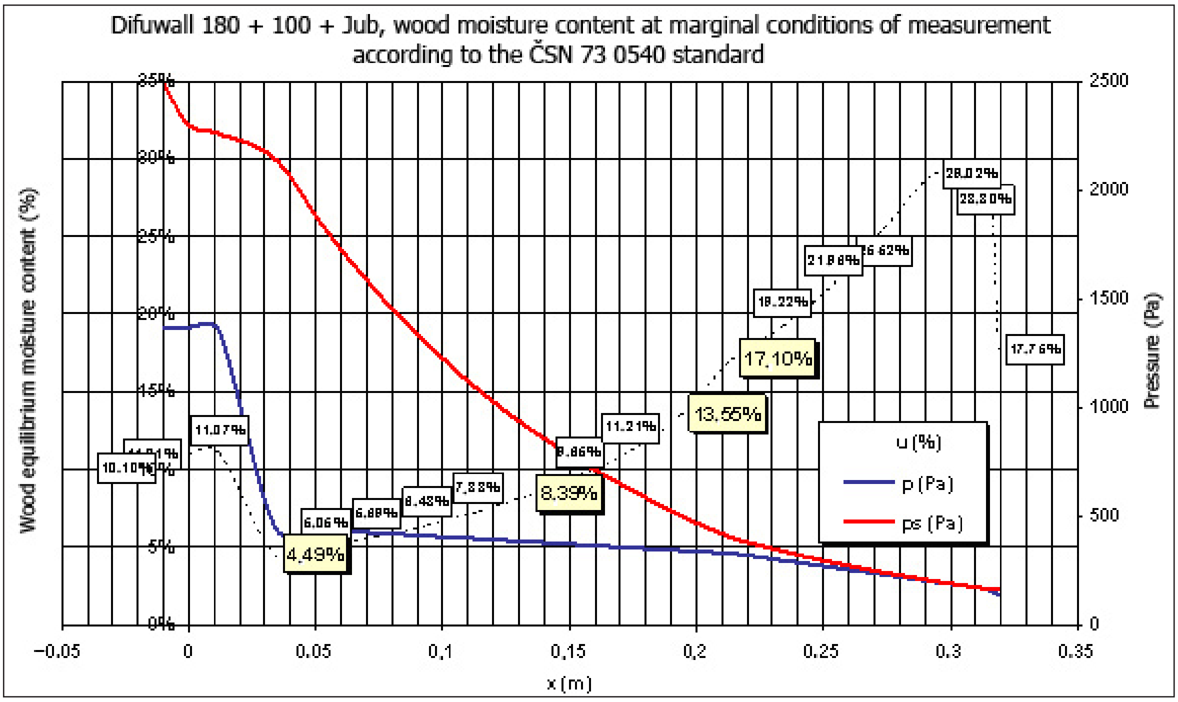
7: *Equilibrium moisture content of wood determined from the course of partial pressures of water vapor and temperatures at marginal conditions in the air-conditioned chambers*



