Interpretation of provisions of the Czech standard ČSN 73 0540 Thermal Protection of Buildings for Residential Wooden Houses and Design Recommended Practice

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Content

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1. Introduction

1.1. Valid and binding regulations

Thermotechnical requirements are bindingly confirmed in two spheres of regulations:

a) Building Act no. 183/2003 Coll. and its Code of Practice no. 137/1998 Coll. on General Technical Requirements for Development (OTP), as amended,

b) Act no. 406/2000 Coll. on Energy Management, its amendment no. 177/2006 Coll. as amended by no. 406/2006 Coll. and its Code of Practice no. 148/2007 Coll. on Energy Demandingness of Buildings as amended.

A specific technical regulation in this field is the Czech standard ČSN 73 0540 Thermal Protection of Buildings (and a set of tied standards), which the above-mentioned statutes are related to and make its requirements binding. Valid requirements are set forth in the second part of the standard i.e. in ČSN 73 0540-2 from April 2007.

Thermotechnical properties of building structures and buildings are specified by calculation methods in accordance with Part 4 thereof using design values of variables in accordance with Part 3 thereof.

1.2. Statutory duties

Pursuant to Sections 15, 22, 28, Code of Practice no. 137/1998 Coll. on General Technical Requirements for Development, buildings shall be designed and executed to comply, under common maintenance and commonly foreseeable effects during their foreseeable lifetime, with the basic requirements including but not limited to

- Health protection, healthy living conditions and environment (condensation, fungi and air exchange according to ČSN 73 0540-2),
- Energy savings and thermal protection of buildings (other requirements according to ČSN 73 0540-2).

The so-called standard values are mentioned in specification of requirements in Section 31 et seq. thereof, which, according to Section 3, paragraph p), mean technical requirement in applicable Czech technical standard ČSN.

Pursuant to Section 2 of the above Code of Practice, the basic requirements for required conditions of indoor environment are valid both for new buildings and building adaptations, maintenance works, alteration of use and other changes of completed buildings.

Pursuant to the same Section of the Code of Practice, requirements raised during building proceedings conducted both in a form of building permit and notification (in this case complance with requirements is documented usually only upon request of an appropriate building office if the office is not sure about meeting of those requirements); however, it is also valid contrariwise that, by its administrative decision, a building office takes over co-responsibility for meeting these requirements if it does not require any documentation.

1.3. Statutory duties ensuing from Act on Energy Management

The Directive of the European Parliament and of the Council 2002/91/EC on the Energy Performance of Buildings (EPBD) should have been implemented into our law at the latest till the 4th January 2006. This European Directive has even more emphasized the requirement for execution of new buildings and changes of existing buildings with low energy demandingness.

The Directive was transposed into the Czech law as of the 1st July 2006 by issuance of amendment of Act no. 177/2006 Coll. to Act no. 406/2000 Coll. on Energy Management, with consequent issuance of unabridged version in Act no. 406/2006 Coll. and with codes of practice, hich were issued during 2007 (particularly Code of Practice no. 148/2007 Coll. on Energy Demandingness of Buildings efficient as of the 1 July 2007 is important for us).

Detetmined buildings shall meet the requirement for low complex energy demandingness as of efficiency of the Act amendment. This energy demandingness of buildings includes, besides heating, ventilation, passive solar gains and gains from internal sources, also cooling, air-conditioning, DHW heating, built-in artificial lighting and real losses of energy systems providing these energies.

Pursuant to Sections 12, 12a), Act no. 406/2006 Coll., **meeting of requirements for energy demandingness of buildings and meeting of comparison indicators** according to Code of Practice no. 148/2007 Coll. for Practical Implementation of Section 6a) of the Act shall be provided under penalty of CZK 100,000. Meeting of the set requirements shall be documented by the Energy Demandingness Certificate.

The required thermotechnical properties (in scope according to ČSN 73 0540-2) for individual structures, rooms and a building as a whole belong among comparative indicators.

Section 6a) of the Act becomes efficient pursuant to Section 15 of the Act as of the 1st January 2009.

However, meeting of paragraphs 1 and 2 of Section 6a) of the Act may be requested by another regulations and documents already now.

E.g. Code of Practice no. 499/2006 Coll. on Building Documentation (implementing the Building Act) requests this duty, pursuant to Annex 1 to Part B (Summary Specifications), Item 7a, and Part D (Documents), Item b), with efficiency as of the 1st January 2007. The condition for entry into the operational environmental programme within applications for grants for thrifty measures by means of building solution (within the first call) was elaboration of an assessment by the process according to Code of Practice no. 148/2007 Coll.

The duty to assess energy demandingness of buildings and to document it by a valid Energy Demandingness Certificate applies for:

a) All new buildings,
b) Major changes of completed buildings with total floorage exceeding 1,000 m^2 influecing energy consumption,
c) Sale or rent of buildings (upon request of a new owner or tenant). This item was changed on the basis of initiative of Members of Parliament in contradiction with the European Directive so that it is valid only for buildings

set in Items a) and b) – even though it is obvious that the so complented requirement is absolutely worthless, which was the intention neither of the Directive nor the presenter of the Act.

Operators of buildings for public, which are used by public administration and institutions that provide public services to large number of persons (i.e. for education, health care, culture, commerce, sport, accommodation and catering services, customer centres) with total floorage exceeding 1,000 m², are obligated to place the Certificate on a publicly accessible place in a building (in addition, the Directive emphasized placement on a prominent place well visible by public).

The Energy Demandingness Certificate of buildings will be valid for 10 years.

Major changes are changes of more than 25% of total building enclosing shell surface or changes of building technical facilities with energy effects where the initial total of influenced consumptions of energies is higher than 25% of total energy consumption. The total floorage is the built-up area of all floors reduced by the plan area of perimeter walls.

Emphasis is laid on real provision of low energy demandingness of buildings and their changes. It does not concern only processing of assessment and proposal of adaptations but also real and provable execution of such buildings.

1.4. Exceptions

Statutory possibility of exceptions exists for binding thermotechnical requirements for existing completed buildings and their individual structures. Pursuant to Act no. 406/2006 Coll. and also pursuant to Czech standard ČSN 72 0540-2, it is possible to prove, in case of changes and repairs of completed buildings, that, pursuant to the special regulation on energy audits (Code of Practice no. 213/2001 Coll. of the Ministry of Industry and Trade as amended), meeting of requirements is for some structures and/or buildings technically, environmentally or economically impracticable regarding the lifetime of a building and its operational purposes. However, internating of a requirement is permissible only to such extent that does not enable malfunctions and faults at use of a building. The builder is obligated to document meeting of conditions which allow this exception e.g. by an energy audit.

In addition, the standard directly specifies buildings for which the standard requirements are valid adequately to possibilities – again, not to enable malfunctions and faults at their use. It concerns particularly:

a) Protected buildings or existing buildings inside monumental preservations (pursuant to Act no. 20/1987 Coll. on State Heritage Care as amended),

b) Buildings affected by natural disasters,

c) Unheated buildings or unheated zones of buildings (with indoor environmental conditions required for storage, operation of technical facilities, etc.)

Regarding malfunctions and faults, it is necessary to check condensation of water vapour on surfaces of and inside structures under conditions of these buildings use; other requirements are usually not taken into account. However, consideration of non-standard marginal conditions is enabled if they are permanently provided.

Below are three correct options how to meet a justified minimum requirement within the exception which are usually combined:

a) To suitably adapt building structures (which is not mostly practically feasible e.g. at heritage monuments and their structures due to heritage preservation care, however it is necessary to use all partial possibilities at all structures where possible),

b) To suitably adapt use of a building to quality of structures (which may be possible only to limited extent, however it is very safe and cheap approach),

c) To suitably solve heating, ventilation or, as the case may be, another air treatment to ensure marginal conditions under which malfunctions and faults do not occur. This approach is safe only to the extent of safety of energy supplies. Therefore, this complementary approach is applied after depletion of the above-mentioned options.

Other suitable options for buildings do not exist. Disrespect for minimum building and technical requirements, unsuitable use or unsuitable operational mode of heating and ventilation lead to malfunctions and faults of buildings which we want to protect.

