Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. VII, 2018
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

HEAT PENETRATION PARAMETERS OF NEWLY PROPOSED THERMAL INSULATING CONCRETES FROM THE VIEWPOINT OF POWER CONSUMPTION AND ENVIRONMENTAL IMPACTS

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Abstract

For passive and low energy buildings, such an external envelope, which can provide a sufficient thermal insulation function with the smallest overall wall thickness., is thermally and financially the most advantageous. Concrete can be a suitable building material. At present, non-reinforced porous concretes, light autoclaved concretes (sand and ash concretes) are used as good insulating materials. New thermal insulating concretes designed by us can be classified into this category. At the same time it is possible to prove by their previously non-tabulated heat penetration parameters that these materials are of relatively higher quality. Use of these materials brings the same effect of desired thermal insulation by only a comparatively small reduction in the concrete wall thickness. As a result, it is possible not only to achieve savings of the indoor living area, but also to declare a more favourable parameter of the building energy intensity, which is a highly reputable parameter. The solved issues are important in agriculture, especially in terms of dimensioning the purpose-built buildings, such as residential buildings, livestock buildings, silos and various buildings designed for storage. With regard to the assessment of the entire life cycle of buildings and the durability of concrete, the choice of this material is favourable both from the viewpoints of power consumption, environmental impacts and economy.

***Key words**: concrete, thermal insulation, environmental impacts.*

INTRODUCTION

Economical and efficient use of energy is becoming increasingly important. It requires a detailed examination of thermodynamic quantities in the context of the laws of thermodynamics, i.e., in particular, the temperature as an internal state quantity of a given thermodynamic system and heat as an external state quantity of this system. In the civil engineering, the investigated thermodynamic system is the building.

The energy losses of the building are related to its properties and the way it is used. In particular, the shape and structure of the building are of principal importance, i.e. what is the size of its outer surface in relation to its total volume, how the building is thermally insulated and, of course, what material the building is built from. That is why the study of different material parameters of different building materials is also so important.

The energy-passive standard of the building can be achieved in particular by using cost-effective technologies, i.e. by using alternative energy sources and energy recovery, as well as using the optimal architectural design and precise execution of the building including its details, such as hermetic sealing of joints and cable and other entries through enclosure structures.

The low-energy building is based on the same principle as the energy-passive building, but it contains relatively fewer energy-optimising elements. The low-energy standard of the building can be achieved with the use of commonly available building materials, i.e. the wall can be built in classic bricks, such as ceramic, porous concrete or lime bricks, it can be based on wood or concrete, but the necessary condition is to find the optimal thickness of wall thermal insulation in dependence on the applicable standards and on the required peripheral load-bearing structure. Concrete can of course not be regarded as an

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ecological material in terms of the production process.

Cement as a basic component of concrete requires an environmentally demanding extraction of initial materials, and also the processing of concrete is energy-intensive because it takes place at temperatures between 1400 and 1500°C. So far unsurpassed way of achieving such high temperatures is the use of high-calorific fuels. Fossil fuels generate large amounts of carbon dioxide and they thus burden the environment. On the other hand, it must be appreciated that concrete is an environmentally compatible building material. Concrete as an alternative to natural stone is highly durable and it has a service life of up to hundreds of years. Mechanisms of concrete degradation are studied, followed by the development of protective treatment of concrete, which is also aimed at extending the concrete service life and thus reducing the need for concrete production in the future. It is from this point of view that different types of concrete can be considered as environmentally friendly products.

HEAT PASSAGE THROUGH A FLAT WALL

Flat wall can be considered the base structural element of a building, i.e. a slab with a constant surface *S* and a thickness *d*, the ends of which are maintained during the time interval τ at constant temperatures T_1, T_2; i.e. at a constant temperature difference $\Delta T = T_1 - T_2$ between the opposite walls of the slab (Figure 1).

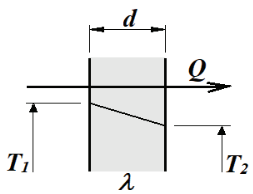

Figure 1. Diagram of heat conduction through a flat wall

The heat *Q* is conducted through the slab perpendicularly to the facial opposite surfaces of the slab according to the *Q* of the Fourier's law, in which the significant material parameter λ acts as the specific thermal conductivity of the slab.

