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RELIABILITY AND SERVICE LIFE OF WOOD STRUCTURES AND BUILDINGS

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Abstract

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Service life of constructions and buildings of wood is dependent on temperature and moisture conditions in layers of the building cladding where the wood framework is built in. Temperature/moisture conditions or the corresponding equilibrium moisture content (EMC) of the construction show considerable effects on the functional reliability of the whole building from the viewpoint of mechanical resistance and stability (ER1), energy savings and thermal protection (ER6) and hygiene, health and environment protection (ER3). To ensure the reliability of constructions and buildings for the period of their supposed service life a more profound analysis of constructions is necessary from the aspect of a global thermal/technical evaluation.

wood, construction, moisture, deformation, creeping, reliability

During last years, a marked shift occurs in the design and realization of buildings as low-energy constructions, ie buildings with the low consumption of energies for their operation and heating and towards the development of corresponding constructions of cladding. The development is particularly aimed at increasing the thermal resistance of the cladding or decreasing its coefficient of heat passage above all by means of increasing the thickness of a heat-insulation layer. Moreover, the maximum reduction occurs of heat losses by air infiltration through constructions and their joints. Methods of the design and realization of buildings and constructions of wood are also subject to these global trends.

However, an endeavour to reach as low as possible heat losses in buildings of wood through decreasing the coefficient of heat passage in cladding constructions and through decreasing or elimination their air infiltration must not affect other fundamental requirements posed on these constructions and buildings. Simultaneously with the above-mentioned trend in energy savings and heat protection the designer and constructor have to see that mechanical properties and stability of constructions and buildings not to be worsened and hygiene and health protection of users of these buildings to be ensured. In increasing one of the properties referring to basic requirements the functional reliability of the constructions and buildings must not be limited or reduced from the viewpoint of other basic requirements and the adequate service life and durability have to be guaranteed. This requirement is also included in ETAG 007 Operating instructions for European technical approvals – Wooden frame structural configurations, article 4.7.1 Viewpoints of durability.

MATERIAL AND METHODS

We shall concentrate on interrelations of three basic functional requirements which are most important for designing and realization of wooden frame constructions: mechanical resistance and stability (ER1), energy savings and heat protection (ER6) and hygiene, health and environment protection (ER3). In addition to instant returnable deformations time-dependent partly irreversible deformations also occur in wooden constructions which are induced by the effect of a long-term load (Cai et. al., 2002). In a European standard for designing wooden constructions (EUROCIDE 5) as well as in a corresponding Czech standard the problem of creeping is dealt with by means of the coefficient of creeping k_{def} (Tab. I) which is dependent on the period of loading and the environment moisture. The European standard establishes 5 categories of load: constant, long-term, medium-term, short-term, instant and 3 classes of use: class1 (protected interior) , class 2 (interior with the occasional occurrence of moisture) and class 3 (corresponds to an unprotected exposure).

The element deformation in the course of time is expressed by a relation:

$$u_{fin} = u_{inst} (1 + k_{def}), \quad (1)$$

where u_{inst} expresses an instant deformation, u_{fin} expresses deformation including creeping after the certain period of load.

I: *Values of the coefficient of k_{def} for solid and glued laminated wood according to(EUROCODE)*

Class of the period of load	Class of use		
	1	2	3
Constant	0.60	0.80	2.00
Long-term	0.50	0.50	1.50
Medium-term	0.25	0.25	0.75
Short-term	0.00	0.00	0.30

Taylor (Taylor et. al., 1994) proposed and tested a relationship of the coefficient of wood creeping on specimens of solid and glued laminated wood of construction dimensions

$$k_{def(t)} = k_{def(\infty)} [1 - e^{-ct}], \quad (2)$$

where $k_{def(t)}$ is the coefficient of creeping in the course of time t (day), $k_{def(\infty)}$ the coefficient of creeping in the course of time $t = \infty$ (or 50 years), $c = -0.0032$ (day^{-1}).

Wood moisture significantly affects creeping. Lowest values are reached under the constant values of the environment moisture corresponding to the class of use 1 ($k_{def(\infty)} = 0.67$). Under conditions of the cyclic alternation of moisture nearly double values of creeping are reached ($k_{def(\infty)} = 1.21$), in an exterior, the creeping is about three-times higher ($k_{def(\infty)} = 2.15$), (Lokaj, 2003).

Degrees of moisture load according to EURОcode EC5:

Class of use 1 – the moisture content in construction materials corresponds to a temperature of 20 °C and relative air humidity exceeding a value of 65% at the outside for several weeks in a year. In the majority of softwood, the mean EMC (equilibrium moisture content) does not exceed 12%.

Class of use 2 – the moisture content in construction materials corresponds to a temperature of 20 °C and relative air humidity exceeding a value of 85% at the outside for several weeks in a year. In the majority of softwood, the mean EMC does not exceed 20%.

Class of use 3 includes climatic conditions resulting in the higher content of moisture as compared with class of use 2. (In the harmonized ČSN ENV 1995-1-1: 2004 standard, classes of use are named "moisture classes".)

If we study requirements for wood moisture in building constructions from the viewpoint of ČSN EN 335-1 and ČSN EN 335-2 standards "Durability of wood and wood-based materials – Definition of classes of threat by biological attack – Part 1 and 2", they are roughly the same. The constructional protection of wood should ensure such moisture of wooden elements when the activity of wood-destroying fungi and insect cannot manifest itself. In Central-European species of wood-damaging insect, the activity stops at a wood moisture below a limit of 10%, in fungi below 20% (with the exception of Merulius lacrymans requiring only 16% moisture). The constructional protection of wood is also to prevent infiltration of rain and ground water into a building, the creation of condensed water and the transfer of capillary water from mineral materials to wood (Reinprecht, 1999).