2. Standard requirements

Separate functional parts of perimeter structures of wooden houses are usually assessed separately; structures of wooden houses are only exceptionally certified together with windows, doors and other openings as composite “light-weight perimeter envelopes” pursuant to ČSN EN 13830.

2.1. Lowest indoor surface temperature

The lowest surface temperature $\theta_{si,min}$ is newly assessed by means of the structure property called the ”lowest indoor surface temperature factor $f_{Rsi,min}$“, or only the „temperature factor“. It is dimensionless. The $f_{Rsi,min}$ value ranges between 0 and 1 so that the better properties, the closer value to 1.

For each building detail, there is only one $f_{Rsi,min}$ value for the standard heat transmission, which is used for calculation of the lowest indoor surface temperature $f_{Rsi,min}$ for any indoor air temperature θ_{ai} and outdoor temperature θ_e by means of the equation

$$\theta_{si,min} = \theta_{ai} - (1 - f_{Rsi,min})*(\theta_{ai} - \theta_e).$$

If we compare it with classic expression of the indoor surface temperature by means of the equation

$$\theta_{si,min} = \theta_{ai} - U_{x,max} * R_{si} * (\theta_{ai} - \theta_e),$$

where $U_{x,max}$ is the local heat transmission coefficient for the place with the lowest indoor surface temperature, then we get clear proof of the argument that f_{Rsi} is the structure property of

$$f_{Rsi,min} = 1 - U_{x,max} * R_{si}$$

Regarding often occurring critical details of the integral building systems, their manufacturers can work out catalogues of the lowest indoor surface temperature factors $f_{Rsi,min}$. Manufacturers of walling material have already started to do so, wooden houses are still waiting for such practical aid.

Catalogue values $f_{Rsi,min}$ allow the designer to verify very easily, even without calculation of temperature fields, requirements laid on the lowest indoor surface temperatures in these details for concrete temperature and humidity conditions of a designed building.

The requirement size has not changed in comparison with wording of the standard from November 2002, only the manner of formulation by means of values f_{Rsi} has changed.

Today, the value $f_{Rsi,min,N}$ is assessed instead of the required standard value $\theta_{si,min,N}$. The critical temperature factor $f_{Rsi,cr}$ and the temperature factor safety surcharge Δf_{Rsi} are used instead of the critical surface temperature $\theta_{si,min}$ and the safety temperature surcharge $\Delta\theta_{si}$, respectively.

The limit value found on an indoor surface in places of thermal bridges in structures and in places of thermal bonds between structures is assessed. Its assessment watches the public health requirement for elimination of fungi on surfaces of structures or elimination of water vapour condensation on too cold indoor surfaces of structures. The coldest structures are usually the perimeter ones, so this requirement usually applies on them. It is the requirement which default may cause faults and malfunctions of structures and, therefore, it is important for assessment of existing buildings and buildings, which the standard requirements apply only adequately to (e.g. monuments, buildings after natural disasters and other exceptions from the standard).

The lowest indoor surface temperature factor $f_{Rsi,min}$ should be minimally on the level of the critical temperature factor $f_{Rsi,cr}$ plus the temperature factor safety surcharge Δf_{Rsi}.

$$f_{Rsi,min} \geq f_{Rsi,N} = f_{Rsi,cr} + \Delta f_{Rsi}$$

The critical indoor surface temperature factor $f_{Rsi,cr}$ is not currently found in tables and diagrams but it is simply calculated by the equation

$$f_{Rsi,cr} = 1 - \frac{237.3 + 2.1 * \theta_{ai}}{\theta_{ai} - \theta_e} * \frac{1}{1.1 - 17.269/\ln(\varphi_i / \varphi_{si,cr})}$$

where φ_i is the design indoor air humidity and $\varphi_{si,cr}$ is the standard critical indoor surface relative humidity, which is 100% for windows, doors and other openings (the dew point or moisture condensation) and 80% for other structures (agreed humidity, at which fungi start to grow on the structure surface – however, growth of mutated fungi was found in practice already at 70% surface humidity; this deviation is perceived within the calculation safety).

The following simplified equations are valid for common 50% design indoor air humidity in residential rooms:

a) doors, windows and other openings

$$f_{Rsi,cr} = 1 - \frac{9.12 + \theta_{ai} / 12.38}{\theta_{ai} - \theta_e}$$

b) other structures

$$f_{Rsi,cr} = 1 - \frac{6.27 + \theta_{ai}/18.02}{\theta_{ai} - \theta_e}$$

The critical temperatures for selected rooms of residential buildings are given in Table 1; others may be found in ČSN 72 0540-3, if needed.

Table 1 – Critical temperature factor $f_{Rsi,cr}$ for outdoor temperature θ_e = -13 °C.

Use	**Temperature/humidity of indoor air** $\boldsymbol{\theta_{ai}/\varphi_i}$	**Doors and windows** $\boldsymbol{f_{Rsi,100}}$	**Other structures** $\boldsymbol{f_{Rsi,80}}$
Living space	21 °C / 50%	0.682	0.781
Staircase	11 °C / 50%	0.583	0.713
Bathroom (average)	25 °C / 65%	0.815	0.909
Swimming pool (dehumidification)	29 °C / 50%	0.727	0.812
Swimming pool (night evaporation)	21 °C / 70%	0.833	0.937

The outdoor temperature θ_e = -13 °C according to the revised ČSN 73 0540-3 from November 2005 is obtained usually for places where the value θ_e = -15 °C was valid before this revision.

The considered indoor air temperatures θ_{ai} are by 1 °C higher than the design indoor temperature θ_i (the resulting temperature, which includes the indoor air temperature and the average indoor temperature of walls enclosing a room, is used at assessment of the heat transmission coefficient, building energy properties and at designing of heating systems).

At assessment at stabilised temperature condition, the temperature factor safety surcharge Δf_{Rsi} takes into account effects of fluctuating outdoor temperatures, loss and phase displacement at their transmission through a structure to the indoor surface together with effect of indoor temperatures fluctuation at heating regulation. The standard values are included in Table 2; in special cases, it is possible to determine this surcharge by more accurate non-stationary calculation (e.g. for very massive structures of historical monuments, but the standard safety surcharges are fully satisfactory for light-weight wooden houses).

It can be generally said that the value of the temperature factor safety surcharge $\Delta\theta_{Rsi}$ amounting to 0.015 corresponds to every value of the safety temperature surcharge Δf_{Rsi} amounting to 0.5 °C.

Table 2 – Safety temperature surcharge $\Delta \boldsymbol{f}_{Rsi}$ in °C

Structure / **Type of heating system**	**Doors, windows and other openings** (windows, sky-lights, doors, gates, roof manholes) **for heating radiator**		**Other structures** (perimeter wall, roof and their link-up)	
	under an opening	**outside an opening or low temperature radiators**	**Massive**	**Light-weight**
Continuous $\Delta\theta_V$ < 5 °C	-0.030	0	0	0.5
Damped with drop of				

resulting temperature 2 °C ≤ $\Delta\theta_V$ ≤ 5 °C	-0.015	**0.015**	0.015	**0.030**
Interrupted with drop of resulting temperature $\Delta\boldsymbol{\theta}_V$ 5 °C	0	0.030	0.030	0.045

The usual heating of residential buildings is included in the middle row of the Table – damped heating; continuous heating is usually not maintained continuously in practice. Concerning windows, doors and other openings, it is suitable to consider the low temperature heating, which economical adaptations tend towards during their use. The perimeter walls and roofs of wooden houses are usually light-weight (see the last column). Suitable safety surcharges for wooden houses are in bold in Table 2.

When calculating the indoor surface temperature and the temperature factor, the overall thermal resistance on the indoor side R_{si} = 0.25 m²*K/W is considered, according to ČSN EN ISO 13788 and ČSN 73 0540-4, for all structures except for doors, windows and other openings. This resistance corresponds to here and there slower air flow in the boundary air layer in a room corner (older version of ČSN 73 0540-2) or behind furniture which is not standing directly at a wall (if furniture is directly at the wall, according to ČSN EN ISO 10211-1, R_{si} = 0.50 m²*K/W should be considered).

