NUMERICAL ANALYSIS OF MOISTURE PERFORMANCE OF SELECTED TYPES OF BUILDING PANEL ENVELOPES

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Summary

Modern non-stationary approach enabling more complex study has recently been employed more frequently along with stationary, standard methods for building structure analysis. These methods, however, require more detailed, more extensive and higher quality input data. Apart from boundary conditions, detailed material parameters are considered for numerical analysis of thermal and moisture performance of building structures carry out by modern calculation methods [2], [5],[9]. The parameters define moisture accumulation and transport in materials. The implementation of calculating tools into planning practice is often retarded due to incomplete material databases. The main objective of the research performed was to determine missing parameters characteristic for panel buildings in the region of Eastern Slovakia in order to apply them to numerical analyses. Moisture storage function showing water accumulation in porous materials in sorption moisture region and capillary water region is one of the aforementioned parameters. The aim of the paper is to determine the parameters of moisture transport for selected two types of porous concrete using ash and silica sand porous concrete carried out by numerical analysis of thermal-moisture performance of building structures in real conditions. Moisture storage function (sorption, suction) and liquid water transport coefficient will be taken into consideration. Applying these parameters into modern calculation methods (WUFI) will enable us to analyse thermal-moisture performance of two types of porous concrete wall constructions in a year time span, alternative solutions for external thermal insulation compounds system and its influence on building materials drying effect.

Keywords: porous concrete panel wall, experimental and numerical analyse, moisture storage function, water transport coefficient, drying affect

1 Introduction

The main objective of the research was to determine missing parameters characteristic for panel buildings in the region of Eastern Slovakia in order to apply them to numerical analyses. Moisture storage function showing water accumulation in porous materials in sorption moisture region and capillary water region is one of the aforementioned parameters.

In addition, the paper features moisture performance analysis of porous concrete after ETICS insulation with three different initial moisture levels within the span of six years.

2 Water accumulation in selected building materials

The existence of unequivocal humidity function related to some climatic parameters is the main prerequisite for mathematical modeling of water accumulation in materials. Relative air humidity is regarded as the determining parameter. Mathematical calculations analyse building constructions in the hygroscopic range from 0 to 100% of relative humidity of the environment. Therefore it is essential to determine the curve specifying water accumulation in the material for the whole hygroscopic range, i.e. sorption moisture region and capillary water region. Humidity in these regions is defined by sorption and suction curves.

Two following types of porous concrete were selected to be examined in the dissertation [8]. They were frequently used in constructions of residential houses, as well as non-residential buildings and industrial halls:

- Porous concrete PB using ash (measured bulk density 685 kg/m^3).
- Silica sand porous concrete X (measured bulk density 515 kg/m^3).

Porous concrete PB is a light concrete with silica filling - ash and gas silicate or more frequently gas concrete; mixing with foaming additive (aluminium powder) results in creating macropores (**Fig. 1**).

It was used in single-layer external cladding of panel construction systems (T 08 B) of flat blocks (**Fig. 3**), skeletal structural systems (e.g. MS 66, MS RP, S 1.2, BAUMS) in civic amenities (schools, shopping centres, etc.) and in type constructions of single- and double-layer flat roofs.

Its use grew significantly in large-scale development between 1970 and 1992 and it is still ranked among the most utilized building materials, however, its properties have been refined. 240 mm thick samples for the research purposes (6 core drills of 45 mm in diameter) were obtained from the walls of the panel structure T 08 B KE in Lunik 2 housing residential area, Kosice. The panels were manufactured in the former Panel Works in Vranov nad Toplou (Hencovce), Slovakia, using Polish technology Unipol in 1964. The samples were taken in November 2006.