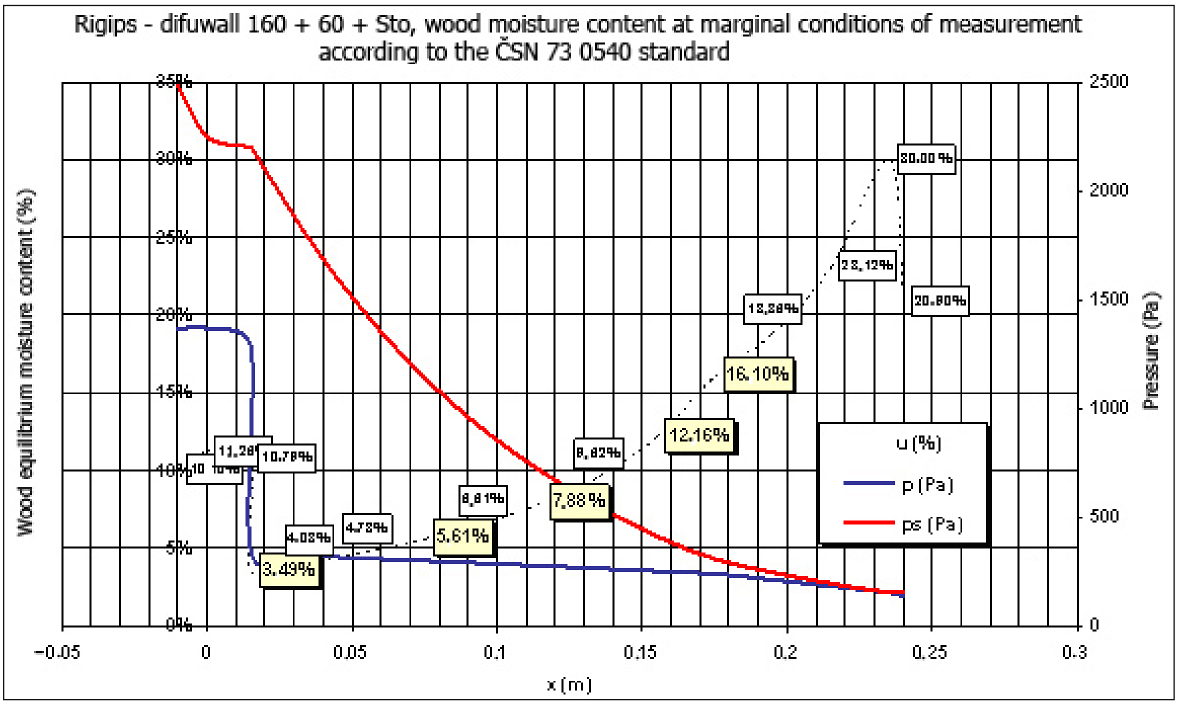
8: *Equilibrium moisture content of wood determined from the course of partial pressures of water vapor and temperatures at marginal conditions in the air-conditioned chambers*

state. The moisture content determined by calculation for this interface is 5.2%. Once again, the measured and calculated values are those from the approximate center of the wood frame section. Lower moisture gradient across the framing section seems to correspond to the re-distribution of the moisture within the wood. The calculated values compared to the moisture content values measured in the air-conditioned chamber are on the safe side.

For the assessment of the cladding structures according to **requirement 1 see art. 6.1 a 6.2 in ČSN 730540 standard** it is necessary to re-calculate



9: *Equilibrium moisture content of wood determined from the course of partial pressures of water vapor and temperatures under marginal conditions according to the ČSN 73 0540 standard*



10: *Equilibrium moisture content of wood determined from the course of partial pressures of water vapor and temperatures under marginal conditions according to the ČSN 73 0540 standard*

the course of temperatures, partial pressures of water vapor and corresponding equilibrium moisture contents to the marginal conditions of interior and exterior environment according to the mentioned standard see figs. 9 and 10. The calculations according to the marginal conditions of the ČSN 73 0540 standard make evident that the equilibrium moisture content of wood in both constructions will not exceed $\mathbf{w_m > 20\ \%}$.

DISCUSSION

Proposal of a method for evaluating the requirement 1

The proposal of a method is demonstrated on an intentionally chosen example of cladding structure that, according to current practice, would be, in view of the construction heat-technology, considered as complying (see tab. IV). To reach the desired effect, the diffuse resistance of vapor barrier layer is lowered to 10% of its declared value using expert assessment. We are building on the premise that the thermal insulation made of mineral fiber can be considered a system composed of air capsules separated by fiber structure. While the fiber structure significantly restricts the transport of water vapor by convection, the transport of water vapor by diffusion does occur in an amount proportional to the diffusion resistance of the material. Each element of the wooden framework is then, within each layer of fiber thermal insulation, exposed to a different environment with a different calculated layer temperature and calculated partial pressure of water vapor in the given layer.

Wood is a hygroscopic material capable of changing its moisture content in relation to the temperature and moisture content of the surrounding environment. The moisture content in wood stabilized at given environment conditions (relative humidity and temperature of air) is called **equilibrium moisture content of wood (EMCW)**. The achieved state is than called **State of Moisture Equilibrium (SME).** With each change in relative humidity and temperature of air, the equilibrium moisture content of wood also changes. If the moisture content of wood is lower than **SME** the wood adsorbs water in the form of water vapors from surrounding environment until it reaches the state of moisture equilibrium. If the moisture content in wood is higher than **SME**, the process inverts and the wood begins to lose water which we call desorption. This process of change of wood moisture content as a function of the relative humidity and temperature of air is reversible but doesn't follow the same curve. At the same relative humidity and temperature of air, the moisture content is higher during desorption than during adsorption by 2.5–3.5%, at a span of air relative humidity RH 30% – 90%. (Gandelová et al., 2002). This can lead us to the assumption that the measured values of equilibrium moisture content of the wooden framework inside the cladding would oscillate in comparison to the calculated values within the span of approx. ± 1.5 %.