The lower thermal resistance on the indoor side R_{si} = 0.13 m²*K/W corresponding to undisturbed air flow along the structure is considered only at windows, doors and other openings similarly to calculation of the heat transmission coefficient.

For designing of buildings, properties of materials and products shall be considered, according to ČSN 73 0540-3, as the design ones set for their real moisture after their building-in and during their use.

Values declared by manufacturers correspond usually to values in dry state; they are used for documenting capability of a product having the declaration of conformity to be put on the market. For designing of buildings, it is necessary to ask the manufacturers for characteristic values (at sorptive moisture) or to use safe general values set in ČSN 73 0540-3 or to recalculate less accurately the values declared for dry state to moisture characteristic values by the following equation

$$\lambda_k = \frac{\lambda_D}{1 - Z_u * w_{mk}}$$

where λ_D is the declared value of the thermal conductance coefficient according to the appropriate standard ČSN EN for a product ;

Z_u is the moisture coeffcient according to Annex A1 to ČSN 730540-3;

u_{mk} is the characteristic moisture of a material, usually $u_{23/80}$.

The lowest indoor surface temperature $\theta_{si,min}$ and the temperature factor f_{Rsi} are usually determined by means of temperature fields of critical details. It is always necessary to také into account the unfavourable co-action of other linked structures in a real spatial combination. If the indoor surface temperature and the temperature factor are obtained by means of the two-dimensional temperature field, they have to meet the standard requirement with sufficient reserve for taking into account the three-dimensional co-acting.

Just for illustration, Table 3 includes the lowest indoor surface temperature factors $f_{Rsi,min,}$ which still guarantee meeting of the requirement for the lowest indoor surface temperature $\theta_{si,cr}$ at the safety temperature surcharges $\Delta\theta_{si}$ amounting to 0.5 °C for doors, windows and other openings and 1.0 °C for other structures for critical surface temperatures according to Table 1. The higher indoor surface temperature factor, the higher quality of the designed detail (higher indoor surface temperatures θ_{si}).

Table 1 clearly shows that details designed in quality for residential rooms are suitable also for staircases and that it is necessary to design details for moist operations such as bathrooms and swimming pools significantly better, with higher indoor surface temperature factor. It may be quite surprising for many designers that the strictest requirements are for night or shutdown modes or even for emergency mode, when the swimming pool is often heated to common temperature of living rooms and dehumidification is switched off for "thrifty" reasons (in case of larger uncovered surface of a swimming pool and low ceiling, humidity may become even higher and problems with surface condensation even more significant). In addition, it is also clear that requirements for detailed design of windows, doors and other openings in humid operations are so strict that they may either invoke need of special frames and glazing or allow surface condensation on windows, doors and other openings together with drainage of the condensate or provision of its evaporation from collecting parts of sills under the condition that its effect on adjacent structures will be excluded.

Practical conclusion: It is advantageous to maximally care for use of such structural principles, which will create neither significant thermal bridges in structures nor thermal bonds between structures or will limit them to maximal extent, as early as in the conceptual phase of the design. The idea about future additional solution of these "tiny" details by a specialist is incorrect – additional adaptations are never sufficiently efficient and are also economically more demanding than solutions created in cooperation with a specialist as early as in the structural concept phase. When designing structures for humid operations, it is necessary to be even more careful.

Concerning wooden houses, it is not suitable to apply Articles 5.1.2 and 5.1.3, ČSN 730540-2, which, under certain conditions allows not to meet requirements for indoor surface temperatures and the temperature factor because risk of surface condensation and condensate leakage are too dangerous for durability of wooden houses.

2.2. Coefficient of heat transmission

The heat transmission coefficient U is the average value valid for the whole structure or its functional part. It includes growth of thermal flow caused by effects of thermal bridges in the structure, and does not include effect of thermal bonds between structures. Its assessment watches balance of individual building parts both in respect to thermal flows (energy point of view) and to the public health requirement of thermal comfort.

Requirements for heat transmission coefficients for residential buildings are set in Table 3, ČSN 73 0540-2; requirements for selected structures are included in Table 4.

Table 4 – Standard values of heat transmission coefficient U_N for residential buildings

Structure description		**Heat transmission coefficient U_N [in W/(m^{2*}K)]** Required values $U_{N,rq}$	Recommended values $U_{N,rc}$
Flat and sloping roofs (up to 45°) Outdoor floor (above outdoor space)		0.24	0.16
Ceilings above unheated attic Outdoor heated walls (external layers from the heating)		0.30	0.20
Outdoor walls Steep roofs with inclination exceeding 45°	light-weight	0.30	0.20
	massive	0.38	0.25
Floors and walls adjoint to soil (with the exception of marginal strips)		0.45	0.30
Indoor ceilings and walls from heated to unheated space		0.60	0.40
Windows, doors and other openings in an outdoor wall and steep roof, from heated space to outdoor environment (including a frame) Their metal frames shall have $U_f \leq 2.0$ W/(m^{2*}K), other frames of these filled openings $U_f \leq 1.7$ W/(m^{2*}K)		1.7	1.2
Splayed roof windows, doors and other openings with inclination up to 45° from heated space to outdoor environment (including a frame) Their metal frames shall have $U_f \leq 2.0$ W/(m^{2*}K), other frames of these filled openings $U_f \leq 1.7$ W/(m^{2*}K)		1.5	1.1
Windows, doors and other openings in an outdoor wall and steep roof, from heated space to partially heated space or from partially heated space to outdoor environment		3.5	2.3
Splayed roof windows, sky lights, etc. with inclination up to 45° from heated space to partially heated space or from partially heated space to outdoor environment		2.6	1.7
Light-weight perimeter envelope (LOP) assessed as an assembly including load-bearing elements with transparent filling panel having the relative area $f_w = A_w / A$, in m^2/m^2, where A is the total area LOP; A_w is the area of transparent panel filling an LOP opening. Frames LOP with $U_f \leq 2.0$ W/(m^{2*}K)	$f_w \leq 0.50$	$0.3 + 1.4*f_w$	$0.2 + f_w$
	$f_w > 0.50$	$0.7 + 0.6*f_w$	

The recommended $U_{N,rc}$-values always reach, with the exception of light-weight perimeter envelopes, ⅔ of the required $U_{N,rq}$-values. It is suitable to design structures of low energy houses with heat transmission coefficients U_{NED} amounting to maximally half of the required $U_{N,rq}$-values; these coefficients are even lower in case of passive houses.

Concerning composite perimeter building structures characteristic for wooden houses, it is particularly important to include the proper effect of thermal bridges occurring in a structure into the heat transmission coefficient U. Inaccurately determined U-values of individual structures lead to too optimistic ideas about low heat consumption for heating of wooden houses, resulting to underdimensioning of a heating system, dissatisfied users and, finally, to bad reputation of this type of development.

The most significant and always repeated mistake is determination of the *U*-value only from the assembly in the ideal section of a structure. This is mistake, which is often caused by ignorance of infrequent users of commercial programmes, who are mislead by the programme menu and use just simple sum of individual material layers. This mistake is demonstrated by the simplest correct process (method of characteristic thermal bridges according to ČSN 73 0540-4), where this heat transmission coefficient in the ideal section U_{id} is used as one element of the result that characterises effect of an assembly of layers. Effect of thermal bridges in a structure ΔU_{tbk} in W/(m^{2p*}K) is added separately:

$$U = U_{id} + \Delta U_{tbk}$$

Effect of thermal bridges usually corresponds to their occurrence in a structure, just for illustration:

a) $\Delta U_{tbk} \approx 0.02$ – nearly without thermal bridges (successfully optimised solution),

b) $\Delta U_{tbk} \approx 0.05$ – with moderate thermal bridges (typical or repeated solution),

c) $\Delta U_{tbk} \approx 0.10$ – with usual thermal bridges (standard solution),

d) $\Delta U_{tbk} \approx 0.15$ and more – with significant thermal bridges (neglected solution).

Use of these values may be considered as educated guess.