Thus, in designing and realizing building constructions of wood with sufficient durability, it is necessary to formulate gradually main principles of construction protection. Without the appropriate solution of the construction from the viewpoint of heat technology and verification of temperature and moisture conditions within the construction it is not possible to guarantee its mechanical strength and stability or the durability of wood and wood-based materials from the viewpoint of threat by biological agents. Therefore, it is necessary to assess all designed constructions not only from the viewpoint of the potential diffusion and condensation of water vapour but particularly from the aspect of temperature/moisture conditions and corresponding EMC. The normal process of verification of the year-long balance of condensed and evaporated water vapour in a construction is not in itself a sufficient criterion for a decision how basic requirements (ER1) Mechanical resistance and stability and (ER2) hygiene, health and environment protection will be affected under conditions of fulfilling a basic requirement (ER6) Energy savings and heat protection, ETAG 007.

The present procedure of the evaluation of year--long balance of water vapour in constructions according to ČSN 730540 standard is different from a procedure given in prEN ISO 13788 (at present ČSN EN ISO 13788 standard). Edge conditions are introduced quite differently in both methods. In ČSN 730540 standard, a construction is evaluated gradually with an increasing outside temperature starting (typical of the CR) with –15 °C and finishing with a temperature of +25 °C while prEN ISO 13788 standard prescribes calculation according to particular months using mean month temperatures and outside air humidity making possible to introduce a different mean temperature and inside air humidity for each of the evaluated months which was not possible when using a standard procedure according to the ČSN.

For the relative humidity of inside air, prEN ISO 13788 standard introduces three ways of its determination according to the type of evaluated space, however, it quite omits temperatures which are lower than the lowest mean monthly temperatures. Thus, the calculation cannot find a situation in the construction at outer temperatures lower than about –5 °C. On the other hand, the advantage of the procedure consists in a possibility to introduce an initial constructional moisture or moisture accumulated during the existence of the construction into the calculation. The maximum amount of condensation water in a construction when using prEN ISO was always lower than when using the ČSN method. The difference of maximum amounts of ≤ 50% was noted in 57% cases (Svoboda, Králíček, 2000).

A substantial difference in the determination of water vapour permeating through the construction results from the method of assessing properties of a steam-proof layer (“moisture stop”) hampering the infiltration of water vapour usually from the internal environment to the building construction. Condensed water vapour could endanger the required function of a building construction or shorten its service life. For example, in the roof cladding an increase in moisture as against the calculation model is caused by heterogenous properties of materials (technological indiscipline during construction, imperfect implementation and ageing of joints) when the multidimensional moisture diffusion occurs in the place of material disturbance. The ČSN EN ISO 13788 standard mentions that a decrease in the equivalent diffuse thickness can occur in damaged materials with high diffuse resistance even by several orders. According to some authors, it is recommended to lower (based on the percentage of damage) the factor of diffuse resistance up to 10% of its original value. In other papers, a reduction even to 1% of its original value is given.

The amount of permeating moisture cannot be determined by analytical calculations thanks to multidimensional diffusion. Thus, it is necessary to use numerical methods or laboratory measurements of diffusion. Laboratory measurements carried out in VÚPS Zlín and in laboratories of FS ČVUT demonstrate a marked increase in the mass flow already at the very small disturbance of layers with large diffuse resistance. Results of the measurement of “moisture stops” in FS ČVUT laboratories by means of the Wet--Cup method when a perforated area amounted to 0.125% of the total specimen area showed a decrease in the equivalent diffuse thickness s_d to a value of 5.3 to 4.7% of the value of an intact material (Slanina, 2004).

Another factors influencing wood moisture in constructions are also actual climatic conditions affecting the building throughout its service life. Installing tight windows considerable decrease in air infiltration occurs and thus, the required intensity $n_N \geq 0.5$ (1/h) of air exchange in a room is not observed. During various working activities, “overproduction” of water vapour occurs, increase in humidity and subsequently also the relative humidity of internal air. Man at rest produces about 50g/h water vapour, during manual labour even double. From the viewpoint of assessing changes in relative air humidity in a reference room under various humidity load (200 g/hour and 400 g/hour) an analysis was carried out for the eastern side of the building where the air exchange intensity correlated with the required value. At the air exchange intensity $n_{pr} \approx 0.5$ ($V_V \approx 25 \div 30$ m^3/h) the relative air humidity ranged in acceptable limits $\varphi_i \approx 35 \div 55\%$ even at the production of water vapours between 200 and 400 g/h. As soon as the air exchange intensity decreased to $n_{pr} \approx 0.2$ relative air humidity increased to $\varphi_i \approx 80\%$ (Ondráš, 2004).

The syndrome of “diseased buildings” discussed by experts already for a long time is also related to the problem. It refers to a problem occurring particularly in buildings of a residential and administrative function implemented in recent years. Their dwellers suffer from not very specific symptoms such as breathing troubles, headaches, eye hurting and weeping, fevers and manifestations of an acute respiration illness, fatigue, concentration disorders. After the several-year systematic study of the problem a number of causal connections has been revealed two causes of them being found to be particularly important: hermetic separation of the inner and outer environment of a building and to a smaller extent also the use of “unsound” materials.

The conception of “diffuse open facades” promoted in western Europe is a positive response to the syndrome mentioned above. In the facades, an external cladding does not include any steam-proof layers thus enabling the free movement of water vapours through the cladding construction. The conceptually proper design of a diffuse open facade has to start from the analysis of some sensitive structurally-physical problems. In the design, it is necessary to analyse in detail questions of the vapour condensation and its year-long migration through the construction. Mostly, however, the positive yearly balance of condensed and evaporated vapour does not suffice and it is necessary to obtain a certainty that the condensation of water vapours will not occur in winter and to support the facade design by structurally-physical calculations of higher resolution (Krňanský, 2005).