To interpret **requirement 1 (see arts. 6.1 a 6.2 in ČSN 730540–2 standards)** first at the interfaces between the layers of the cladding, or in other places where the wooden framework or wood-based construction boards are built into the cladding, we set, by calculation according to the ČSN 73 0540 standard considering one-dimensional conduction of heat and moisture, the temperatures and partial pressures of water vapor and saturated water vapor. From those values we calculate the relative humidity of air in the surrounding environment in a given place. Out of the temperature and relative humidity of the surrounding environment we can then derive the supposed wood moisture content in the given zone of the construction using for example the Tchulicky's nomogram. From the span of such calculated values of wood moisture equilibrium in the cladding, we can reliably categorize the assessed construction into a relevant utilization class (see basic requirements 1 and 3). We can also reliably specify the thermal conductivity of wood in the framework. **If it is possible to reliably categorize the corresponding construction of cladding into the utilization class 1 or 2 according to the ČSN 73 1702 standard and prove that the equilibrium moisture content would, in the whole of the respective zone, comply with the value $w_m \leq 20\%$, it is possible to consider requirement 1 see art. 6.1 a 6.2 in ČSN 730540 standard as accomplished.**

Evaluation of requirement 1 in sample construction

At the below described cladding structure, the following layer interfaces are subject to evaluation:

IX: *Example of evaluated construction with the efficiency of vapor barrier of 10%*

Construction structure (from interior):

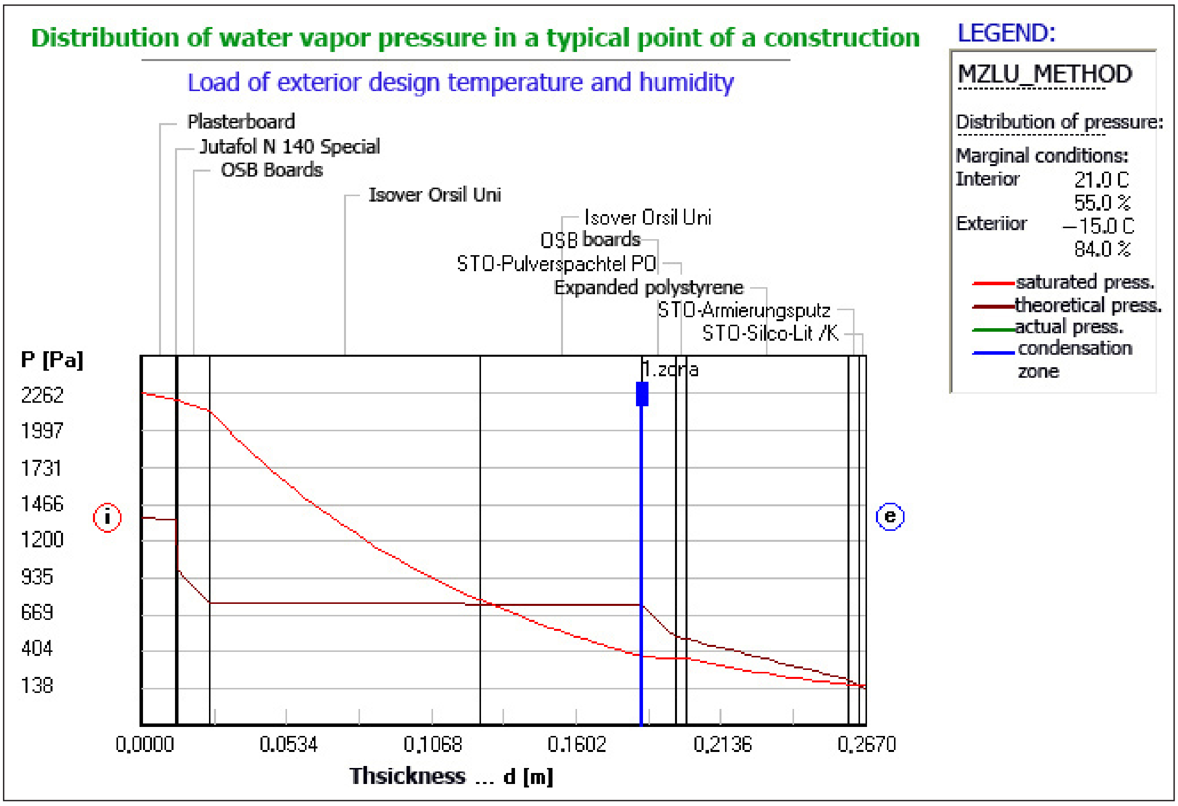
Number	Name	D [m]	L [W/mK]	C [J/kgK]	Ro [kg/m3]	Mi [-]
1	Plasterboard	0.0125	0.2200	1060.0	750.0	9.0
2	Jutafol N 140	0.0003	0.3900	1700.0	560.0	**14827.5**
3	**OSB boards**	0.0120	0.1300	1700.0	650.0	200.0
4	**Isover Orsil U**	0.1000	0.0400	840.0	40.0	1.0
5	**Isover Orsil U**	0.0600	0.0400	840.0	40.0	1.0
6	**OSB desky**	0.0120	0.1300	1700.0	650.0	200.0
7	**STO-Pulverspac**	0.0040	0.8700	900.0	1300.0	25.0
8	Expanded polystyrene	0.0600	0.0440	1270.0	20.0	50.0
9	STO-Armierungs	0.0040	0.7000	900.0	1300.0	125.0
10	STO-Silco-Lit	0.0022	0.7000	900.0	1800.0	80.0