It is clearly seen that any mistake at incorrect assessment of low energy and passive houses may range up to multiple of low values of heat transmission coefficients in the ideal section U_{id}. In other words – effect of thermal bridges at currently designed buildings is comparable with effect of structure assembly and their effect is increasing at low energy and passive houses. It means that the design of assemblies with high thicknesses of thermal insulations is not sufficient for reaching of necessary heat transmission coefficients *U* but it is similarly or even more necessary to optimise thermal bridges in a structure to eliminate their effect as much as possible.

Frequent mistake is also negligence of structurally less significant conducting elements in the thermal insulation layer and no consideration of technological tolerances in composite structures. These effects have increasing significance at low energy and passive houses.

Correct ways of calculation of the heat transmission coefficient *U* are described by traditional national processes in ČSN 73 0540-4:2005 and by European (international) standard methods adopted in last ten years (e.g. ČSN EN ISO 6946, ČSN EN ISO 10211-1, ČSN EN ISO 10211-2, ČSN EN ISO 10077-1 and ČSN EN ISO 10077-2). The mentioned methods differ by degree of accuracy, however all of them include effect of thermal bridges in structures. Calculation methods in Czech and European standards are newly summarised in the revised Czech standard 73 0540-4:2005.

Methods of approximate calculation of the *U*-value from two extreme limits are described in ČSN EN ISO 6946 and ČSN 73 0540-4.

Method of characteristic thermal bridges described above gives more accurate calculation, however effect of individual linear and point thermal bridges in a structure is found by methed of thermal fields. The consequent sum of their actions in a structure above the level of heat transmission through the ideal assembly gives the summary effect, which, rated to 1m², gives more accurate values of ΔU_{tbk}.

More detailed calculations of characteristic thermal bridges in structures may be used for catalogues of individual linear and point thermal bridges. Use of catalogue values will provide *U*-values with accuracy comparable with the method of thermal fields.

It is possible to elaborate a guideline catalogue of values of summary effect of thermal bridges ΔU_{tbk} which may be used for simple approximate calculations for structures with similar occurrences of thermal bridges.

Practical conclusion: To reduce the heat transmission coefficient *U* and subsequently energy demand for heating, it is necessary not only to design higher thicknesses of thermal insulations but also to eliminate maximally thermal bridges in structures, as early as in the conceptual phase of the design.

2.3. Linear and point heat transmission factors

The last revision of ČSN 73 0540-2 includes assessment of individual thermal bonds between structures by means of linear and point heat transmission factor ψ and χ which were introduced by the amendment Z1 from March 2005.

Significance of this assessment is growing with decrease of heat transmission through individual structures – this is the reason why this assessment is gradually introduced in more developed European countries. Another reason is purely practical – many designers will finally begin to carefully think about optimisating a detail of mutual connection of structures from the point of heat transmission when assessing this effect. It is the step from designing of individual structures to parallel perception of their system co-action within the whole building.

Requirements refer to values ψ and χ set for a warp of external dimensions.

Concerning linear details of perimeter walls connections, the required ψ-value amounts to at most 0.60 W/(m*K) with the exceptions of link-ups to doors, windows and other openings where the value of 0.10 W/(m*K) is required. Concerning linear details of connections of roofs and doors, windows and other openings, the y-value of 0.30 W/(m*K) is required.

Concerning individual point thermal bonds caused by penetrations of bar structures such as columns, beams and brackets, the χ-value of max. 0.90 W/(m*K) is required.

The recommended values reach again ⅔⅔ of the required values; low energy buildings should have thermal bonds optimised so that their effect is lower than a half of the required one, and thermal bonds of passive houses should be even lower.

These requirement watch deviations of individual, the least acceptable thermal bonds, the common thermal bonds should be even more favourable. Some thermal bonds can have negative values ψ and χ.

Effect of all thermal bonds on the heat exchanging building envelope, which is formed by the perimeter structure of the building system boundary, can be totally expressed by the partial specific heat transmission loss caused by ΔH_{tb} in W/K from the equation

$$\Delta H_{tb} = \Sigma\psi * \ell + \Sigma\chi$$

When optimising thermal bonds, the total effect of thermal bonds within the whole building $\Delta H_{tb} \approx 0$ can be reached but it is uneasy objective for low energy and passive houses.

Correct methods of calculation assessment describe methods newly summarised in ČSN 73 0540-4:2005, specified in details in ČSN EN ISO 10211, ČSN EN ISO 14683 and ČSN EN ISO 13789.

It is possible to elaborate a guideline catalogue of values ψ and χ for structures with similar shape and material design, which may be used for simple approximate calculations. The guiding general values are a part of ČSN EN ISO 14683 (they are not too suitable for designing thanks to significant inaccuracies and missing determining parameters), more accurate values ψ and χ may be provided by manufacturers of integral building systems. Manufacturers of walling systems has already started to do so.

Neglected or inaccurately determined linear or point factors of heat transmission ψ and χ of thermal bonds between structures lead again to underestimation of constructional optimisation of details, faulty ideas about low consumption of heat for heating of wooden houses and underdimensioning of a heating system.

Practical conclusion: It is necessary to optimise design of details of mutual connection of structures of low energy buildings from the point of heat transmission. This will ensure minimisation of linear and point heat transmission factors ψ and χ of thermal bonds in these details.

2.4. Drop of contact floor temperature

This property expresses thermal comfort at contact of a usually shoed user with the floor surface. The contact floor temperature $\Delta\theta_{10}$ must not decrease below the standard value in Table 5.

Table 5 – Required values of contact floor temperature drop $\Delta\theta_{10,N}$

Building and room type	**Floor category**	**Contact floor temperature drop $\Delta\theta_{10,N}$ (in °C)**
Residential building: child‘s room, bedroom Public building: playroom of creches and kindergartens, intensive care ward, children’s ward	I. Very warm	≤ 3.8
Residential building: living room, study, antechamber abutting rooms, kitchen Public building: operating theatres, antetheatre, medical offices, preparatory room, examination room, duty room, hospital corridor and antechamber, adult’s ward, office, drafting room, art room, study, gym, classroom, storage room, laboratory, restaurant, cinema, theatre, hotel room Production building: permanent sedentary workplace	II. Warm	≤ 5.5
Residential building: bathroom, toilet, antechamber in front of a apartment Public building: toilet, bathroom, dressing room, corridors, waiting rooms, hospital staircases, dancing hall, meeting room, warehouse with permanent attendance, foodstuff shop, night shelters, permanent workplace in an exhibition hall and	III. Less warm	≤ 6.9

museum without a mat or prescribed warm shoes Production building: permanent workplace without a mat or prescribed warm shoes		
Buildings and rooms with no requirements	IV. Cold	> 6.9

It is not necessary to verify the requirement at floors with permanent trafficable wall-to-wall cover from textile flooring and at floors with surface temperature permanently higher than 26 °C.

Drop of contact floor temperature $\Delta\theta_{10}$ is determined according to ČSN 73 0540-4 on the basis of the floor thermal absorption *B* and the average indoor floor surface temperature θ_{si}. The floor thermal absorption *B* is mostly affected by the trafficable floor surface layer, effect of other layers on this partial property is decreasing with their increasing distance from the surface. The average indoor floor surface temperature θ_{si} is increased in case of decreasing of the heat transmission coefficient *U*, e.g. by additional warming-up from the side of the ceiling of the assessed above floor with flooring.

Regarding floors with floor heating, drop of the contact floor temperature $\Delta\theta_{10}$ is determined and verified for indoor floor surface temperature θ_{si} set without any effect of the floor heating at the design outdoor temperature θ_e = 13 °C.

Other structures, which building users touch similarly to floors, such as perimeter walls forming supporting surface of benches, beds, etc., may be assessed analogically.

Practical conclusion: Very warm and warm floors in residential buildings can be best provided by using suitable trafficable layers and their subfloors with high thermal absorption *B.* Regarding floors above outdoor environment, above ventilated air layers or on the ground, this requirement is best met by significant reduction of the heat transmission coeffcient *U,* of course together with the appropriate thermal absorption *B.*

2.5. Condensation of water vapours inside structures

The best designed wooden houses exclude condensation of water vapours inside a structure as a risk factor that threatens their durability.

