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RESEARCH ARTICLE

Context of product data bases in energy efficient architecture

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Abstract

The increasing cost of energy has drawn attention to the need to reduce the energy consumption of buildings in Hungary. There are a number of ways to reduce the energy demand of buildings, among these; the most common solution is the thermal insulation of the building envelope. The declared thermal conductivity factor given in the product catalogues forms the basis for designing the different thermal insulation structures, although these factors can differ significantly from the properties of the built-in state. The lack of a performance based approach is particularly significant: the effect of the environment, the use and the neighbouring constructions must all be taken into account when designing the thermal insulation [4]. This paper was written with the purpose of examining which factors influence the insulating capacity of the built-in material, how can they be quantified with the help of the Hungarian/European/International standards, and what research has already been carried out with reference to the given effect.

Keywords

thermal insulation · insulating capacity · built-in material

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1. The performance based approach in the field of thermal insulations

The (post-) insulation of buildings is becoming increasingly prevalent in Hungary. The energy conscious retrofit is often carried out without involving experts, with just adjacent buildings as examples. The lack of a performance based approach is particularly significant as the effect of the environment, the intended use and the neighbouring constructions must all be taken into account when designing the thermal insulation [4].

The Performance Based Design (PBD) of building structures is an international concept. The main difference is that it is counter to the more traditional prescriptive approach. While the prescriptive approach comes from the experience of "what has worked before", PBD focuses on the required target performance and looks for the appropriate solution within the knowledge of the actual properties. The prescriptive approach is extremely valuable, because it takes as a basis the actual knowledge and experience of those who have used the material product in practical situations. However, the problem is that this approach does not acknowledge that every case is unique, and that demands and effects are continuously changing in time and space. The solution for the problem is PBD, which is based on the effects and demands, and then assigns the solution. Ultimately, PBD looks for the answer within the understanding of the requirements. PBD does not exclude the prescriptive approach; it utilizes the experiences of the users and attempts to solve a task from another point of view [5].

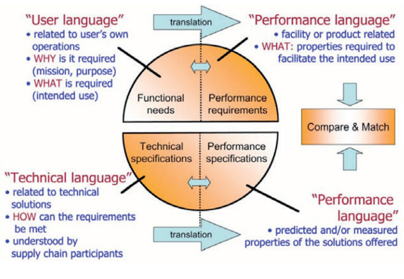

Fig. 1. International Council for Research and Innovation in Building and Construction – Development Foundation, *Performance Based Design of Buildings, PeBBu Domain 3 Final Report, Rotterdam, 2005, p. 19.*

The aim of the paper is to examine how PBD can be currently applied by architects in Hungary in the field of building thermal insulation (this will be further developed in the author's doctoral thesis); the factors that can influence the thermal insulation capacity of the built-in material, and how can they be estimated in the design phase.

2. The energy calculation in Hungary

In the three level calculation (I. Integrated energy parameter, II. Specific heat demand coefficient, III. Thermal transmittance of each building element) of the currently operative TNM regulation 7/2006 in Hungary, the thermal conductivity factor of thermal insulation appears in the required values for level III (Eq. 1) [19].

$$U = 1/(1/\alpha e + \sum d/\lambda + 1/\alpha i) \quad (1)$$

U - thermal transmittance (W/m^2K)
α - heat transfer coefficient (W/m^2K)
λ - thermal conductivity factor (W/mK)
d - thickness (m)

The declared thermal conductivity value must be assigned by the given laboratory results (figure 2) according to the MSZ EN ISO 10456 standard.

The declared value reflects the laboratory assessed insulating capacity; however, there are a number of modifying factors that effect these in the built-in situation. These factors have been collected during the building and operation phases in the chart below (figure 3), and then annexed to the standards that contain the calculation method for the given effect. The TNM regulation 7/2006 takes into account the role of thermal bridging, through correction of the thermal transmittance; this depends on the number of the thermal bridges at the given building structure. This paper examines the factors that modify the thermal insulation's thermal conductivity on a general surface.