RESULTS

From the set of external cladding structures commonly used in prefabricated family houses of the wooden frame construction three types were selected for basic heat-technical assessment. According to basic criteria and requirements, these types can be considered to be virtually identical. Particular constructions show the same thickness of a heat-isolation layer, the same proportion of heat bridges (elements of wooden frame construction) and differ only in the type of construction panels ensuring the stability of a construction in the plane of a wall and in the type of commonly used contact thermal insulation systems.

From the viewpoint of heat-technical assessment, the selected constructions can be classified as constructions fulfilling requirements of harmonized standards. If we extend the assessment by findings given in the previous text and focus on monitoring the temperature and moisture conditions inside the external cladding constructions we can state (on the basis of calculations carried out by means of commonly used software) that it is possible to suppose different service life and reliability of the construction in particular variants.

To assess temperature and humidity conditions more accurately, thermal insulation was separated to three layers of various thickness. A corresponding relative humidity RHx of the environment at particular interfaces of layers was assigned to calculated temperatures and partial pressures of water vapours and from the alignment chart of EMC a respective EMC ωx corresponding to a temperature and humidity in the given interface. In Čulicky's nomogram of EMC which is also constructed for negative air temperatures down to –20 °C, corresponding values of EMC end by a value of 28%. Therefore, where the corresponding wood moisture in the heat-insulation layer exceeds the value of 28% a symbol > 28 is given.

Basic assessment according to harmonized ČSN standards
(ČSN EN ISO 13788, ČSN EN ISO 6946, ČSN 730540)
Cladding No. 1.1
Construction structure (from an interior)

Number	Name	D[m]	L[W/mK]	C[J/kgK]	Ro[kg/m^3]	Mi[-]	Ma[kg/m^2]
1	Plasterboard	0.0125	0.2200	1060.0	750.0	9.0	0.0000
2	PE foil	0.0002	0.3500	1470.0	900.0	**144000.0**	0.0000
3	Particleboard	0.0130	0.1100	1500.0	800.0	12.5	0.0000
4-6	Rockwool Rockm.	0.1400	0.0400	840.0	100.0	2.0	0.0000
7	Particleboard	0.0130	0.1100	1500.0	800.0	12.5	0.0000
8	Baumit Kl. Sp.	0.0020	0.8000	920.0	1300.0	50.0	0.0000
9	Baumit EPS-F	0.0600	0.0400	1270.0	17.0	40.0	0.0000
10	Combined layers	0.0050	0.7368	920.0	1540.0	42.2	0.0000

Thermal resistance and coefficient of heat passage according to ČSN EN ISO 6946 standard

Thermal resistance of the construction R: 3.725 m2K/W
Coefficient of heat passage of the construction U: **0.257 W/m2K**

Diffuse water vapours 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 edge conditions:

interface:	i	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	e
temp. [C]:	19.4	19.0	19.0	18.3	2.2	–2.7	–4.3	–5.0	–5.0	–14.7	–14.7
pd [Pa]:	1243	1239	252	246	240	238	237	231	228	146	138
pd” [Pa]:	2250	2200	2199	2097	714	489	427	400	400	169	169

At the outside design temperature water vapour condensation does not occur in the construction.

At the recommended degradation of moisture stop parameters conditions in the construction will change (see cladding 1.2, Fig. 1).

Cladding No. 1.2
Construction structure (from an interior):

Number	Name	D[m]	L[W/mK]	C[J/kgK]	Ro[kg/m^3]	Mi[-]	Ma[kg/m^2]
2	PE foil	0.0002	0.3500	1470.0	900.0	14400.0	0.0000

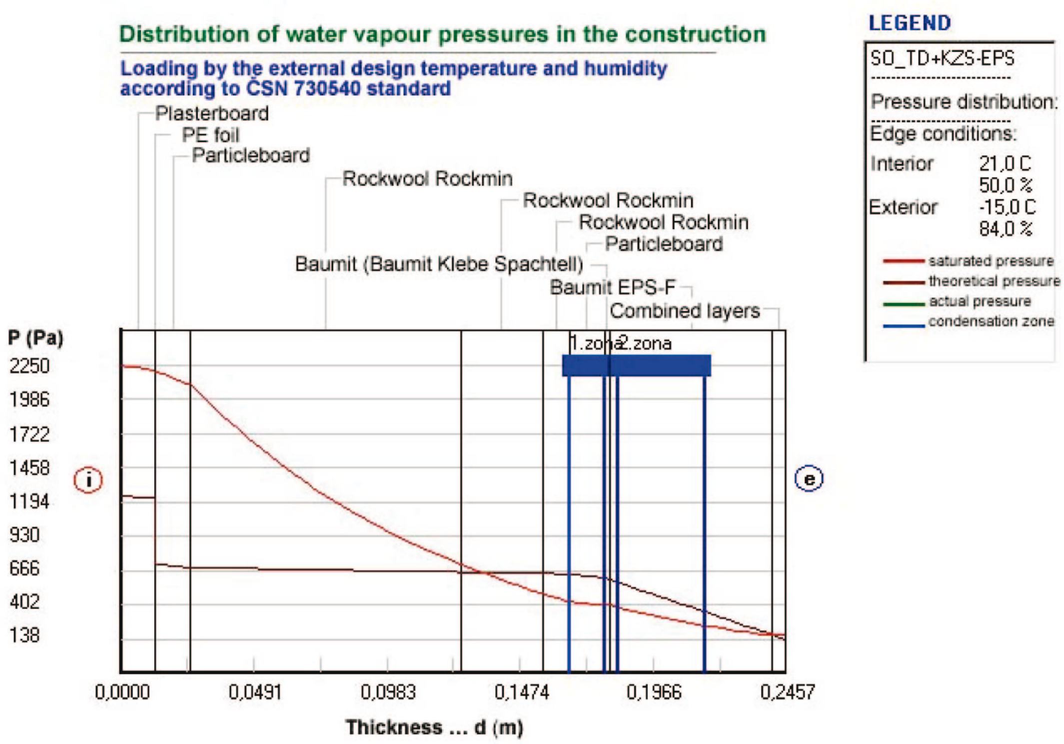
Diffuse water vapours under design conditions and moisture balance according to ČSN 730540 standard (without the effect of built-in moisture and solar radiation)