However, if condensation of water vapours is allowed inside a structure of a wooden house, then the following limitations shall be met:

a) No condensed quantity of water vapours may be left in annual balance of condensation and evaporation of water vapours, which would permanently increase the structure water capacity. Annual quantity of condensed water vapours inside a structure G_K, in kg/(m^2*a) shall be lower than annual quantity of evaporable water vapours inside a structure G_V, in kg/(m^2*a)

b) Regarding warm decks, structures of wooden houses, structures with external thermal insulation system, external cladding or another perimeter structure with low vapour permeable external surface layers, the limit is the lower value of the following ones:

$G_{k,N}$ = 0.10 kg/(m^2·a), or 3% of basis weight of a material,

Regarding other building structures, the limit is the lower value of the following ones:

$G_{k,N}$ = 0.50 kg/(m^2·a), or 5% of basis weight of a material.

In addition to these direct standard annual limitations of condensed quantity of water vapours G_K in kg/(m^2·a), it is necessary, if using wood and/or materials based on wood, to limit condensation of water vapours by means of checking the following concurrently valid provisions referred in a standard:

a) To meet conditions for use of these materials in building structures according to Articles 5.1 and 5.4 of ČSN 73 2810:1993,

b) To comply with permitted moisture of these materials according to ČSN 49 1531-1,

c) To prevent jeopardising of the required function of a structure at exceeding of 18% balanced weight moisture of these materials.

The key significance in composite or assembled structures of wooden houses has a vapour barrier which shall be located by the internal side of thermal insulation. It is often forgotten that this layer is formed by discontinuous separate strips or parts and that mechanical connecting binding materials damage this layer during execution of a building structure. Leakages are more significant at vapour barriers with very high vapour resistance factor μ. It is also usually valid that the thinner the vapour barriers, the bigger is risk of their damage.

It means in practice that the vapour resistance factor μ of a vapour barrier may be by one or even two grades lower that this property of the initial material. Risk and water vapours condensation inside a structure of a wooden house should be assessed for properties of layers on the internal side of thermal insulation reduced by the above described manner.

In respect of safety, the layers on the external side of thermal insulation are considered with the highest available vapour resistances. This concerns also a layer efficiently protecting the thermally insulating layer of a structure of a wooden house against wind.

Practical conclusion: Condensation of water vapours in structures of wooden house shall be completely eliminated, if possible. When calculating, it is necessary to consider the real untighness of layers caused particularly by effect of building-in and operation in case of thin internal layers with higher vapour resistance factors $\boldsymbol{\mu}$. When assessing existence of condensation, the decisive factors are the results of the original Czech calculation method; when assessing balances of condensed and evaporable moisture, the balance calculation according to ČSN EN ISO 13788 has higher information value (both calculations are performed concurrently in commercial programmes).

2.6. Air permeability of joints and leakages in building perimeter envelope

Requirements for air permeability of the building perimeter envelope are based on the assumption that the required hygiene air exchange cannot be provided by leakages in perimeter envelope. It is caused by a fact that such air exchange varies, it may be inadequate if needed and excessive if not needed. In addition, exfiltration in top floors provides not hygiene supply of polluted air and, therefore, is in contradiction with intended purpose. Air exchange by leakages is uncontrolled, which excessively increases energy consumption. When using today windows and doors, which are very tight, this exchange is also too low not to require additional mechanical ventilation. Infiltration also excludes possibility to recuperate discharged air heat and possibility to use pre-heating (or cooling) of air in the earth exchanger. Air permeability of a building perimeter envelope contributes only a little to air exchange provided by another manner. We are trying to maximally eliminate it in low energy and passive houses.

Functional joints of windows, doors and other openings are exceptional because their allowed air permeability is included in Table 6 which means that only adequate tightness of functional joints is required. However, execution of tighter functional joints with nearly zero air permeability (under the condition of forced ventilation with heat recuperation) is recommended at low energy and passive houses.

Air permeability of other joints and leakages in structures and between structures of a wooden house shall be nearly zero during their use. This is ensured by generation of at least one continuous air-tight layer by the internal face of a structure. Besides used material, its tightness is affected particularly by joints and badly sealed crawl spaces or openings in a layer.

Table 6 – Required values of joint air permeability coefficient $\boldsymbol{i}_{LV,N}$

<table>
<tr><th colspan="2" rowspan="2">Functional joint at a window or a door</th><th colspan="2">Required value of factor of air permeability of joints
$i_{LV,N}$ [in $m^3/(s \cdot m \cdot Pa^{0.67})$]</th></tr>
<tr><th>Building with natural or combined ventilation</th><th>Building with only forced ventilation or air-conditioning</th></tr>
<tr><td colspan="2">Entrance door into an air lock of a building at total height of the above-ground part of a building $h \le 8$ m</td><td>$1.60 * 10^{-4}$</td><td>$0,87 * 10^{-4}$</td></tr>
<tr><td colspan="2">Other building entrance doors
Doors separating an integral part of a building</td><td>$0.87 * 10^{-4}$</td><td>$0.30 * 10^{-4}$</td></tr>
<tr><td>Other external windows and doors at at total height of the above-ground part of a building h</td><td>$h \le 8$ m
$8< h \le 20$ m
$20< h \le 30$ m
$h > 30$ m</td><td>$0.87 * 10^{-4}$
$0.60 * 10^{-4}$
$0.30 * 10^{-4}$
$0.10 * 10^{-4}$</td><td>$0.10 * 10^{-4}$</td></tr>
<tr><td colspan="2">Light-weight perimeter envelope including windows ans doors</td><td>$0.05 * 10^{-4}$</td><td>$0.05 * 10^{-4}$</td></tr>
</table>

The total air permeability of the building perimeter envelope is checked by expermental determination of the total intenzity of air exchange n_{50} at pressure difference 50Pa according to ČSN EN ISO 13829. It is recommended to provide lower intensities of air exchange n_{50} than are in Table 7. Recommendation for low energy and passive houses is very strict and very diffucultly realisable.

Table 7 – Recommended values of total intensity of air exchange $n_{50,N}$

Building ventilation	$\boldsymbol{n_{50,N}}$ **[$m^3/(m^3 \cdot h)$]**
Natural	4.5
Forced	1.5
Forced with heat recuperation	1.0
Forced with heat recuperation in buildings with especially low heat demand for heating	0.6

The required exchange of fresh air is set particularly in public health regulations.

Regarding rooms in residential buildings during periods of their unuse, ČSN 73 0540-2 recommends for rooms of residential buildings the lowest intensity of air exchange $n_{min,N}$ = 0.1 m^3/(m^3·h) unless a special statute and operation conditions set otherwise.

In the period when these rooms are used, the required intensity of air exchange recalculated from minimum quantities of necessary fresh air ranges between n_N = 0.3 m^3/(m^3·h) and n_N = 0.6 m^3/(m^3·h).

Fresh air demand is calculated on the basis of daily, weekly and season snapshot of use. Regarding residential rooms, at least 15 m^3/h and 25 m^3/h per capita are required at idle activity with metabolic heat production up to 80 W/m^2 and at activity with metabolic heat production exceeding 80 W/m^2, respectively. Air exchange in sanitary facilities is usually set forth in m^3/h related to equipment unit (per a shower, dressing locker) in public health regulations. The given values shall be provided during operating hours usually the whole year round.

Mounting of efficient waste air heat recuperation equipment with proved total efficiency at least 60% is required, if, in case of forced ventilation or air-conditioning, the total intensity of building air exchange n > 2 m^3/(m^3*h) during at least 8 hours a day. This equipment is recommended for n > 1 m^3/(m^3*h) and for low energy or passive houses.

The thermal insulation layer of a structure shall be on the external side efficiently protected against wind action. This requirement is important at assembled or composite structures, particularly at structures with ventilated air layer adjoining the thermal insulation. The thermal insulation, which can be from the ventilated layer blown through by cold outdoor air, is unefficient in the ventilated part of the thermal insulation layer. If wind blows through the whole thickness of thermal insulation, the structure behaves as if there is no thermal insulation at all.

2.7. Lapse of resulting room temperature in winter

The thermal stability in winter is assessed for a critical room, which has to show at most required lapse of the winter resulting room temperature $\Delta\theta_V$(t) at the end of the cooling *t*.