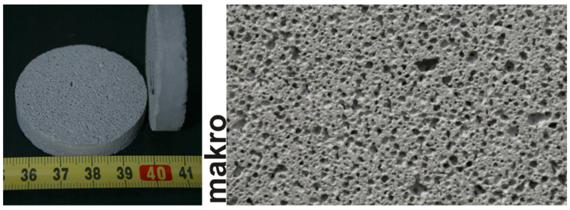


Fig. 1 Porous concrete PB sample

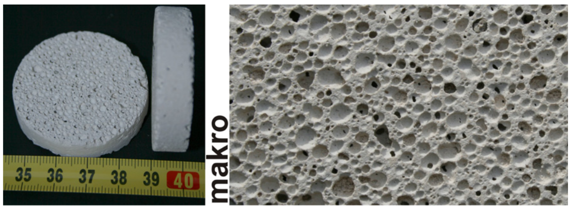


Fig. 3 Porous concrete X sample

Fig. 2 Panel block of flats structural system T08B, row and solo house Košice, on the right detail of external cladding

Porous concrete X is a light concrete with silica sand and lime - cement (gas silicate) or less frequently gas concrete; mixing with foaming additive (aluminium powder) results in creating macropores (**Fig 2**).

It was used in single-layer external cladding of panel structural system (P 1.15, and PS-82) of flat blocks between 1980 and 1992. Prefabricated wall panels were created by connecting several reinforced panels using steel bars – tensioned steel tie bars, into one unit. The analysed 300 mm thick samples were taken from panel construction walls P 1.15 in KVP residential area, Kosice (**Fig. 4**). The total of 6 samples were taken in the form of core drills of 45 mm in diameter.

The panels were most likely manufactured in Porous Concrete Works Sastin, Slovakia, using Swedish technology Siporex in 1980. The samples were obtained in December 2006.

Fig. 4 Panel construction P 1.15, Tahanovce residential area, Kosice, the detail of external cladding on the right

3 Moisture storage function

The sorption curve covers the sorption moisture region, i.e. hygroscopic range up to 97% [1] of relative air humidity. Measuring procedure of the sorption curve was carried out by the method of parallel exposure [1], [6]. After reaching equilibrium state characterized by zero weight growth of the sample in the boxes, sorption curve values of the analysed material were obtained.

Following sorption curves (**Fig. 5**) were attained for the selected types of porous concrete. They were contrasted to sorption curves of similar building materials [6] from software database WUFI [13] or database [12].

Several measuring devices and techniques based on various physical principles can be used for measuring suction curve defining water accumulation in capillary water region. The method in which the determining measuring medium is water comprised in the sample was selected for the measuring purposes. This method is referred to [3] as sufficiently precise, particularly suitable for evaluation of the building materials whose porous systems were exposed to external conditions (weather, pollution, impact of salts, etc.). Measuring was conducted by means of pressure plate extractors produced by Soilmoisture Equipment Corp. [10], [11]. The concept of measuring is based on observations and recording of water weight loss in the saturated sample corresponding to the pressure inducing the change. Suction curve measurements were carried out in Pressure Plate Extractor (PPE) [10] (max 5 bars) and Pressure Membrane Extractor (PME) [11] (max 100 bars).

The transition between relative humidity φ andcapillary pressure is defined by Kelvin's formula (1):

$$\varphi = \exp\left(-\frac{p_k}{\rho_w . r_p . T} \right) \tag{1}$$

where

p_k [Pa] = capillary pressure;
ρ_w [kg/m^3] = bulk density;
r_p [J/(kg.K)] = gas constant of water vapour;
T [K] = absolute temperature.

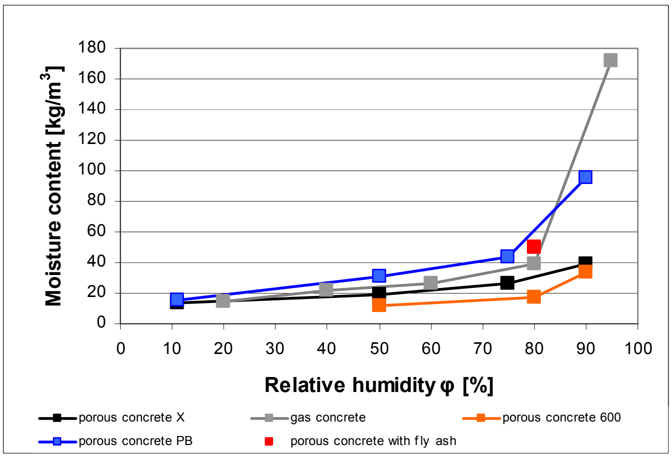


Fig. 5 Comparison of sorption curves of three types of porous concrete. Black curve - porous concrete X, grey curve - gas concrete (Sastin) ρ=580 kg/m^3[6], orange curve - porous concrete "Porenbeton 600" ρ=600 kg/m^3 WUFI 4.2 database [13], blue curve - porous concrete PB and red point defines equilibrium moisture w_{80} for porous concrete using ash 600 [12].

