# Measuring the thermo-technical parameters of aerated autoclaved concrete by dynamic method

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**Abstract:** Aerated autoclaved concrete is used as one of basic materials of partition constructions. Its characteristics contribute for energy consumption decrease of construction work.

Bulk density and humidity of aerated autoclaved concrete (AA concrete) are significantly influencing its thermal conductivity and other thermo-technical characteristics. This article shows the results of measurements of thermal conductivity of AA concrete (based on fly ash) at different bulk density and variable humidity of the material. The ISOMET 2104 (www.appliedp.com) a portable measuring device was used in this experiment. Acquired results demonstrate functional relationships between thermal conductivity of AA concrete, bulk density and humidity. The reliability and accuracy of the method of measuring and the measuring device was also vindicated.

**Keywords**: aerated autoclaved concrete (AA concrete), thermal conductivity, bulk density, humidity, measurement

## INTRODUCTION

The thermal conductivity coefficient λ belongs to basic thermo-technical parameters of building materials, including AA concrete. The manufacturers of building materials indicate the value of λ usually defined on dried material. In praxis, however, the materials always have a certain humidity which causes impairment of its thermo-technical conditions. Therefore it is important to know the value of λ at different humidity levels. Stationary measurement methods (characterized by long-term thermal stress of tested sample) do not allow us to measure the λ of humid materials. On the other hand, there are also other procedures (e.g. Hot wire method) that enable measuring λ on materials with relatively high humidity. In terms of ASTM D – 5334 – 08 Standard, this technique is also used in ISOMET, which allows us to measure the thermo-technical characteristics at different humidity and temperature levels of the material, in lab on testing samples as well as directly on the construction.

The issue of the effects of bulk density of AA concrete on change of λ is quite adequately processed in scientific literature. According to many authors [2,6], it is nonlinear. In other words, the thermal conductivity of a material remarkably increases with increasing value of bulk density of the material. In the cases of very small bulk densities (under 100 kg/m$^3$) coefficient λ can even decrease with bulk density increasing. At higher bulk densities, the curvature of the function is very small and at certain relatively narrow interval of bulk densities, this relation can be considered to be linear.

There is less information about the influence of humidity on the coefficient of thermal conductivity λ. Even though the influence of humidity on λ is widely known, literary evidence is often limited only to general definition of this relation, without specific numerical data or functional relationships.

Generally, the coefficient λ increases with increasing humidity. Some authors report that this function is also nonlinear. However, it is often simplified to linear [1,3].

In our article we present results acquired by measurements of thermal conductivity coefficient λ of AA concrete at various bulk density and humidity, made by ISOMET 2104 device. The goal of experiment was to gain exact dependencies of thermal conductivity coefficient λ from concrete humidity at different bulk density of fly-ash AA concrete. The article came to existence on the base of research results of project VEGA Nr. 1/0472/11 with name: „Correlative relations among characteristics of aerated autoclaved concrete and their use in process of quality management in constructions.“

## USED MATERIAL AND MODIFICATION OF SAMPLE PIECES

The fly-ash AA concrete produced by PORFIX, Inc. Zemianske Kostoľany was the measurement subject. The producer prepared sample pieces with various bulk density of 479, 517, 559 and 614 $kg/m^3$ in dry state. Samples had cube form of 100 mm edge. Before own measure, the material humidity was modified. Needed amount of water was calculated with regard to sample weight for set humidity level (1, 3, 5, 10, 15, 20 and 30 %) (humidity by mass). Consequently, calculated amount of water was applied on the sample surface and was let to infuse into sample. Due to homogeneous humidity distribution, these samples were packed in sealable PE bag and stocked in independent-sealing PE boxes. They were left untouched for 2 weeks, and then, thermal characteristics of aerated autoclaved concrete were observed. Just prior to the measure and after the measure, the real humidity level was checked by gravimetric method. Basic characteristics of used AA concretes are shown in table 1.