3–4 (inner sheeting OSB board – wooden framework)
4–5 (wooden framework in 10cm distance from the inner side – 6cm distance from the exterior side)
5–6 (wooden framework – outer sheeting OSB board)
6–7 (outer sheeting OSB board – ETICS)

If we compare the facts stated in the heat-technical assessment against the criteria for construction design according to **ČSN 73 1702** standard, it is evident that the **OSB 3 board**, acting as outer sheeting of a wooden framework and ensuring the construction rigidity in the wall plane, will suffer extended exposure to an environment corresponding to utilization class 3. for the wooden construction there is a risk of a mould or wood-destroying fungi attack. High equilibrium moisture content of the construction may be a cause of a rise in calculated deformations, when, while assessing the deformations, more pronounced creeping under load must be taken into account starting already from the utilization class 2 (see basic requirement 1). Also the amount of heat-losses through the cladding will rise in function of the extreme rise of moisture content of the build-in materials (see basic requirement 6).

CONCLUSION

Assessing the sample construction in view of the requirement 1 – art. 6. 1. ČSN 73 0540 standard:



11: *Chart of distribution of water vapors pressure within construction*

X: *Distribution of water vapor pressures and temperatures within construction according to ČSN 73 0540 standard, completed with calculated relative air humidity in given layer* ***RH x*** *and respective equilibrium moisture content of wood at given interface* $\boldsymbol{w_m\ x}$

Water vapor diffusion under design conditions and moisture balance according to ČSN 730540 standard:
(Without the effect of built-in moisture and solar radiation)

The course of temperatures and pressures under design marginal conditions:

interface:	**i**	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**	**9-10**	**e**
temp. [C]:	19.5	19.1	19.1	**18.6**	**3.3**	**–5.8**	**–6.4**	–6.4	–14.7	–14.7	–14.8
p [Pa]:	1367	1356	993	**759**	**749**	**743**	**508**	498	205	156	138
p,sat [Pa]:	2262	2214	2214	**2137**	**776**	**374**	**357**	356	169	169	168
RH x (%)				35,5	96,5	100	100				
$\boldsymbol{w_m}$ **x (%)**				~7,2	**27,5**	**MH**[a)]	**MH**[a)]				

[a)] MH ~ limit of hygroscopicity (point of saturation of fibers)

XI: *Balance of condensed and evaporated moisture according to ČSN EN ISO 13788 standard*

Balance of condensed and evaporated moisture according to ČSN EN ISO 13788 standard:

During the model year condensation occurs in the construction.

Condensation zone No. 1

Month	Condensation zone limit [m]		Actual cond. /evap.	Accumulated moisture
	left	right	Gc [kg/m²s]	Ma [kg/m²]
12	0.1848	0.1848	3.97E-0009	0.0106
1	0.1848	0.1848	4.97E-0009	0.0234
2	0.1848	0.1848	3.98E-0009	0.0331
3	0.1848	0.1848	–2.64E-0009	0.0260
4	-	-	–1.25E-0008	0.0000
5	-	-	-	-
6	-	-	-	-

Maximum amount of condensate Mc,a: **0.0331 kg/m²**

At the end of the model year, the zone is dry. (that is: Mc,a < Mev,a).