Suction curves of selected types of porous concrete are shown in **Fig. 6**. As suction curves of porous concrete studied in Slovakia did not cover the whole hygroscopic range, these curves were compared to the available public database [12] or WUFI database [13]. **Fig. 6** compares three types of porous concrete.

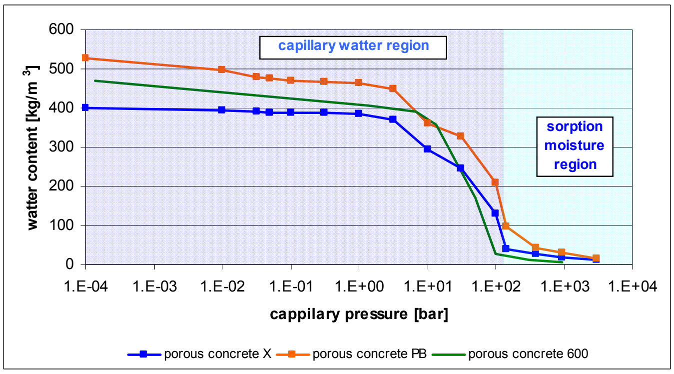


Fig. 6 Suction curve of porous concrete X and PB compared to curves of porous concrete "Porenbeton 600" [13].

Suction curves of porous concrete X and PB are compared to values for similar type of porous concrete "Porenbeton 600" $\rho = 600$ kg/m^3 from database [13]. Suction curves of all analysed materials represent S-shape. Suction curve of porous concrete X in sorption moisture region is almost identical with porous concrete "Porenbeton 600" suction curve. In fact, this results from similar values of equilibrium humidity of both materials in the area of 90% relative air humidity.

Porous concrete PB reaches highest values of equilibrium humidity (95 kg/m^3) in the sorption moisture region and therefore the suction curve of this material has a different shape in this area. Suction curves of all examined porous concrete types for certain materials in capillary water region have a typical shape concluded by the value of capillary humidity w_{cap}. This value for analysed building materials ranges between 400 do 530 kg/m^3.

4 Implementation of the obtained parameters into numerical analysis

The implementation of attained parameters into numerical models enables us to execute detailed analysis of a building structure in real conditions. In order to achieve precise outcomes of the analyses that would realistically describe the structure's condition in certain time intervals, it is essential to implement appropriate and exact material parameters. The selection of a similar material from a database for the purposes of calculation simulation will presumably result in approximate results.

Test reference year for Vienna „Wien, Hohe Warte" from database [14] was used for the calculation as a boundary condition. Calculation was carried out in the simulation programme WUFI 4.2 during three year time span respecting weather conditions.

4.1 Entered calculation conditions

Numerical analysis assumes three identical wall building structures, namely wall system from porous concrete X insulated by contact insulation system. Calculations in regard to time show water content loss in porous concrete panel with different initial moisture levels (**Tab. 1**). Furthermore, the impact of the moisture on the thermal and technical properties of the model building structure will also be studied.

4.2 Calculation boundary conditions

Following boundary conditions were considered in the analysed period:

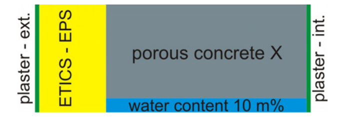
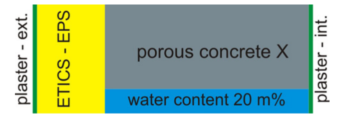
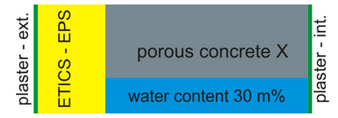
- Outside: Wien/Wien Hohe Warte (**Fig. 7**)
- Wall orientation: West
- Incline: 90°
- Inside: EN 15 026
- Humidity load: normal
- Duration of numerical analysis: 6 years

4.3 Material parameters

Along with material parameters utilised in Glaser methods (**Tab. 2**), other parameters - moisture storage function and liquid water transport – must be considered in dynamic analysis of building structures performance.