Table 1. Basic characteristics of used AA concretes

| | | | | |
|---|---|---|---|---|
| **Bulk density in dry state $\rho_v$ [$kg \cdot m^{-3}$]** | 479 | 517 | 559 | 614 |
| **Compressive strength $R_c$ [MPa]** | 2,76 | 3,65 | 4,04 | 5,14 |

## MEASUREMENT METHODS

Measuring of thermal parameters was made by ISOMET 2104 with superficial sensor. It is a portable device for measurement of thermal conductivity coefficient, specific volume thermal capacity, thermal diffusivity, and the temperatures of isotropic materials by changeable needle and superficial sensors. It applies a dynamic method which allows to reduce measure time to 10-16 minutes.

The measurement itself is based on analysis of thermal response of examined material to the impulses of thermal flow. Thermal flow is induced by Joul losses on resistance wire in sensor, which is in direct thermal contact with tested sample. The quantification of thermal conductivity coefficient and coefficient of specific volume thermal capacity is based on evaluation of periodically sampled temperature records as time function. Wide measure range of device allows to test various materials with different mechanical characteristics.

The superficial sensor, intended for hard and solid materials, was used by measuring of thermal characteristics of aerate autoclaved concrete. This type of sensor requires surface diameter at least 60 mm. Tested sample piece has to be modified to secure good thermal contact with sensor. This has direct influence to the accuracy of measurement, and its importance is more significant with increasing thermal conductivity of tested material. Thickness of tested material is minimum of 10 mm (in dependence on thermal conductivity).

## TEST RESULTS

The results of measurements of thermo-technical characteristics of AA concrete are shown in table 2. The dependency of the coefficient of thermal conductivity λ on humidity is graphically shown in figure 2. The dependency of the coefficient of thermal conductivity λ on bulk density is shown in figure 3.


Fig. 1. ISOMET 2104 with superficial sensor

Table 2. Thermal characteristics of AA concrete

| Bulk density in dry state $\rho_V$ [kg·m$^{-3}$] | Humidity by mass $V_{hm}$ [%] | Thermal conductivity coefficient $\lambda$ [W/m·K] | Specific volume thermal capacity $c \cdot \rho$ [J/m$^3$·K] | Thermal diffusivity $a$ [m$^2$·s$^{-1}$] |
|---|---|---|---|---|
| 479 | 0 | 0.090 | $4.54 \cdot 10^5$ | $1.91 \cdot 10^{-7}$ |
| | 5 | 0.107 | $5.75 \cdot 10^5$ | $1.87 \cdot 10^{-7}$ |
| | 10 | 0.136 | $7.54 \cdot 10^5$ | $1.80 \cdot 10^{-7}$ |
| | 20 | 0.205 | $10.82 \cdot 10^5$ | $1.90 \cdot 10^{-7}$ |
| 517 | 0 | 0.098 | $4.75 \cdot 10^5$ | $2.06 \cdot 10^{-7}$ |
| | 5 | 0.121 | $6.19 \cdot 10^5$ | $1.86 \cdot 10^{-7}$ |
| | 10 | 0.145 | $7.41 \cdot 10^5$ | $1.89 \cdot 10^{-7}$ |
| | 20 | 0.227 | $11.54 \cdot 10^5$ | $1.98 \cdot 10^{-7}$ |
| 559 | 0 | 0.117 | $5.82 \cdot 10^5$ | $2.01 \cdot 10^{-7}$ |
| | 5 | 0.136 | $7.39 \cdot 10^5$ | $1.75 \cdot 10^{-7}$ |
| | 10 | 0.164 | $9.06 \cdot 10^5$ | $1.81 \cdot 10^{-7}$ |
| | 20 | 0.217 | $12.60 \cdot 10^5$ | $1.73 \cdot 10^{-7}$ |
| 614 | 0 | 0.122 | $6.20 \cdot 10^5$ | $1.90 \cdot 10^{-7}$ |
| | 5 | 0.148 | $7.95 \cdot 10^5$ | $1.86 \cdot 10^{-7}$ |
| | 10 | 0.172 | $9.61 \cdot 10^5$ | $1.81 \cdot 10^{-7}$ |
| | 20 | 0.237 | $12.72 \cdot 10^5$ | $1.88 \cdot 10^{-7}$ |