The course of temperatures and pressures under design edge conditions:

interface:	i	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	e
temp. [C]:	19.4	19.0	19.0	18.3	2.2	–2.7	–4.3	–5.0	–5.0	–14.7	–14.7
pd [Pa]:	1243	1223	719	690	655	**645**	**641**	**613**	**595**	**175**	138
pd” [Pa]:	2250	2200	2199	2097	714	**489**	**427**	**400**	**400**	**169**	169
φx (%)					91.7	100	100	100	100	100	
ωx (%) ~					**23**	**> 28**	**> 28**				

Year-long moisture balance:

Amount of condensed water vapour Gk: 0.033 kg/m^2/year
Amount of evaporated water vapour (evaporation capacity) Gv: 1.560 kg/m^2/year
Condensation occurs at an outdoor temperature lower than 0.0 0C.



1: *Distribution of water vapour pressures in the cladding construction No. 1.2*

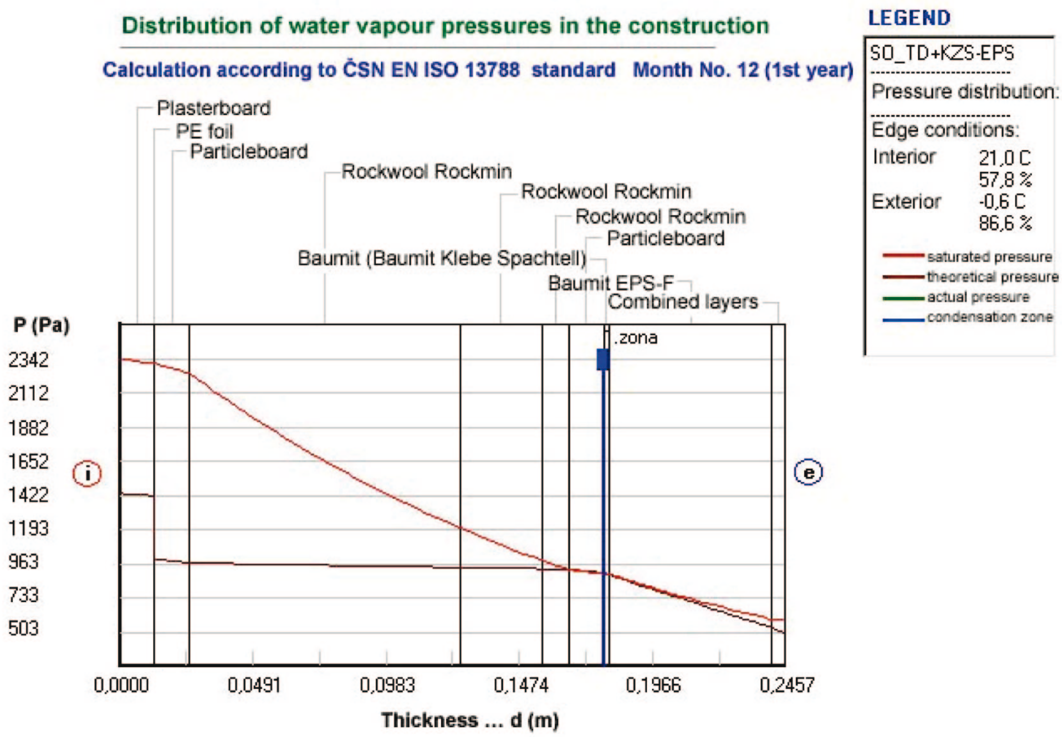
At the recommended degradation of the moisture stop layer parameters the construction of cladding No. 1.2 can be evaluated (according to ČSN 730540 standard) as satisfactory from the viewpoint of the amount of condensed water vapour as well as the year-long balance of condensed and evaporated water vapour. With respect to the fact that at the design temperature of surrounding air –15 °C conditions occur in the construction when EMC can virtually reach a value of the fibre-saturation point and water vapour condensation already occurs at a surrounding temperature lower than 0 °C there is a realistic condition that for the certain part of a year, the construction will not correspond to conditions for its inclusion to the class of use 2 according to EUROCODE 5.

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

Condensation zone No. 1

Month	Condensation zone limit left [m]	right	Actual cond./evap. Gc [kg/m²s]	Accumulated moisture Ma [kg/m²]
12	0.1787	0.1787	1.14E-0009	0.0031
1	0.1787	0.1787	1.14E-0009	0.0061
2	0.1787	0.1787	–1.29E-0009	0.0030
3	---	---	–1.81E-0008	0.0000

At the end of a model year the zone is dry.



2: *Distribution of water vapour pressures in the cladding construction No. 1.2*

According to ČSN EN ISO 13788 standard, the course of water vapour pressures and saturated water vapour is more favourable with respect to different edge conditions of the method of calculation (Fig. 2). Based on the evaluation, condensation in the construction will occur in the course of two month in a year. Thus, it is possible to conclude a potential increase in EMC in the construction exceeding 20% for the period of more than several weeks in a year (compare with the definition of the class of use 2 in EUROCODE 5).