The slab thermal resistance parameter is then derived as the ratio of the thickness *d* of the slab and its specific thermal conductivity. The parameter *k* for the slab heat transfer, which is in some cases used quite frequently, is defined as an inverted value of the thermal resistance of this slab (Ziman, 1972).

The overall thermal resistance parameter of the composite flat wall is given as an algebraic sum of the parameters of thermal resistances of the partial layers of the composite wall. The total parameter *U* of the composite wall heat transfer is given as an inverse value of the sum of the thermal resistances of the partial layers of the wall.

Specifically, for a flat wall composed of two different layers of specific thermal conductivities λ_1, λ_2 and different thicknesses d_1, d_2.

$$U = \frac{1}{\frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2}} \quad (1)$$

The required value of the average heat-passage parameter of the dwelling building enclosure with a common indoor environment is 0.30 $W \cdot m^{-2}K^{-1}$ according to „Czech Technical Standard 73 0540-2: 2011 Thermal Protection of Buildings-Requirements".

The recommended value for a heavy wall is 0.25 $W \cdot m^{-2}K^{-1}$ and for the light wall it is 0.20 $W \cdot m^{-2} \cdot K^{-1}$. The recommended heat passage value for passive buildings is 0.18 to 0.12 $W \cdot m^{-2}K^{-1}$. Respecting this standard requires thermal insulation of the wall by a layer of thermal insulation.

However, facade insulation, for example with the use of polystyrene, means an increase of the building costingness, or requires the solution of related technological problems.

Reduction of requirements for insulation can be achieved by using new and innovative materials for load-bearing systems that exhibit reduced heat transfer.

From an economical point of view, it is most advantageous for energy-passive and low-energy buildings to choose such material for a building envelope that can provide sufficient thermal insulation functionality with the smallest overall thickness of the external wall.

MATERIALS AND METHODS

For the laboratory measurements, two measuring instruments were used: the commercial multifunctional device Isomet 2114, and a prototype device of a thermostatic calorimeter chamber with computerized touch probes (Kušnerová, 2012; 2014; 2016). On each studied concrete sample, a total of 40 direct measurements using Isomet 2114 and more than 150 direct measurements on the thermostatic calorimetric device were performed and evaluated. Three kinds of samples of the newly proposed concretes B 200, B 300, B 400 were examined (Gola, 2015), see recipes of the concretes B 200, B 300, B 400 (Table 1).

Table 1. Recipes of the concretes B 200, B 300, B 400

Concrete designation	Filler (0.063/4mm) [kg]	Cement CEM 42.5R [kg]	Water [kg]	Water parameter [-]	Super – plastizer [kg]
B 200	446.0	198.0	376.3	1.9	0.99
B 300	422.8	276.0	358.9	1.3	1.38
B 400	414.5	375.5	394.2	1.5	1.88

RESULTS AND DISCUSSIONS

Determination of parameters of heat transfer of samples made of concrete

The heat transfer parameters *k* of the samples made of the proposed thermally insulating concretes B 200, B 300, B 400 of identical geometric dimensions (0.15 m x 0.15 m x 0.15 m), but of different composition of their material according to the formulations declared in the publication (Gola, 2015) (Table 2), were determined. For the samples, the thermal insulation cladding was chosen with a comparable layer of expanded polystyrene (with geometric dimensions of 0.15 m x 0.15 m x 0.20 m and a specific thermal conductivity of 0.04 $W \cdot m^{-1}K^{-1}$).

Table 2. Newly tabulated heat transfer parameters *k* of the samples of heat insulating concretes and heat transfer parameters *U* of these samples, which had polystyrene insulation cladding

Concrete	λ $\left[\frac{W}{m \cdot K}\right]$	d [m]	k $\left[\frac{W}{m^2 \cdot K}\right]$	λ_P $\left[\frac{W}{m \cdot K}\right]$	d [m]	U $\left[\frac{W}{m^2 \cdot K}\right]$
B 200	0.1400	0.15	0.933	0.040	0.20	0.165
B 300	0.1625	0.15	1.083	0.040	0.20	0.169
B 400	0.1935	0.15	1.290	0.040	0.20	0.173

In all cases, the recommended value of the heat passage parameter through the wall of the energy-passive building was achieved.

Determination of parameters of heat transfer of comparative commercially used concretes

In order to compare the heat transfer parameters of the samples of proposed heat insulating concretes, the heat transfer parameters *k* of the samples of commercially used concretes were determined: B_H compact concrete, B_C brick concrete, B_C lightweight autoclaved non-reinforced porous sand concrete and B_A light autoclaved non-reinforced porous ash concrete of identical geometric dimensions (0.15 m x 0.15 m x 0.15 m) (Table 3).