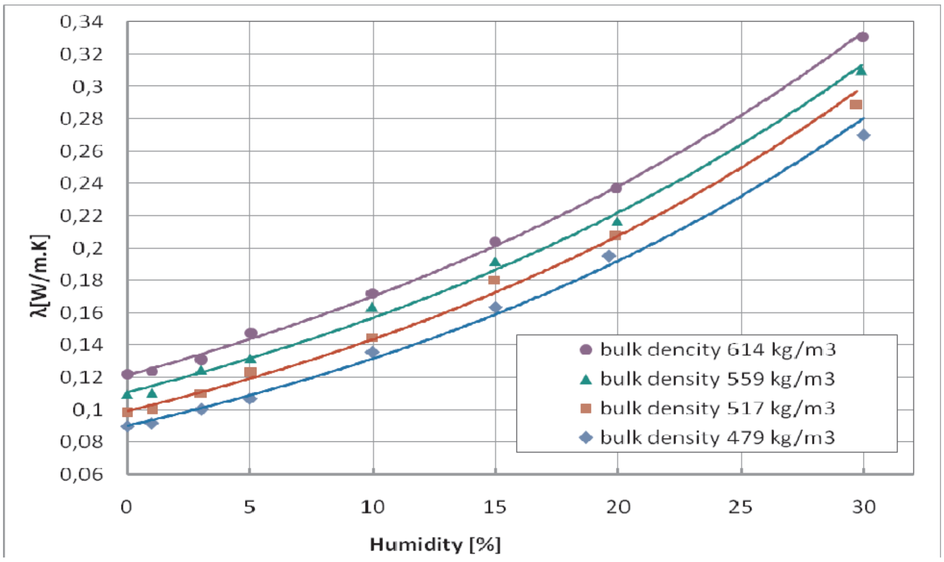


Fig. 2. The relation between the coefficient of thermal conductivity λ and humidity by mass of AA concrete at different bulk densities in dried condition.

## Evaluation of the results

The results of the measurements proved that the use of dynamic method is favorable for reaching anticipated relations. The influence of AA concretes humidity on its factor of thermal conductivity was proved to be dominant. The value of λ increased rapidly as the humidity of the material increased. For example, dried AA concrete with bulk density of 479 kg/$m^3$ showed the value of λ approximately of 0.09 W/m·K. At 5% humidity of the material, the value of λ was equal to 0.11 W/m·K, at 10% humidity λ = 0.14 W/m·K, at 30% humidity λ = 0.27 W/m·K. AA concrete with higher bulk densities showed similar tendency. It is documented in figure 2.

The relation between the factor of thermal conductivity λ and humidity is nonlinear. Exponential function, which most accurately copied measured values, was proved to be the most suitable function. However, the curvature of these functional relations is relatively small - close to linear function. These results correspond with literary information. Various authors [1,3] indicate linear relation between thermal conductivity and humidity of the material. However, studies with exponential relations are also published [2,6]. Obtained results confirm that the relation is slightly nonlinear and we can consider it to be linear at certain, relatively narrow, interval of humidity.

The influence of bulk density on thermal conductivity of AA concrete is also striking. The factor of thermal conductivity remarkably increased when the bulk density increased. For example, the AA concrete in dried condition with bulk density of 479 kg/$m^3$ showed λ = 0.09 W/m·K. The AA concrete with bulk density of 517 kg/$m^3$ had λ = 0.1W/m·K, the λ was equal to 0.11 W/m·K at 559 kg/$m^3$, and at 614 kg/$m^3$ the λ = 0.12 W/m·K. These differences became greater when humidity increased.