Table 8 – Required values of lapse of winter resulting room temperature $\Delta\theta_{v,N}$(t)

Room (space) type	**Lapse of resulting room temperature in winter $\Delta\theta_{v,N}$(t) [in °C]**
Stay of persons after interruption of heating in case of - heating by radiators, radiant heating panels and hot air - heating by stoves and floor heating;	 3 4
Without stay of persons after interruption of heating - cause by heating break - massive building, - light-weight building, - at the prescribed lowest resulting temperature $\theta_{v,min}$, - at foodstuff storage, - at danger of water freezing.	 6 8 θ_l - $\theta_{v, min}$ θ_l - 8 θ_l - 1
Water tanks (water temperature)	θ_l - 1

Thermal stability of a building in winter expresses its capability to maintain adequate indoor temperature conditions even at the end of heating break or at emergency shutdown of the heating system.

However, assessment of thermal stability at indoor air overheating in summer is decisive for wooden houses as well as for other light-weight buildings.

2.8. Room thermal stability in summer

Thermal stability in summer is assessed for a critical room, where the following parameters are assessed:

a) Either the highest daily growth of room air temperature in summer

b) Or the highest daily room air temperature in summer $\theta_{al,max,N}$.

Required standard values of the highest daily growth of room air temperature in summer $\Delta\theta_{al,max,N}$ or the highest daily room air temperature in summer $\theta_{al,max,N}$ for non-production residential buildings are given in the first row of Table 9.

Table 9 – Required values of the highest daily growth of room air temperature in summer $\Delta\theta_{al,max,N}$ and the highest daily room air temperature in summer $\theta_{al,max,N}$

Building type		**Highest daily growth of room air temperature in summer** $\Delta\boldsymbol{\theta}_{al,max,N}$ **[in °C]**	**Highest daily room air Temperature in summer** $\Delta\boldsymbol{\theta}_{al,max,N}$ **[in °C]**
Non-production		5.0	27.0
Others with internal source of heat	≤ 25 W/m^3	7.5	29.5
	> 25 W/m^3	9.5	31.5

The solution providing sufficient thermal stability by means of building design together with a superposed earth heat exchanger for cooling of ventilation air or cooling of accumulating structures by intensive night ventilation is preferred over drawing level of insufficient building thermal stability with its air-conditioning. It is cheaper both from investment and operation point of view, more energy economical and, in case of reduced energy supplies, safer from operation point of view.

Even buildings with air-conditioning shall meet either the conditions that the highest daily growth of room air temperature in summer $\Delta\theta_{al,max,N} \leq 12$ °C or the highest daily room air temperature in summer $\theta_{al,max,N} \leq 32$ °C, while neither the cooling capacity of air-conditioning nor heat gains from technological facilities and office equipment are not included in calculation made for this purpose. These conditions provide savings at dimensioning and operation of air-conditioning equipment. Default in fulfilment of this requirement is allowed only exceptionally if it is proved that its fulfilment is technically, environmentally or economically impracticable regarding the building lifetime and its operational purposes.

Summer building cooling is usually more than twice energy demanding than building heating, therefore this energy demandingness is emphasized also in the Directive on Energy Performance of Buildings (EPBD) [4].

2.9. Heat transmission through building envelope

Heat transmission through the building envelope expresses fundamental effect of the building design on heat demand for building heating and subsequently on low energy demandingness of a building.

New residential buildings are required to comply with the standard required values of the average heat transmission coefficient $U_{em,N}$ of structures on the building system boundary (envelope) in dependence on volume factor of the building shape *A/V* (according to some ENs the „building compactness indicator", originally also called the „building geometric characteristics"). The required and recommended standard values are given in Table 10.

Table 10 – Standard values of average heat transmission coefficient $U_{em,N}$

Volume factor of building shape A / V [in m²/m³]	**Average heat transmission coefficient $U_{em,N}$ [in W/(m²·K)]**	
	Required values $U_{em,N,rq}$	**Recommended values $U_{em,N,rc}$**
≤ 0.2	1.05	0.79
0.3	0.80	0.60
0.4	0.68	0.51
0.5	0.60	0.45
0.6	0.55	0.41
0.7	0.51	0.39
0.8	0.49	0.37
0.9	0.47	0.35
≥ 1.0	0.45	0.34
Intermediate values (rounded to hundredth)	$0.30 + \frac{0.15}{(A/V)}$	$0.75 * U_{em,N,rq}$

All standard requirements of ČSN 73 0540-2 are valid concurrently. Therefore, there is also another elimination of the required and recommended values U_{em}, which is obtained from the required and recommended values of individual structures by means of the following equation

$$U_{em,N} = H_N / A$$

where H_N is the standard value of specied thermal loss, which may be determined on the basis of general relation by sum of standard heat transmission values though separate structures and the summary standard heat transmission through thermal bonds between structures

$$H_N = \Sigma\, A_J * U_{J,N} * b_J + \Delta H_{1b,N}$$

The expected values of standard limitation of summary effect of thermal bonds are expressed by the equations $\Delta H_{1b,N,rq} = \Sigma\psi * \ell + \Sigma\chi = 0.06$ W/K, $\Delta H_{tb,N,rc} = 0.03$ W/K and $\Delta H_{N,NED} = \Delta H_{N,PAD} \approx 0$ for the required, recommended and low energy/passive levels. Requirements for individual structures cannot be met quite accurately but they are always exceeded to create a systematic reserve for not too high total action of thermal bonds. Therefore, the standard account for total action of thermal bonds effect can be considered, both on the required and recommended levels, as zero without any impact on strictness of the requirement and to express the second limit of the average heat transmission factor by single equation for all standard values.

$U_{em,N} = (\Sigma A_{J,N} * U_{J,N} * b_J + \Delta H_{1b,N} * b_J / A$

The lower of the values according to the above equation and Table 10 is valid for assessment of U_{em}.

Low values U_{em} form the basic assumption for the total low energy demandingness of a building according to EPBD [4].

In case of changes and repairs of completed buildings, the same requirement shall be met under the following conditions:

a) In case of changes and repairs of more than 25% of the perimeter envelope from the building completion or from the last assessment of structural energy properties of a building,

b) In case of required processing of the energy audit or the Energy Demandingness Certificate according to relevant notices to Act no. 406/2006 Coll. on Energy Management (Codes of Practice no. 213/2001 Coll., as amended, particularly no. 425/2004 Coll., Code of Practice no. 148/2007 Coll.).

Pursuant to these codes, it is possible to prove in case of changes and repairs of completed buildings that meeting of the structural energy requirement is technically, environmentally or economically impracticable regarding the lifetime of a building and its operational purposes. In this case the required structural energy properties of a building may be exceeded to the extent not to enable malfunctions and faults at its use.

It is easier for lower volume factors of building shape to meet the structural energy requirements even though the required values are stricter. E.g. the requirement for U_{em} of buildings with $A/V < 0.5$ m^2/m^3 can be reached with the required values of the heat transmission coefficient U in the area of windows and doors under 20% of the total building floorage. At buildings with the energy unfavourable higher shape factor A/V, it is necessary to apply lower heat transmission coefficients through individual structures for meeting the requirement. Decrease of the shape factor A/V corresponds with more compact volume designs and leads to decrease of energy consumption at perimeter structures with the same quality. That's the reason why the architectural concept of shape design of a wooden house is so important.

Wooden houses with significant thermal insulation and optimised thermal bridges in structures (U-values under half of the required values) with optimised thermal bonds between structures, forced ventilation with recuperation and the low shape factor enable to reach the accepted low energy up to passive energy quality of houses.

Suitable building utilities will emphasize this fact even more.

2.10. Classification of heat transmission through building envelope

The heat transmission values U_{em} for the building envelope can be transferred to expression by means of the classification indicator CI that is used as an aid when describing the scale of classification classes A through G (from the best to the worst solution). This expression is used for graphical rendering of the result of heat transmission assessment of the building envelope by a coloured building envelope label.

So, it is not another assessment. It is only another rendering form of the result of standard assessment U_{em}, which is more understandable for laymen.