Property	Sets of conditions			
	I(10°C)		II(23°C)	
	a,	b,	a,	b,
Reference temperature	10°C	10°C	23°C	23°C
Moisture	u_{dry} [a]	$u_{23,50}$ [b]	u_{dry} [a]	$u_{23,50}$ [b]
Ageing	aged	aged	aged	aged

[a] u_{dry} is a low moisture content reached by drying according to specifications or standards for the material concerned.

[b] $u_{23,50}$ is the moisture content when in equilibrium with air at 23 °C and relative humidity of 50 %.

Fig. 2. *MSZ EN ISO 10456 (Building materials and products. Hygrothermal properties. Tabulated design values and procedures for determining declared and design thermal values)*, Hungarian Standards Institution, 2008, Chapter 4 p. 3.

The Hungarian standard can be found in the second column of the chart, with the European/International standards in the third column. The experts who have already assessed the given factor can be seen in the fourth column.

The effects that influence the thermal conductivity factor	Hungarian standard	European/ International standard	Effect assessed by
Building phase			
fastening	MSZ-04-140-2:1991*	MSZ EN ISO 6946:2008	
further layers	MSZ-04-140-2:1991*		
Operation phase			
actual temperature		MSZ EN ISO 10456:2008; MSZ EN ISO 15927-1:2003; MSZE 24140:2012	I. Budaiwi A. Abdou M. Al-Homoud
actual moisture content	MSZ-04-140-2:1991*	MSZ EN ISO 10456:2008; MSZ EN ISO 15927-1:2003; MSZE 24140:2012	I. Budaiwi A. Abdou
absorption		MSZ EN 1609:1999; MSZ EN 12087:1997/ A1:2007	A. Karamanos, S. Hadiarakou, A. M. Papadopoulos
convection	MSZ-04-140-2:1991*		
compression	MSZ-04-140-2:1991*		Sándor Kruchina
UV radiation			
ageing		MSZ EN ISO 10456:2008	

The standard marked "*" was withdrawn on 15th January 2012.
The pre-standard MSZE 24140:2012 is now operative.

Fig. 3. The factors influencing the thermal conductivity and the relevant standards.

3. The introduction and interpretation of the correction factors in the standards and measurement results

3./A Building phase

The thermal insulation material typically loses its homogeneity because of the fastenings (with anchors or installing between rods), which create thermal bridges at fixing points. The quality of the thermal insulation does not change on the overall surface, however, the anchor fastenings can cause compression of thermal insulation material at fixing points and as a result, the density and the thermal conductivity will also change. The compression effect will be detailed further in section 3./B.

In general, the thermal insulation is hidden, so the next question is the effect of the subsequent layers. The MSZ-04-140-2 standard contains two charts (one of them – figure 5 is from Hungarian measurements), in which there are correction factors for different construction conditions (figure 4: 1-7., figure 5: 2., 5.).

Material and construction method	κ
1. Polystyrene foam, later plastered or covered with a concrete layer	0.42
2. Perlite concrete (ρ <= 400 kg/m^3), later covered with a concrete layer	0.57
3. Bitumoperlite (ρ <= 300 kg/m3), later covered with a concrete layer	0.51
4. Expanzit, later plastered	0.20
5. Polystyrene foam between two wall layers	0.10
6. Isolyth between two wall layers	0.10
7. Perlite in bulk between two wall layers	0.38
8. Polyurethane (40 kg/m3) in ventilated air gap	0.25
9. Isophenic in ventilated air gap	0.25
10. Nikecell in ventilated air gap	0.50

Fig. 4. *MSZ-04-140-2 (Power engineering. Dimensioning calculuses of buildings and building envelope structures)*, Hungarian Standards Institution, 1991, Appendix I p. 14 chart 4.