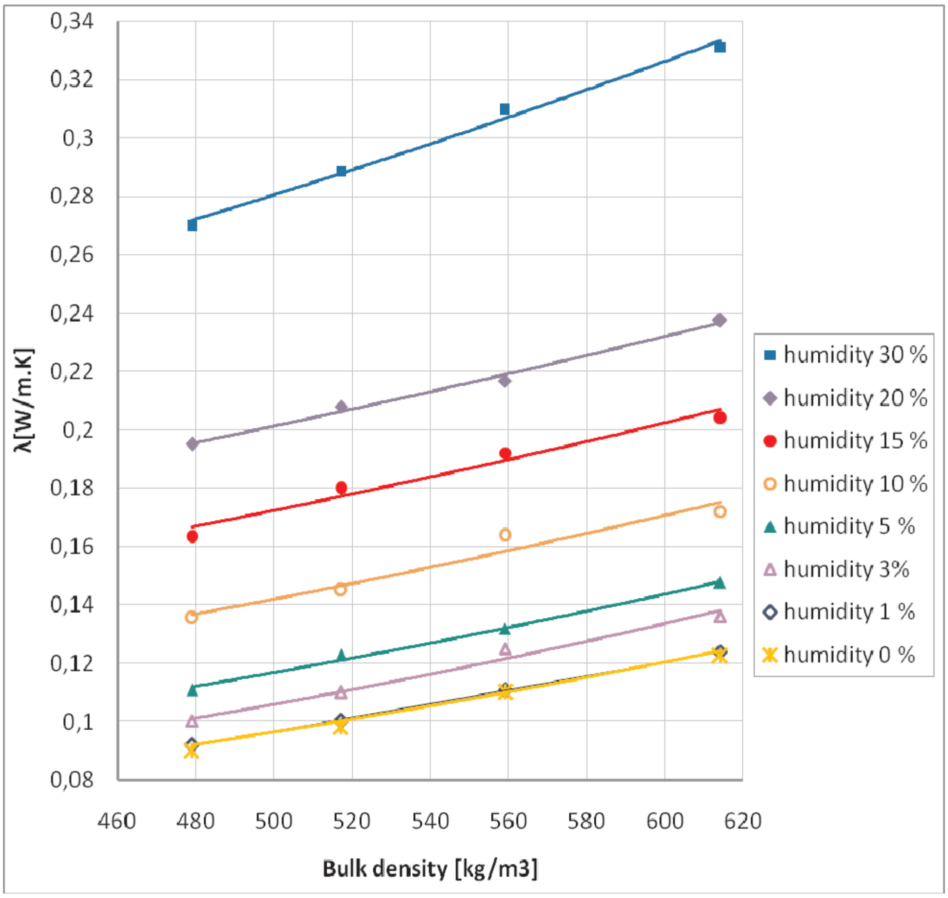


Fig. 3. The relationship between the thermal conductivity and bulk density of AA concrete (in dried state) at different levels of humidity.

According to the literature [2,6], the relation between bulk density and thermal conductivity is nonlinear. However, this tendency is clearly indicated only in wide enough spectrum of bulk densities, while the greatest curvature is in the area of very small bulk densities (under 100kg/m)[3]. The results presented in figure 2 document only very small curvature of functional relation. They can be considered linear in given interval of bulk densities of AA concrete. Various authors wrote about this relation [1,3].

AA concret's humidity also remarkably influenced its thermal capacity. As the humidity increased, the values of volume thermal capacity also increased. We can allege that the results (volume thermal capacity) corresponde with the coefficient of thermal conductivity results. Both of these characteristics are highly dependent on the degree of impletion of pores by water (humidity). Seeing that water is much better conductor of heat than air and also has much higher thermal capacity, the values of given characteristics increased when humidity increased, as expected.

The influence of humidity wasn't evident in the values of thermal conductivity. We cannot observe clear relation of a given characteristic and humidity from acquired results.

## CONCLUSIONS

Acquired results allow to precisely define the heat transmission through aerated autoclaved concrete construction in dependency from marginal conditions, where mainly the thermal conductivity of AA concrete showed significant dependency from humidity. The measurements of ISOMET 2104 device led to acquirement of functional dependencies between coefficient thermal conductivity and bulk density, and between thermal conductivity and AA concrete humidity. The reliability and accuracy of the method of measuring and the measuring device was also vindicated. This along with the velocity and simplicity of measurement creates premises for mass usage of the device as in scientific research as in everyday praxis.

In further research we prepare measurements of thermo-technical characteristics of AA concrete using this method at minus temperatures, with emphasis to phase transition – water state change in porous material. These measurements would more refine the thermal transition modeling through aerated autoclaved concrete constructions.

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