If we admit that a building where the sufficient exchange of inside air is not ensured is realized in this way (the syndrome of "diseased" building) then moisture conditions in the construction will be even impaired (see cladding 1.3 and Fig. 3). For the identical construction of external cladding we consider the design relative humidity of inside air RHi 60%.

Cladding No. 1.3
Diffuse water vapours 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 edge conditions

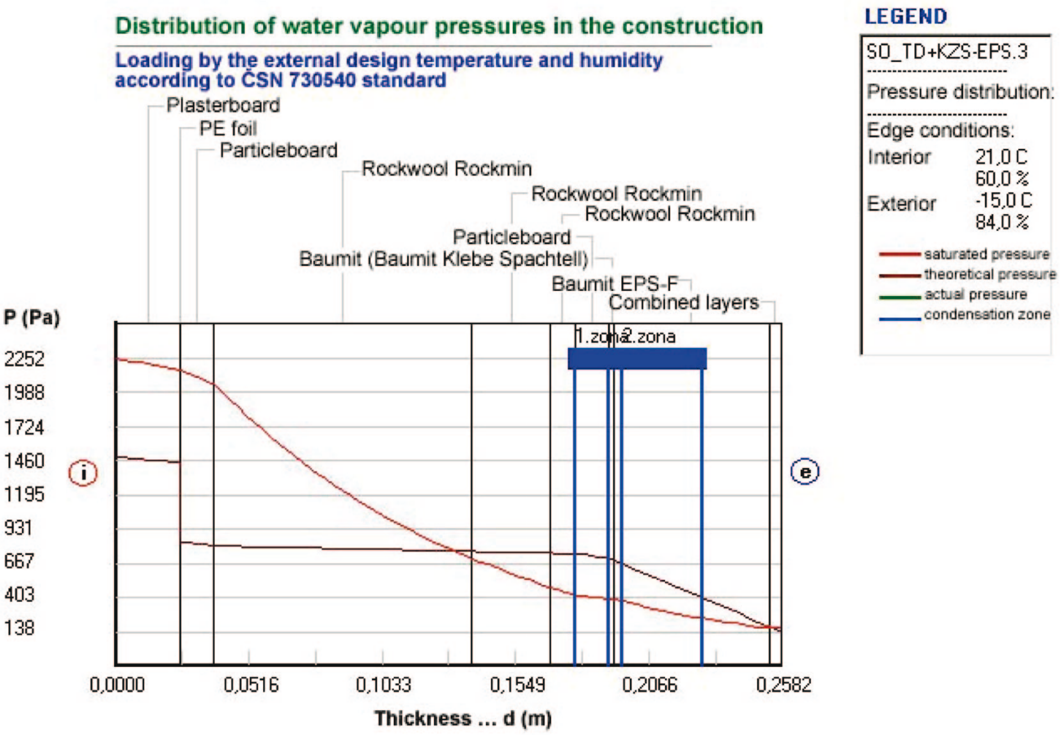
interface:	i	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	e
temp. [C]:	19.4	18.7	18.7	17.9	2.0	–2.8	–4.4	–5.1	–5.1	–14.7	–14.7
pd [Pa]:	1491	1444	837	803	761	748	744	710	689	183	138
pd" [Pa]:	2253	2153	2153	2053	705	484	423	397	396	169	169
φx (%)					100	100	100	100	100	100	
ωx (%) ~					> 28	> 28	> 28				

Year-long moisture balance

Amount of condensed water vapour Gk: 0.086 kg/m²/year

Amount of evaporated water vapour (evaporation capacity) Gv: 1.194 kg/m²/year

Condensation occurs at an outside temperature lower than 0.0 °C.



3: *Distribution of water vapour pressures in the cladding construction No. 1.3*

Under these edge conditions the amount of condensed water vapour will increase 2.5-times in an identical construction and the amount of evaporated water vapour will decrease by 23.5%. Although the total amount of condensed water vapour is below the admissible value according to ČSN 730540 standard, the year-long balance of condensed and evaporated water vapour is positive, the condensed water in the outer particleboard of class V 100 can negatively influence the moisture of wooden frame construction thanks to capillary forces. The increased amount of condensed water vapour also negatively influences the thermal conductivity of construction and insulation materials just in the winter period. In present heat-insulation materials, manufacturers usually do not declare the dependence of their heat conductivity on mass moisture and in the calculation of heat losses a designer will calculate with the coefficient of heat passage identical with a calculation for the external cladding No. 1.1. In consequence of the fact it is possible to suppose that the calculated need of energy for heating a building will be substantially lower than the actual consumption. To admit an increase in the moisture of materials built in a construction in the winter period is, however, counter-productive particularly in designing constructions for low-energy buildings.

A number of contractors of wooden constructions began to use OSB boards (oriented structural boards) in recent years. These boards show excellent mechanical properties and in OSB3 boards, a possibility is declared to use them in the moist environment. We can try to apply the identical approach for assessing the reliability and service life of wooden frame constructions on a commonly supplied construction structure (cladding No. 2, Fig. 4) under identical edge conditions (RHi = 60%).