It concerns partial building assessment within the complex assessment of its energy demandingness. This result can be given as a partial basic fact when elaborating the Energy Demandingness Certificate according ČSN EN 15217 and Notice no. 148/2007 Coll. on Energy Demandingness of Buildings. Use of partial energy labels gives better idea about reserves within the building design and design of individual utilities affecting the resulting balance of energy demandingness of a building.

Concerning buildings meeting the standard requirement $U_{em,N,rq}$, the classification indicator is determined by the equation

$CI = U_{em}/U_{em,N,rq}$

which fully corresponds with the earlier used degree of thermal demandingness

$STN = 100*U_{em}/U_{em,N,rq}$.

Buildings meeting the standard requirement are classified in classification classes A through C which express the compliance quality of the requirement:

Classification class A: $CI \le 0.30$ - Very thrifty

Classification class B: $0.30 < CI \le 0.60$ - Thrifty

Classification class C: $0.60 < CI \le 1.0$ - Suitable

The last class may be further divided to

Classification class C1: $0.60 < CI \le 0.75$ - Suitable for the recommended level

Classification class C2: $0.75 < CI \le 1.0$ - Suitable for the required level

The classes A and B are suitable for passive and low energy buildings, respectively. However, it does not mean that buildings with envelopes in the class B could not be the base for passive standard of a building – the decisive is the total nominal energy demand for heating e_{A1} i.e. a bit different indicator related to the total building floorage A_c (defined in Act no. 406/2006 Coll.).

Buildings not meeting the standard requirement fall into the classification classes D through G and the classification indicator *CI* is determined by means of the average heat transmission factor $U_{em,s}$ i.e. differently from the foregoing assessment by the energy demandingness degree *STN.*

The value $U_{em,s}$ corresponds to average state of the existing building stock of the Czech Republic till 2006. The standard defines the value $U_{em,s}$ on the basis of analysis of available data and knowledge about the building state with the help of the required value $U_{em,N,rq}$ by means of the equation

$U_{em,s} = U_{em,N,rq} + 0.60$

The classification indicator *CI* for buildings not meeting the standard requirement fall to the level of average state of the existing building stock of the Czech Republic given by the value of $U_{em,s}$ is determined on the basis of the equation

$CI = 1 + (U_{em} - U_{em,N,rq}) / 0.6$.

The classification classes D and E correspond to these buildings which are a bit better than the current average state as follows:

Classification class D: 1.00< $CI \leq 1.50$ - Unsuitable

Classification class E: 1.50 < $CI \leq 2.0$ - Unthrifty

The classification indicator *CI* for buildings, which state is worse than the average state of the existing building stock of the Czech Republic, is determined on the basis of the simple equation

$CI = 1 + U_{em}/U_{em,s}$

The classification classes F and G correspond to these buildings which are a bit worse than the current average state as follows:

Classification class F: 2.00< $CI \leq 2.50$ - Very unthrifty

Classification class G: $CI > 2.5$ - Extraordinarily unthrifty

3. Standard recommende practice [5]

3.1. General concept of buildings [5]

The resulting building properties can be usually best affected during creation of the general concept in the preparatory phase of the design, particularly by good coordination with the building concept of load bearing function, heating and lighting. Such concept should be characterised, besides others, by balance of volume and structurally technological design of all spaces and structures at the lowest energy demandingness of a building.

Buildings are designed to have low heat demand for heating and to provide thermal protection in accordance with the required standard values unless other regulations set forth even stricter requirements. The contracting parties can agree upon their own stricter objectives e.g. on the level of the recommended standard values.

The resulting energy properties of a building as a whole are decisive in case of concurrent meeting of all other thermal protection requirements for individual structures and the whole building.

It is suitable to design such building designs to meet efficiently the requirement of low energy demandingness i.e. with low investment demandingness and low environmental load through the entire life cycle of a building. In addition to principles mentioned herein, other recommendations and experiences described in literature for low energy and passive houses enabling the most advantageous design for a concrete case.

When preparing the total concept of a building and during the subsequent detailed designing, the designing teams shall consistently take into account the need of low energy demandingness. Building energy properties of a will be affected (to different extent based on the nature of a concrete project) particularly by

a) Choice of a site and siting of a building within it,
b) House orientation with respect to impact of direct solar radiation during a year, currently existing and future expected shading of a building by surrounding

development, ground and greenery, prevailing wind direction;

c) Building shape (shape compactness, articulation of surfaces) which are easily expressed by the shape volume factor *A*/*V* according to special regulation i.e. by the ratio between the cooled building envelope surface and heated building volume (lower values *A*/*V* are usually more favourable),

d) Exclusion or limitation of conceptual causes of thermal bridges in structures and strong thermal bonds between structures,

e) Interior arrangement with respect to accordance of heating modes, thermal zones and orientation of rooms,

f) Size of heated and indirectly heated floorages (volumes) and their adequacy for given purpose,

g) Size of glazed areas on individual facades,

h) Expected indoor heat gains according to the operation nature,

i) Other relations.

Alternatives of the design concept together with the clear energy target should be subjected to guideline calculations of building energy properties (e.g. pursuant to ČSN EN 832 and a special statute using preliminarily chosen properties of structures on the system boundary), particularly values of heat transmission coefficients (laying usually between required and recommended standard values or lower at buildings with particularly low heat demand for heating) and then to continue with the generally most advantageous alternatives in the next designing phase.

When changing existing buildings, it is necessary to prepare the concept of their energy renewal under the presumption that, after the change, a building will have its lifetime comparable with a new building. It is necessary to take into account verified or estimated residual lifetime of individual elements of a building, conditions of their surface layers, requirements for changes of heating mode, operational changes, etc.

When designing new structures that will form a new integral part of a changed building (annexes, superstructures), the used process is the same as at new buildings. When designing necessary adaptations of existing structures within an original building, existing thermotechnical properties found experimentally or professionally estimated on the basis of literature or experience from other buildings and specified levels of new requirements (required, recommended or even more progressive) shall be taken as the base of the design.

A partial change and/or replacement of structures in an existing building can bring about a change of parameters of indoor environment (e.g. increase of air humidity caused by replacement of windows for new more sealed ones or implementation of protective water proofing membrane under roofing of a sloping roof or repair of a warm flat deck by adding another waterproofing layer). In such case, it is necessary to concurrently improve properties of other structures (e.g. jambs, heads and sills by additional thermal insulation) or concurrently change operational mode (force ventilation).

Regarding buildings with large glazed area, particularly office ones, it is necessary to care for energy demand for cooling in transition and summer season. The following issue may help to significant reduction of operational energy demand. Suitable concept based on adequate size of glazed areas (in respect to house orientation), suitable shielding means, building materials with thermal capacity and suitable ventilation mode including cooling by night air. Mechanical cooling and air-conditioning of building should be exceptional solution for building (parts of buildings, rooms) with particularly strict requirements for thermal stability (operating theatres, special technologies) and, in other cases, only as a complement if "natural" building possibilities are exhausted. Air-conditioning and ventilation shall be controllable according to rooms and current operational requirements. At the same time, recuperation of heat discharged from cooled rooms should be solved particularly at bigger volumes of treated air, if local conditions enable it.

Regarding buildings with a light-weight perimeter envelope (usually on the wooden, metal, plastic base), it is possible to compensate low thermal capacities of a perimeter envelope by combination with massive building core with thermal capacity i.e. with massive floors and massive indoor structures. However, surfaces of layers with thermal capacity of such structures shall be located on the side of a room, where this effect shall be utilised without other “shielding” layers (soffits, light-weight claddings, thermal insulations by the floor surface. The total effect of such solution should be, particularly at more extensive designs assessed via detailed calculation simulation based on expected climatic load in characteristic seasons of a year and in relation to heating and ventilation systems.

Humidity of building materials to be build in shall be low, however at most on the level of prescribed by a manufacturer.

Due to used wet process during development, in the staring period of building operation air humidity in a building may be, sometimes significantly, higher than are the design values. In such case, it is necessary to ensure more intensive, totally higher ventilation of a building (or in combination with heating) by means of technical and organisational measures, with different operational mode than the design conditions are.