The construction technique for various thermal insulations	κ
1. Thermal insulation constructed under exterior panels or ventilated roof connecting with outside air, without coating, depending on the vapour diffusion resistance:	
R_w< 0.8 × 10^9 m^{2}Pa/kg;	0.35
R_w = 0.8-5 × 10^9 m^{2}Pa/kg;	0.25
R_w> 5 × 10^9 m^{2}Pa/kg	0.10
2. Insulation layer with porous surface, covered with mortar or concrete layer during the building phase	0.30
3. Hygroscopic thermal insulation materials, light-weight concretes in such envelope structure, where the inner relative moisture is above 80%	
-if it connects to the air of the room directly	0.25
-if it is separated by a vapour proof or concrete layer	0.25
4. Thermal insulation, the density of which is less than 400 kg/m^3 and is prone to warp and compression and is constructed as a vertical layer	
-mineral wool, polystyrene foam	0.20
-as boards or prefabricated	0.15
5. Thermal insulation boards built on a flat roof in a single layer with flat joints	
-without mounting	0.25
-with mounting at least from one side	0.10

Fig. 5. *MSZ-04-140-2 (Power engineering. Dimensioning calculuses of buildings and building envelope structures)*, Hungarian Standards Institution, 1991, Appendix I p. 14 chart 5.

3./B Operation phase

- Actual climatic conditions

As can be seen from the tables, the declared thermal conductivity factor reflects the material's thermal insulating capacity at a given temperature and moisture content. Nevertheless different temperatures and moisture content values occur during the building's operation phase. Standard MSZ EN ISO 10456 contains the conversion method for the different environmental conditions (Eq. 2, 3); however, the input data can be substituted only in the knowledge of the climate, the internal temperature and moisture load. If no data is available, MSZ EN ISO 15927 and the pre-standard 24140 provide help. In general, it can be seen that the change in moisture content influences the thermal conductivity factor much more than the change in temperature.

$$F_T = e^{f_t(T2-T1)} \qquad (2)$$

F_T - the correction factor for temperature
f_t - the temperature conversion coefficient
T_1 - the temperature of the first set of conditions
T_2 - the temperature of the second set of conditions

$$F_m = e^{f_u(u2-u1)} \quad \text{or} \quad F_m = e^{f_\psi(\psi2-\psi1)} \qquad (3)$$

F_m - the correction factor for moisture
f_u - the moisture conversion coefficient mass by mass
f_ψ - the moisture conversion coefficient volume by volume
u_1 - the moisture content mass by mass of the first set of conditions
u_2 - the moisture content mass by mass of the second set of conditions
ψ_1 - the moisture content volume by volume of the first set of conditions
ψ_2 - the moisture content volume by volume of the sec ond set of conditions

Standard MSZ 04-140-2 contains a correction factor in the case of increased inner relative humidity (figure 5: 3.).

- Factors modifying thermal conductivity

Thermal insulation materials have excellent insulation properties due to the enclosed dry and immobile air [8].

The moisture content is significant because the thermal conductivity factor under normal circumstances of air is λ_{air}= 0.026 W/mK. The thermal conductivity factor of water is λ_{water}= 0.6 W/mK. If the material gets wet, and water replaces the air, the thermal insulation material significantly loses its insulation capacity [8]. Because of this, it is particularly important in the design phase to examine what kind of moisture effects the thermal insulation is exposed to and how it influences the thermal conductivity factor. An experiment [8] was carried out at the Aristotle University in Thessaloniki, which examined the deterioration of the thermal conductivity factor of stone wool after short term water absorption by partial immersion [13] and after long term water absorption by immersion [14]. The chart below shows the results (figure 6).

	Type B-050	
Lot number	51343284A	
Thickness	50 mm	
Dimensions	300 mm × 300 mm	
Specimen No.	I	II
Measured dimensions [mm]	299×290	295×300
Measured weight [g]	267.1	252.8
Water absorption EN 1609 [g]	283.4	266.1
Weight difference [g]	16.3	13.3
(max 1 kg/m^3)	0.19	0.15
Thermal conductivity coefficient λ [W/mK]	0.03173	0.03164
Thermal conductivity coefficient λ after EN 1609 [W/mK]	0.03807	0.03456
Water absorption EN 12087 [g]	297.1	272.7
Weight difference [g]	30	19.9
(max 3 kg/m^3)	0.34	0.23
Thermal conductivity coefficient λ after EN 12087 [W/mK]	0.03772	0.03661
Thermal conductivity coefficient λ after drying [W/mK]	0.03268	0.03224

Fig. 6. **A. Karamanos, S. Hadiarakou, A. M. Papadopoulos**, *The impact of temperature and moisture on the thermal performance of stonewool,* Energy and Buildings 40 (2008), p. 1410.