Cladding No. 2
Construction structure (from an interior)

Number	Name	D[m]	L[W/mK]	C[J/kgK]	Ro[kg/m³]	Mi[-]	Ma[kg/m²]
1	Plasterboard	0.0250	0.2200	1060.0	750.0	9.0	0.0000
2	PE foil	0.0002	0.3500	1470.0	900.0	**14400.0**	0.0000
3-5	Rockwool Rockm.	0.1400	0.0400	840.0	100.0	2.0	0.0000
6	OSB boards	0.0120	0.1300	1700.0	650.0	350.0	0.0000
7	Baumit Kl. Sp.	0.0020	0.8000	920.0	1300.0	50.0	0.0000
8	Baumit EPS-F	0.0600	0.0400	1270.0	17.0	40.0	0.0000
9	Baumit Kl. Sp.	0.0020	0.8000	920.0	1300.0	50.0	0.0000
10	Baumit silicone	0.0030	0.7000	920.0	1700.0	37.0	0.0000

Heat resistance and the heat passage coefficient according to ČSN EN ISO 6946 standard
Heat resistance of a construction R: 3.623 m^2K/W
Coefficient of heat passage of a construction U: **0.264 W/m^2K**

Water vapour diffusion in 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 edge conditions:

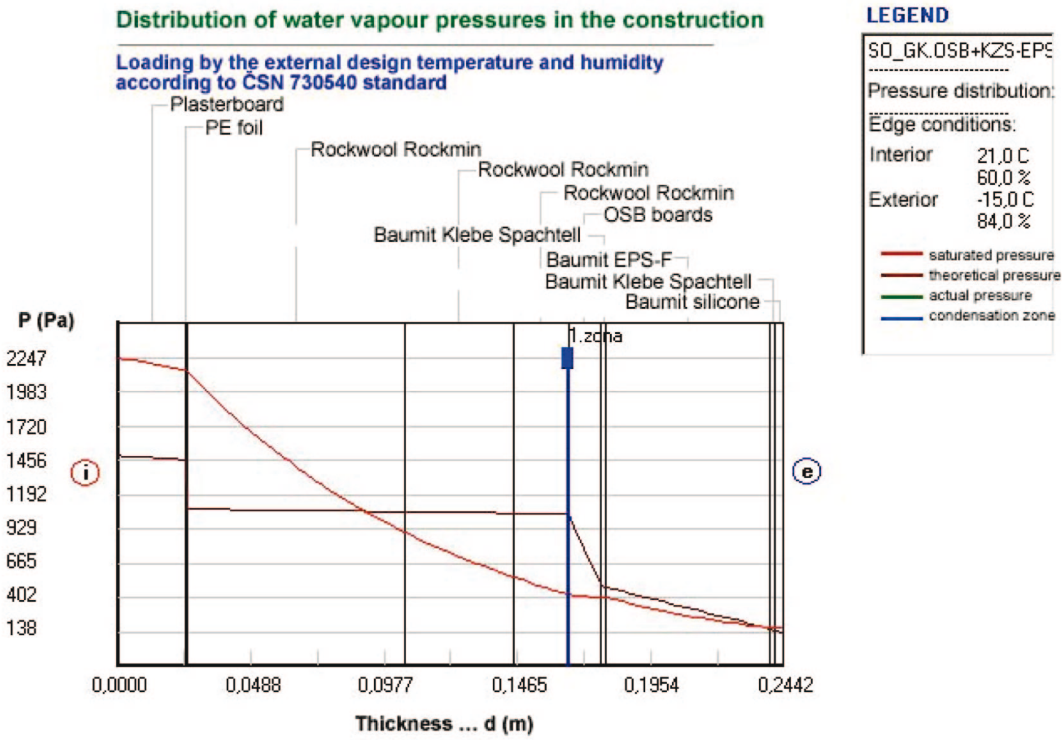
interface:	i	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	e
temp. [C]:	19.4	18.6	18.6	5.5	–1.0	–4.3	–4.9	–4.9	–14.7	–14.7	–14.7
pd [Pa]:	1491	1462	1083	**1062**	**1052**	**1047**	**495**	**481**	166	153	138
pd" [Pa]:	2247	2145	2144	**905**	**562**	**427**	**406**	**405**	169	169	169
φx (%)				100	100	100	100	100			
ωx (%) ~				**> 28**	**> 28**	**> 28**					

Year-long moisture balance
The amount of condensed water vapour Gk: 0.256 $kg/m^2/year$
The amount of evaporated water vapour (evaporation capacity) Gv: 0.684 $kg/m^2/year$
Condensation occurs at an outside temperature lower than 10.0 °C.

Balance of a condensed and evaporated moisture according to ČSN EN ISO 13788 standard
Condensation zone No. 1

	Condensation zone limit			Act. cond./evap.	Accum. moisture
Month	left	[m]	right	Gc [kg/m²s]	Ma [kg/m²]
11	0.1652		0.1652	8.89E-0009	0.0230
12	0.1652		0.1652	1.81E-0008	0.0715
1	0.1652		0.1652	1.81E-0008	0.1200
2	0.1652		0.1652	1.64E-0008	0.1597
3	0.1652		0.1652	2.46E-0009	0.1663
4	0.1652		0.1652	–1.90E-0008	0.1170
5	0.1652		0.1652	–3.50E-0008	0.0232
6	---		---	–4.48E-0008	0.0000

At the end of a model year the zone is dry.



4: *Distribution of water vapour pressures in the cladding No. 2 construction*

At the given edge conditions, the structure assessed fulfils criteria of harmonized standards for studied properties from the viewpoint of a basic requirement (ER 6) energy savings and heat protection according to ETAG 007. On the basis of evaluation according to ČSN 730540 standard it follows that condensation inside constructions occurs at outside temperatures lower than 100C. A condensation zone occurs only on the interface of a wooden frame construction with heat insulation and the outside OSB board. However, a zone and duration when the wooden frame construction will be subject to conditions for wetting above the EMC 20% has markedly extended. According to ČSN EN ISO 13788 standard, condensation will occur for a period of five months and the construction will dry up to a built-in EMC after next circa three months. Such a construction virtually does not fulfil criteria for the class of use 2 according to EUROCODE 5. Thus, it is possible to suppose that after building into a construction (moreover demonstrating the syndrome of a diseased building mentioned above) an inadmissible creeping of the construction will occur after a certain time.