For the samples, the insulation cladding was chosen with a comparable layer of expanded polystyrene (with geometric dimensions of 0.15 m x 0.15 m x 0.20 m and a specific thermal conductivity of 0.04 $W \cdot m^{-1} \cdot K^{-1}$). Only in the cases of the samples of thermally insulating concretes the recommended values of the heat passage through the wall of the energy-passive building was reached, and these values were higher than those of thermally insulating concretes B200, B300, B400.

Table 3. Comparatively declared heat transfer parameters *k* of the samples of concretes and heat transfer parameters *U* of heat transfer of these samples, which have thermal insulation cladding made of polystyrene

Concrete designation	λ $\left[\frac{W}{m \cdot K}\right]$	d [m]	k $\left[\frac{W}{m^2 \cdot K}\right]$	λ_P $\left[\frac{W}{m \cdot K}\right]$	d [m]	U $\left[\frac{W}{m^2 \cdot K}\right]$
B_H	1.30	0.15	8.667	0.040	0.20	0.195
B_C	0.63	0.15	4.200	0.040	0.20	0.191
B_S	0.21	0.15	1.400	0.040	0.20	0.175
B_A	0.20	0.15	1.333	0.040	0.20	0.174

The use of a concrete wall (made for example from thermal insulation concrete B 200) with polystyrene insulation cladding (thickness 0.2 m, specific thermal conductivity 0.04 $W \cdot m^{-1} \cdot K^{-1}$) instead of a brick wall (thickness 0.30 m, specific thermal conductivity 1.01 $W \cdot m^{-1} \cdot K^{-1}$) with the same polystyrene insulation cladding is very advantageous. With a comparable heat transfer parameter (0.169 $W^2 \cdot m^{-1} \cdot K^{-1}$), the total thickness of this wall is 0.5 m. The difference between the two thicknesses of composite walls is 0.15 m. For the wall with geometric dimensions 4 m x 2.4 m, this saving of internal volume makes 1.44 m^3, for 4 walls this saving is 5.76 m^3. Savings in the living area of the room then make a considerable area of 2.4 m^2 (15%) of its living space.

CONCLUSIONS

The differences between the values of the heat passage parameters of the samples of concretes with thermal insulation cladding are not negligible because they represent a possible variability in the total thickness of the composite wall, in the thicknesses of the load bearing wall and of its thermal insulation layer. Especially with respect to the wall built from bricks, it represents considerable savings of the residential space of the building combined at the same time with an increase in the total energy intensity parameter of the house.

ACKNOWLEDGEMENTS

This research has been elaborated in the framework of the project SGS SP2017/116 and the project RMTVC No. LO1203.

REFERENCES

Gola M., Václavík V., Valíček J., Harničárová M., Kušnerová M., Dvorský T., 2015 Drainage concrete based on cement composite and industrial waste. *Advanced Structures materials* 2015. 70, 155-165.

Kušnerová M.; Gola L.; Valíček J.; Václavík V.; Harničárová M.; Pandová I.; Koštial P., 2016. Comparative measurements of the thermal properties of solid materials on a new device and using a new non-stationary method. *Defect and Diffusion Forum* 2016, 366, 63-72.

Kušnerová M.; Valíček J.; Harničárová M., 2014. Measurement of physical properties of polyurethane plaster. *Gradevinar* 2014. 66 (10), 899-907.

VŠB-TU Ostrava, 2012. Equipment for the identification of physical properties of solid materials. Inventors: Kušnerová, M., Valíček, J., Václavík, V., Daxner, J. *Utility model* CZ 23861 U1. 24.05. 2012, Czech Republic, 2012.

VŠB-TU Ostrava, 2012. The device for identifying the physical properties of solid materials. Inventors: M. Kušnerová, J. Valíček, V. Václavík, J. Daxner, Prague: Industrial Property Office ČR: UV 23861, U1, G01N 25/18 (2006.01), G01N 27/18 (2006.01), Owner: VŠB-TUO, Ostrava, CZ a D&DAXNER Technology, s.r.o, Ostrava, CZ, 2012.

Ziman J. M., 1972. Transport properties. In Principles of the theory of solids, 2nd ed.; Cambridge, Univ. Press, Great Britain, 1972, Volume 7, pp. 231-235.