Liquid water transportation parameters include moisture storage function (**Fig. 8**) and liquid water transport coefficient (**Fig. 9**).

Tab. 1 Wall structures variants used in calculations

scheme/variant		water content in porous concrete X (kg/m^3)	water content in porous concrete X(m%)
a)		**56**	**10**
b)		**112**	**20**
c)		**168**	**30**

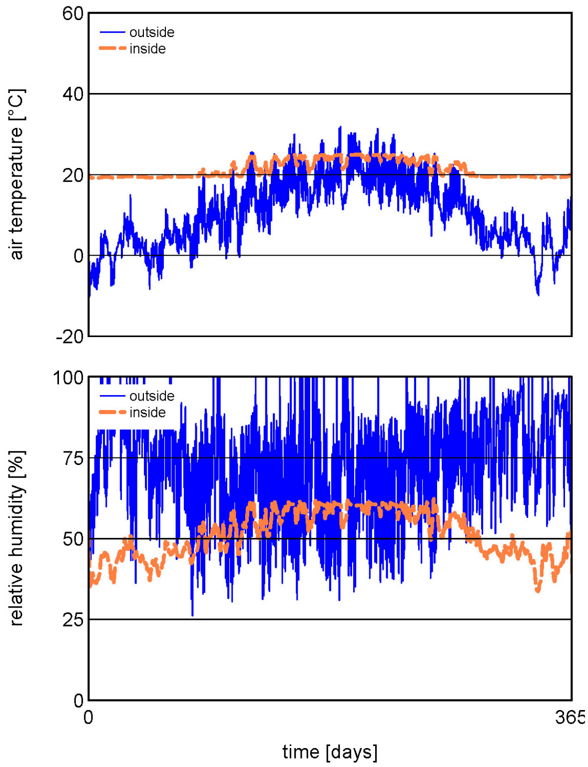


Fig. 7. Air temperature and relative humidity [14]

5 Conclusion

In conclusion we can say that numerous objects in Slovakia whose exterior claddings are made of light concrete are being reconstructed at present and therefore it is important to perform computations of the constructions so as to create optimal concepts for their reconstruction. The aim of this research was to determine the parameters of moisture transport for selected types of porous concrete X and PB in order to carry out numerical analysis of thermal-moisture performance of building structures in real conditions. Along with Glaser's calculations [1], [8] of the known material parameters (λ – thermal conductivity, c - specific heat capacity, ρ – apparent density, μ – moisture resistance factor), other parameters, namely moisture storage function (sorption, suction) and liquid water transport coefficient [4], [7] are taken into consideration.

Tab. 2 Material parameters

material	**d (m)**	**λ_{dry} (W/m.K)**	**c (J/kg.K)**	**ρ (kg/m^3)**	**μ (-)**
plaster – int.	0,015	0,8	850	1900	19
porous concrete X	0,3	0,16	850	560	8
ETICS – EPS	0,1	0,04	1500	30	50
plaster – ext.	0,01	0,8	850	1900	25
d - thickness, λ - thermal conductivity, c - specific heat capacity, ρ - apparent density, μ - moisture resistance factor					

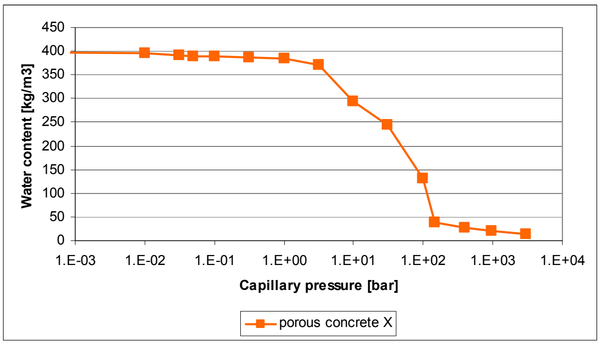


Fig. 8 Moisture storage function of porous concrete X [5].