The change in the thermal conductivity factor under absorption is an important factor if the concealed thermal insulation material becomes wet, e.g., if water penetrates behind the facade because of unsuitable window sill design. It can be seen from the chart (figure 6) that the material regains its former quality after drying, but if the leak happens in November (maybe several times because of repeated rain), the material has insufficient time to dry out during the heating period. Figure 7 illustrates how wetting can extend to a significant area of the facade; even influencing the energy consumption of the whole building.

The effectiveness of the motionless air enclosed by the thermal insulation material can be reduced if the material is in direct (ventilated structure), or indirect contact (filtration through the wall) with convection circulations. Standard MSZ-04-140-2 (see table) contains the correction values referring to ventilated structures (figure 4: 8-10., figure 5: 1.).

Compression causes an increase in the material's density, as a consequence of this, the thermal conductivity factor changes. This effect is widespread with fibrous thermal insulation materials; figure 8 shows the thermal conductivity factor of glass wool as a function of density [9, p. 104].

Fig. 7. Block of flats in Kelenföld (moisture can be seen on a large area, covering entire panels of the building).

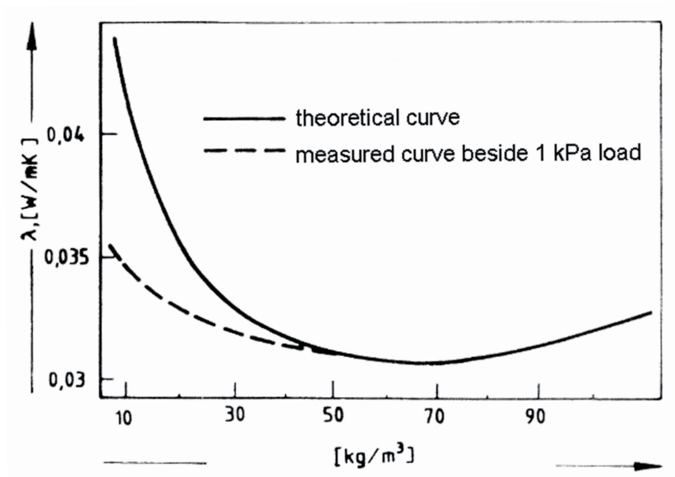

Fig. 8. The thermal conductivity factor of glass wool as a function of density [9, p. 104].

At the correction factors in the chart (Standard MSZ-04-140-2) the proneness for compression is also defined (figure 5: 4.).

In general, the thermal insulation structure is hidden between different layers, so UV radiation does not have a direct effect, as a result, standards do not address this issue.

Ageing must also be taken into account when designing the thermal insulation. All the materials, even to a minor extent, change over time, with a resultant loss in quality. The ageing depends on the type, facing, structure, thickness etc. of the material and other factors impacting it. There are no simple rules to estimate the properties of the material after many years. According to Standard MSZ EN ISO 10456, the declared thermal conductivity factor must be assigned in aged condition, or the calculation must be made for not less than half the working life. The individual product standards contain the relevant calculation method [17].

4. Summary – adaptation and adaptability of the standards

The former Hungarian standard, the present operative standards and the laboratory measurements all illustrate the importance of the thermal conductivity modifications factors referred to in figure 3. The standard MSZ-04-140-2 gives correction factors (κ) for certain effects at particular materials, meanwhile the MSZ EN ISO standards contain formulas,which are necessary for the substitution of the precise climatic data; this magnifies the task of architects and energy experts in Hungary as it can be extremely complicated to conclude the input data. (The pre-standard MSZE 24140 deals with this issue, although it has yet to become the official standard.) In addition to this the calculation without simulation is achievable only with difficulty because of the instationer conditions [18]. As a consequence of this the regulations are not entirely suitable for the estimation of the material properties of a given insulation. To ensure the appropriate choice of materials over the long term the expansive analysis of the crucial relationships from the point of complex requisitions, building structures and material types in respect of regulations and scientific literature is essential.

In order to achieve this goal, it is necessary to establish a calculation method with the help of which, it is possible to setup a current database that gives adequate modifying values according to the thermal insulation material and the conditions under which it is used.

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