In the last construction assessed the mechanical resistance and stability in the plane of a wall are ensured by gypsum wood-fibre boards (cladding No. 3 and Fig. 5). A basic requirement (ER 6) is ensured by means of a contact heat-insulation system from mineral fibres. Both materials demonstrate substantially lower diffuse resistance than materials used in previous constructions and the evaluation is carried out for identical edge conditions (RHi = 60%).

Cladding No. 3
Construction structure (from an interior)

Number	Name	D[m]	L[W/mK]	C[J/kgK]	Ro[kg/m^3]	Mi[-]	Ma[kg/m^2]
1	Fermacell	0.0120	0.3200	1265.0	1150.0	13.0	0.0000
2	PE foil	0.0002	0.3500	1470.0	900.0	**14400.0**	0.0000
3-5	Rockwool Rockm.	0.1400	0.0400	840.0	100.0	2.0	0.0000
6	Fermacell	0.0120	0.3200	1265.0	1150.0	13.0	0.0000
7	Baumit (HaftMortel)	0.0020	0.8000	920.0	1300.0	18.0	0.0000
8	Min. fibres	0.0600	0.0450	1150.0	100.0	1.4	0.0000
9	Baumit (HaftMortel)	0.0020	0.8000	920.0	1300.0	18.0	0.0000
0	Baumit silicone	0.0030	0.7000	920.0	1700.0	37.0	0.0000

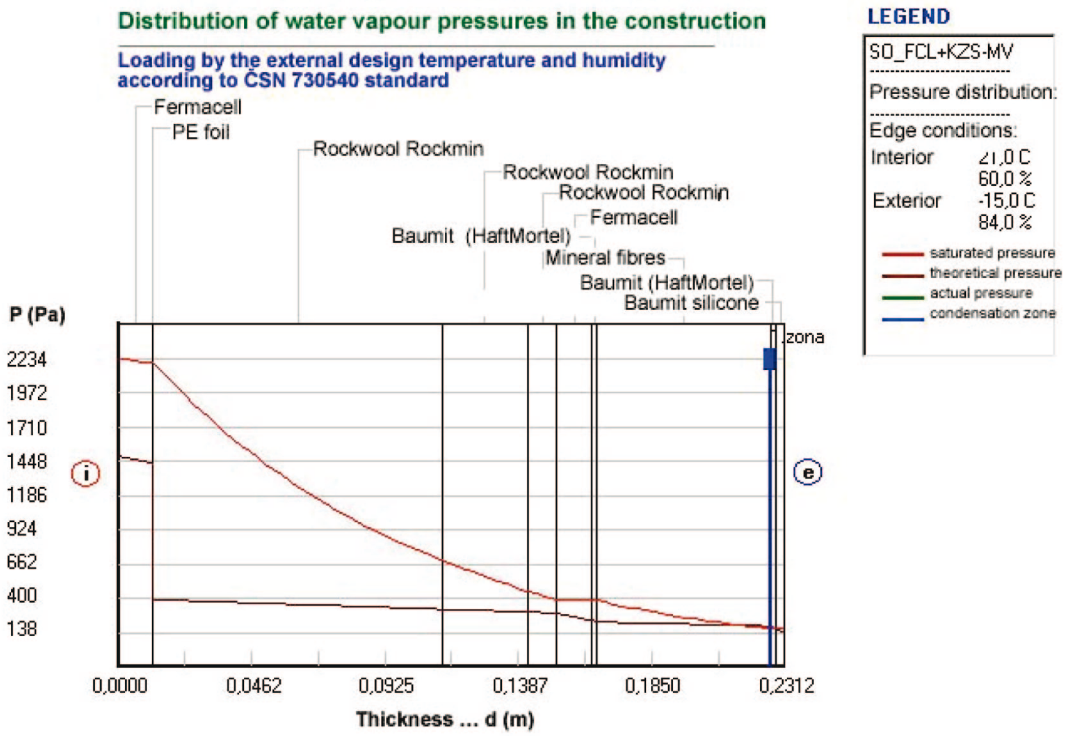
Heat resistance and coefficient of heat passage according to ČSN EN ISO 6946 standard
Heat resistance of a construction R: 3.308 m^{2}K/W
Coefficient of heat passage of a construction U: **0.288 W/m^{2}K**

Water vapour 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 edge conditions:

interface:	i	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	e
temp. [C]:	19.3	19.0	19.0	1.7	–3.5	–5.2	–5.4	–5.5	–14.7	–14.7	–14.7
pd [Pa]:	1491	1435	393	320	299	291	235	222	**192**	**179**	138
pd” [Pa]:	2234	2198	2197	692	458	395	386	386	**170**	**169**	169
φx (%)				46.2	65.3	73.7					
ωx (%) ~				**9.5**	**13**	**15**					

Year-long moisture balance
The amount of condensed water vapour Gk: 0.018 kg/m^2/year
The amount of evaporated water vapour (evaporation capacity) Gv: 12.639 kg/m^2/year
Condensation occurs at an outside temperature lower than -10.0 °C.



5: *Distribution of water vapour pressures in the construction of cladding No. 3*

In this structure, a very small condensation occurs at the relative humidity of inner air RHi = 60%. However, condensation occurs out of the zone where the wooden frame construction is situated. The amount of evaporated water vapour is three orders higher than the amount of condensed water vapour. With respect to a low outside temperature when condensation will occur according to calculations it is possible to suppose that the equilibrium moisture content in a frame construction will exceed a value of 12%, namely maximally by 3% only for several days in a year. Thus, the construction can be designed and dimensioned according to EUROCODE 5 for the class of use 1. If we substitute the value of heat conductivity calculated for determined conditions for the design coefficient of heat conductivity of wood instead of a value given in Table I, column 8 ČSN 730540-3 standard, the degradation of the coefficient of heat passage by heat bridges will significantly decrease in the construction. It is possible to state that the construction will be best from the viewpoint of reliability and service life.