Regarding buildings with damp and wet operations, where it is not possible to completely exclude occasional water vapour condensation on indoor surface of structures or splashing water, the indoor surfaces of structures are designed with long-term water load resistant materials. It is recommended to design similarly the indoor surface of adjoining structures.

Rooms in buildings may be ventilated so that quality requirements for indoor environment at low energy demandingness are met. It is not recommended to solve ventilation of bathrooms exclusively via windows. It is not recommended to place windows above tubs in bathrooms of apartments. It is not recommended to use digesters without air exhaust in kitchen of apartments unless forced room ventilation is concurrently solved. In case of forced air exchange in rooms with variable humidity such as kitchens and bathrooms, it is recommended to ensure automatic switching of exhaust fans at relative air humidity over 80%.

3.2. Designing of buildings with very low energy demandingness [5]

The base of a design is balance of all elements effecting energy balance of a building. Reached low demand of heat for heating thanks to suitable conceptual and detailed building design can be usually advantageously combined with suitable application of heating systems utilising renewable energy sources to different extent. Very low energy demandingness should be ensured during the whole life cycle of a building.

Buildings with very low energy demandingness have the average factor of heat transmission U_{em} significantly lower that the required standard value is. In contracting relations, this requirement shall be easily expressed by the classification indicator *CI* ≤ 0.60 or classification class B and better (i.e. A).

Usual expression of energy properties of a building with very low energy demandingness is areal nominal demand of heat for heating e_A related to 1m² of the total floorage of the heated part of a building and a year (defined in Act no. 406/2006 Coll.). The set value is compared with the specified level i.e. regardless of building shape.

Low energy houses are buildings with annual areal nominal demand of heat for heating e_A not exceeding 50 kWh/(m^2·a) which use a very efficient heating system. Based on the technique state, this limiting value may be further decreasing in future.

Passive houses are buildings with annual areal nominal demand of heat for heating e_A not exceeding 15 kWh/(m^2·a). Such low energy demand of a building can be covered without use of a usual heating system, only by means of forced ventilation system containing efficient recuperation of heat from exhausted air and a small equipment for additional air heating in the period with very low outdoor temperatures. The more, after an operational break design indoor air temperatures shall be reached in adequate time stipulated in the design documents. However, the total quantity of primary energy necessary for building operation (heating, DHW and electric energy for appliances) shall not exceed the value of 120 kWh/(m^2·a). The primary energy is the energy which needs to be released at energy transformation in the place of source. The following recalculation is used according to the source nature: primary energy = energy needed necessary at the building inlet * energy transformation factor. If no more detailed local data or other binding values (e.g. in Notices to Act no. 406/2006 Coll.) are available, the considered energy transformation factors for electric energy, usual fuels, usual remote heating and renewable energy sources are 3.0, 1.0, 1.1, 0 respectively.

When preparing conceptual and detailed design of buildings with very low energy demanding ness, the process shall be observed very carefully. Perimeter structures shall be designed to have values of heat transmission factor lower than standard recommended values. It is recommended to use forced ventilation. The air-handling equipment with heat recuperation designed for the above are usually compact and proven ones. They shall be designed to provide particularly:

a) Hygiene harmlessness and good quality of air in required quantity,

b) Possibility to control output of such equipment according to current operational requirements within large range of values, designed, if needed, in more circuits,

c) Exclusion of noise propagation between individual rooms through air-handling piping (this requirement can be met by suitable arrangement of individual branches of air ducts, mounting of efficient noise attenuators in air ducts, etc.),

d) Possibility of regular cleaning and inspections,

e) High certified efficiency of heat recuperation.

If the design includes a superposed earth heat exchanger serving for pre-heating of fresh air, it shall meet public health requirements and shall be designed so that the condensate flows off into a place accessible for cleaning and inspections. The total efficiency of a earth exchanger has to be proved by detailed calculation simulation taking into account local conditions (depth of location, type of earth, moisture ratio, underground water presence and character), arrangement of branches within the system, material, expected time course of operation, etc. Favourable investment costs of earth exchanger can be reached by suitable combination with other necessary building activities (excavations and foundations, building of a retaining wall, etc.).

If active solar elements serving for support of DHW heating, heating or electric energy production shall be a part of a building, it is suitable to design them to become integral parts of perimeter structure.

A number of requirements have to be usually met to reach the level of a passive house:

a) The conceptual approach is a must, it is particularly necessary to respect as best as possible and in details local conditions and utilising the most compact shape of a heated part of a building. Calculation of heat demand is usually done in two levels, first as guideline calculation for selection of a concept and then detailed calculation according to designed alternatives. Indoor heat gains from persons, appliances and technological equipment shall be determined especially carefully because they play enormously significant role in the energy balance of a passive building.

b) It is recommended so that the nominal thermal loss of a building (according to ČSN EN 832) related to 1 m² of floorage of a heated part of a building does not exceed 0,3 W/(m*K).

c) Values of heat transmission factors of perimeter structures shall not exceed the value of 0.15 W/(m*K). If it is structurally possible (without extensive increase of structure price) are recommended values lower (e.g. $U \leq 0.12$ W/(m^{2*}K) is suitable for roofs). Windows shall have the resulting heat transmission factor $U \leq 0.8$ W/(m^{2*}K) (calculation assessment according ČSN EN 10077-1) at total energy permeability of solar radiation $g \geq 0.5$. If the heat transmission factor of some (individual) glazed areas is slightly higher, the unfavourable effect of such cold area shall be especially carefully eliminated.

d) All perimeter structures are their connections shall be solved to minimise thermal bridges in structures and thermal bonds between them by means of careful design with detailed elaboration of all details as well as careful execution and its checks. Solutions with minimised effect of thermal bonds are such solutions when the individual linear heat transmission factor of a thermal bond specified by means of external dimensions of structures according to ČSN EN ISO 14683 does not exceed one tens of values ψ according to Table 3a in ČSN 73 0540-2. Summarised effect of thermal bonds of building envelope should be very close to zero. If it exceeds this value, effect of thermal bonds shall be included into the energy assessment. Concerning window mounting joint, it is recommended to cover a part of a window frame by a strip of thermal insulation, which is a part of thermal insulation in a non transparent part of a structure or is linked to it.

e) Perimeter structures shall be practically air-tight. Experiment verification according to ČSN EN 13829 its Table 6 is always recommended before complete completion of a building.

f) Forced ventilation shall have the total efficiency of heat recuperation higher than 75% and low consumption of operational electric energy.

g) Low thermal losses shall be reached at preparation and distribution of hot water.

h) High efficiency of electric energy use shall be reached when using energy thrifty electric appliances.

Winter gardens, glazed recessed balconies and similar spaces usually do not contribute to further improvement of energy balance of a passive house. If they are designed for other reasons, it is necessary to provide their perfect thermal separation from heated spaces and efficient ventilation and determined suitable manner of their use. Structures separating the heated zone from these spaces are usually designed similarly with other perimeter structures.

Besides these quotations from [5], it is possible to find other suitable structural recommendations in Annex A – Designing Instructions of ČSN 73 0540-2.

Conclusion

The amended thermotechnical and energy requirements for building structures and buildings form the assumption of balanced design of wooden houses without risk of faults and defects, with low operational demands and favourable indoor environment. Requirements follows the trend formulated by the European Directive EPBD on Energy Demandingness of Buildings.

Literature

[1] Notice to Building Act no. 137/1998 Coll. on General Technical Requirements for Development

[2] Act no. 406/2006 Coll., unabridged version of Act no. 406/2000 Coll. on Energy Management, as resulting from later amendments

[3] Notice no. 148/2007 Coll. on Energy Demandingness of Buildings

[4] Directive 2002/91/EC on Energy Demandingness of Buildings (EPBD)

[5] ČSN 73 0540-2:2007 Thermal Protection of Buildings - Part 2: Requirements

[6] ČSN 73 0540-3:2005 Thermal Protection of Buildings - Part 3: Design Values of Variables

[7] ČSN 73 0540-4:2005 Thermal Protection of Buildings - Part 4: Calculation methods

[8] Šála J.: Zateplování budov (Warming up of Buildings), Grada 2000

[9] Tywoniak J.: Nízkoenergetické domy. Principy a příklady (Low Energy Houses. Principles and Examples), Grada 2007