The condensation takes place on the inner surface of the exterior OSB 3 board during 3 months. During the following 2 months, the condensate dries up.

XII: *Balance of condensed and evaporated moisture according to ČSN 73 0540 standard*

Annual moisture balance:

The amount of condensed water vapor Mc,a: **0.062 kg/m².year**

The amount of evaporable water vapor Mev,a: **0.616 kg/m².year**

The condensation occurs at exterior temperature lower than **5.0 °C**.

The condensation takes place on the inner surface of the exterior OSB3 board during approx. **147 days/year.**

Although the assessed construction complies with the criteria of **requirements 2 and 3** see tab. IV), it can be considered as **non-complying** in view of **requirement 1.**

- The condensation occurs at the interface between the heat insulation and the exterior structural OSB3 board. Nevertheless, this board must not be used in **utilization class 3** (see tab.II).
- According to the ČSN 73 0540 standard, the condensation in this zone occurs virtually during **approx. 147 days/year** (see tab XII). Compare to the definition of the **utilization class 2** according to the ČSN 73 1702 standard and Eurocode 5.
- According to the **ČSN EN ISO 13788 standard**, the condensation in this zone occurs during **three months** (see tab. XI). This evaluation of condensation does not reflect the state of propagation of moisture in the construction with the exterior air temperature below –2.5°C. Compare to the definition of **utilization class 2** according to ČSN 73 1702standard and Eurocode 5.
- The temperature/moisture state in the construction beginning at the interface of layers **4–5** (see fig. 11) is reflected by the equilibrium moisture content of softwood $\mathbf{w_m}$ > **20 %** and can even reach the limit of hygroscopicity (see tab. X).

CONCLUSION

This work is dealing with the possibility of improving the existing way of designing and assessing the wooden building constructions using the existing model in order to increase their reliability and service life that are significantly influenced by the moisture content of built-in materials. The wood in wooden frame cladding changes its moisture content depending on temperature and moisture conditions of the environment it is built into. This means that for the equilibrium moisture content to rise over the level permissible for the reliable function of a given construction, the water vapor condensation doesn't necessarily have to occur right in the wooden framework of the cladding. Common heat-technical assessment can thus be considered as not fully capable to determine these influences on the reliability and service life of wood-based constructions and buildings. The extension of the existing method of design and assessment of building constructions according to the ČSN 73 0540 standard by interpretation of equilibrium moisture content in relation to the temperature/moisture conditions and their time behavior inside a construction offers a reliable prerequisite for improving the reliability and service life of these constructions and buildings.

SOUHRN

Rovnovážná vlhkost dřeva při různých teplotně vlhkostních podmínkách v obvodovém plášti dřevostaveb ve vztahu k jejich spolehlivosti a životnosti

Tato práce se zabývá možností zpřesnit dosavadní způsob navrhování a posuzování stavebních konstrukcí pomocí stávajících modelů navrhování tak, aby se zvýšila spolehlivost a životnost konstrukcí a staveb na bázi dřeva. Životnost a funkční spolehlivost staveb a konstrukcí ze dřeva a z materiálů na bázi dřeva je výrazně ovlivňována vlhkostí těchto materiálů. Dřevo v dřevěné rámové konstrukci obvodového pláště mění svoji vlhkost v závislosti na teplotních a vlhkostních podmínkách prostředí, ve kterém je zabudováno. To znamená, že k tomu, aby rovnovážná vlhkost dřeva v konstrukci překročila hodnotu přípustnou pro spolehlivou funkci dané konstrukce, nemusí bezpodmínečně docházet ke kondenzaci vodních par v obvodovém plášti přímo v místě rámové konstrukce. Běžné tepelně technické posouzení lze považovat za ne zcela dostačující pro odhalení těchto vlivů na funkční spolehlivost a životnost konstrukcí a staveb na bázi dřeva. Rozšíření stávající metodiky navrhování a posuzování stavebních konstrukcí dle ČSN 73 0540 o navrhované vyhodnocování rovnovážné vlhkosti dřeva ve vztahu k teplotně vlhkostním podmínkám a jejich časovému průběhu uvnitř konstrukce dává dostatečně spolehlivý předpoklad pro zvýšení spolehlivosti a životnosti těchto konstrukcí a staveb.

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