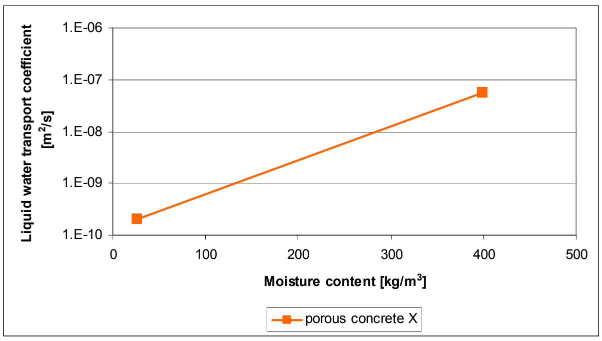


Fig. 9 Liquid water transport coefficient of porous concrete X [5].

Implementation of the parameters into modern computational methods (e.g. WUFI, Delphin, etc.) enables us to carry out or examine the following apart from the previously discussed:

- evaluation of thermal-moisture performance of a building peripheral construction in a year time span,
- analysis of the executed rehabilitation arrangement,
- alternative solutions for external thermal insulation compounds system and its influence on the building structure,
- building materials drying affected by different surface finishes,
- thermal conductivity variations (heat transfer coefficient U – value) depending on the moisture condition of a structure.

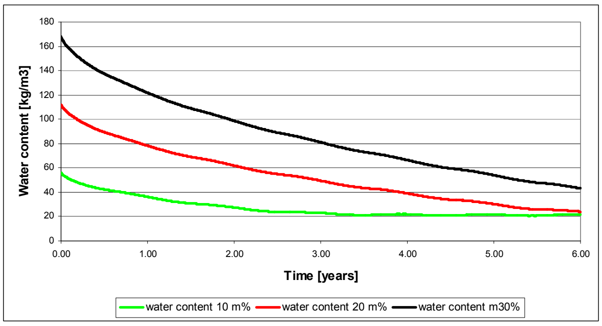


Fig. 10 Water content loss in porous concrete X in 6 years

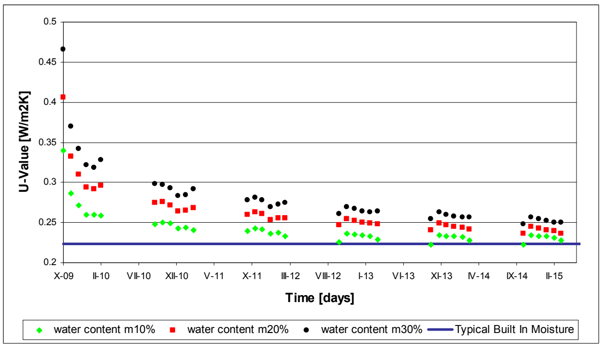


Fig. 11 U - value of a building structure according to [5] schemes covering the time period of 6 years

Based on the study and analysis of thermal and moisture performance of selected porous concrete X, it can be concluded that drying of porous concrete walls insulated by ETICS with thermal insulation on the basis of polystyrene foam is a lengthy process. Regarding water content initial differences in water content are even (**Fig. 10**). Within the period of 6 years the examined materials with 10% and 20% water content reach equilibrium moisture. This time period is, however, not sufficient for the material with 30% water content to reach equilibrium state. The difference is still greater than 10 kg/m^3.

During the drying process of “wet” material (porous concrete) the values of thermal conductivity change significantly (**Fig. 11**). For alternative c) with 30 m% initial water content U-value equals 0,37 W/m^2.K This value is higher by 0,15 W/m^2. K compared to U - value assumed for typical built-in-moisture. In comparison to alternative a) (10 m%) the difference between the calculated and the assumed value is 0,063 W/m^2·K . Water content in alternative c) will decrease to the value of alternative a) in 5 years. The loss of water content will also affect U-value in each alternative.

This analysis shows that excessive value of built-in-moisture has a direct impact on the transmission heat loss coefficient (H_T Value) and thus on the energy consumption increase. Water content in a building structure or its capability of evaporating of the structure can be influenced by the vapour resistance of interior and exterior surfaces.

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