DISCUSSION

Equilibrium moisture content (EMC) and its acceptable changes in the course of using a building are most important from the viewpoint of basic requirements to ensure the functional reliability of a wooden frame building structure. Problems of testing the moisture are substantially more complicated as compared with the determination of equilibrium mass wood moisture by means of calculation methods to verify diffusion and condensation of water vapours in a construction. The amount of water vapour flowing through the construction, eg within the air permeability of materials, can be even higher than the amount of water vapour corresponding to differences in the partial pressure of water vapour affecting the construction. The flow of water vapour flowing within the flow of moist air is characterized by the coefficient of water vapour filtration. There is a question, however, how the determined values of the coefficient of air permeability and of the coefficient of water vapour filtration will prove in the moisture condition of a construction (Řehánek, 2005).

For materials of wooden frame building structures, these values are usually not known. Moreover, air permeability of joints and contacts of particular layers can enter the total moisture balance in a construction. Complicated calculation procedures to verify the diffusion and convection of water vapours are hardly usable in the common designing practice. Thus, wood itself is a reliable indicator of moisture conditions in the cladding construction.

CONCLUSION

Within the study of the partial stage of a research plan we will focus on the continual measurement of EMC in selected constructions of actual buildings.

Through the comparison of measured results with various calculation procedures other criteria will be defined for designing and assessing wooden frame building structures from the viewpoint of their general reliability and service life.

SOUHRN

Spolehlivost a životnost konstrukcí a staveb ze dřeva

Funkční spolehlivost a životnost dřevěných rámových stavebních sestav je determinována rovnovážnou hmotnostní vlhkostí dřeva v těchto stavebních sestavách a její přijatelnou změnou v průběhu užívání stavby. Problematika ověření rovnovážné vlhkosti dřeva je však podstatně složitější než zjištění rovnovážné vlhkosti dřeva pomocí výpočtových metod, sloužících pro ověřování difuze a kondenzace vodní páry v konstrukci. Množství vodní páry proudící konstrukcí v rámci vzduchové propustnosti materiálů může být řádově větší, než množství vodní páry prostupující konstrukcí difuzí, odpovídající rozdílům parciálních tlaků vodní páry působících na konstrukci. Množství vodní páry proudící konstrukcí v rámci toku vlhkého vzduchu je charakterizováno součinitelem vzduchové propustnosti a součinitelem filtrace vodní páry jednotlivých materiálových vrstev stavební sestavy. Pro materiály dřevěných rámových stavebních sestav nejsou zpravidla hodnoty těchto součinitelů známy. Mimo to může celkovou bilanci vlhkosti materiálů zabudovaných v takovéto konstrukci ovlivnit i vzduchová propustnost spár a styků materiálů tvořících jednotlivé konstrukční vrstvy. Složité výpočtové postupy pro ověření difuze a konvekce vodní páry jsou navíc v běžné projekční praxi těžko použitelné.

Pro základní tepelně technické posouzení byly ze souboru skladeb obvodových stěn běžně používaných u montovaných rodinných domů vybrány tři typy dřevěných rámových stavebních sestav, které lze podle základních kritérií považovat prakticky za shodné. Jednotlivé konstrukce byly záměrně upraveny tak, že mají shodnou tloušťku tepelně izolační vrstvy, shodný podíl tepelných mostů (prvků dřevěné rámové konstrukce v tepelně izolační vrstvě) a liší se pouze typem použitých konstrukčních desek zajišťujících stabilitu konstrukce v rovině stěny a typem běžně používaných kontaktních zateplovacích systémů. Z hlediska tepelně technického posouzení lze zvolené konstrukce klasifikovat jako konstrukce splňující požadavky příslušných harmonizovaných norem. Pokud tato tepelně technická posouzení rozšíříme o poznatky uvedené v předcházejícím textu a zaměříme se na sledování teplotně vlhkostních podmínek uvnitř konstrukcí obvodových stěn, můžeme z analýzy výpočtu provedeného pomocí běžně užívaného software konstatovat, že u jednotlivých variant obvodových stěn lze předpokládat odlišnou životnost a spolehlivost posuzovaných konstrukcí.

Přesnější posouzení teplotně vlhkostních podmínek uvnitř ověřovaných konstrukcí je možno zajistit rozdělením tepelně izolační vrstvy s dřevěnou rámovou konstrukcí do tří vrstev různé tloušťky. Vypočteným teplotám a parciálním tlakům vodní páry na jednotlivých rozhraních vrstev byla přiřazena odpovídající relativní vlhkost prostředí RHx a z nomogramu rovnovážné vlhkosti dřeva příslušná rovnovážná hmotnostní vlhkost dřeva ωx, odpovídající teplotě a vlhkosti prostředí v daném rozhraní vrstev.

V Čulického nomogramu rovnovážné vlhkosti dřeva, který je zpracován i pro záporné teploty vzduchu do –20 °C, končí odpovídající rovnovážná vlhkost dřeva hodnotou 28 %. Proto tam, kde odpovídající hodnota rovnovážné vlhkosti dřeva může za normových podmínek po určitou dobu přesahovat hodnotu 28 %, je uveden symbol > 28. U obvodových stěn, u kterých dochází za normových okrajových podmínek k překročení rovnovážné vlhkosti dřeva 20 % v dřevěné rámové konstrukci po dobu delší než několik týdnů v roce, lze předpokládat snížení jejich funkční spolehlivosti a životnosti.

dřevo, konstrukce, vlhkost, deformace, dotvarování, spolehlivost

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