AN EXPERIMENTAL INVESTIGATION OF LIME BASED PLASTERS MOISTURE AND TEMPERATURE INDUCED DEFORMATION.

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Abstract: *The problem of the reconstruction of the historical building coat is in material comparability. The basic of the convenient material choice for reconstructions is to recognize some physical properties of used materials. The crucial properties are moisture and temperature induced expansion. The objective of this paper is to experimentally determine moisture and temperature induced deformations of two lime based plasters. The measurements are performed for moisture content from the dry state to the saturation water content and temperature range of 5 – 60°C. Temperature and moisture induced length differences were measured using LVDT MACRO SENSOR SBP 375040.*

Keywords: MOISTURE INDUCED DEFORMATION, THERMAL DEFORMATION, PLASTERS, EXPERIMENTAL MEASUREMENT

1. Introduction

Historic buildings are built from components with porous structure. They are subjected to the weather actions. Effects such as water absorption, moisture and heat transfer, freezing, melting and drying cause the destruction of the buildings.

Mechanisms responsible for typical defects as the cracking and the spalling of facades are associated with length or volume changes of porous materials due to moisture content or to temperature changes [1-3]. These crucial properties are moisture and temperature induced deformation are often less appropriate regarding to the variable moisture content and temperature in the masonry which leads to low durability and short service life of surface layers. The choice of materials for surface layers reconstructions should be estimated on the basis of knowledge of their thermal and moisture induced deformation behavior.

Moisture expansion is often not taken into account in practical calculations, although a higher content of moisture can lead to hygric stress in the same range as thermal stress. [4].

In this paper experimental determination of the dependences of moisture induced expansion of two commercial lime-based plasters upon moisture at temperatures 20°C and 60°C is presented. Thermal expansion was determined upon ambient relative humidity 40%.

2. Experimental methods

2.1. Basic material parameters

All the studied samples were one year old.

Measuring the bulk density and open porosity were carried out in this manner: Each sample was dried to remove physically bounded water. After that the samples were placed into the desiccator with vacuum pump from the desiccator. The specimen was then kept under water for 24 h. The mass of each specimen (dry sample - m_d, water saturated sample – m_s, immersed water saturated sample m_A) was measured with 0.01 g accuracy. The volume V of the sample was determined from the formula $V = \frac{m_s - m_d}{\rho_w}$, where ρ_w is the water density. The open porosity ψ_o was calculated according the formula $\Psi_o = \frac{m_s - m_d}{V\rho_w}$. The bulk density ρ was calculated according the formula $\rho = \frac{m_d}{V}$.

The pore size distribution curves were measured by mercury intrusion porosimetry. The experiments were carried out using the instruments Poremaster 60GT.

The measurements of the sorption isotherms were determined using the climatic chamber. The climate maintains the desired temperature with the accuracy $\pm 0{,}4°C$ and relative humidity with the accuracy $\pm(0{,}2\% RH$ for low RH and $2\% RH$ *for high RH).*The weight changes were measured by milligram accuracy for a capacity up to 310 g.

2.2. Moisture and thermal deformations

Both, the moisture induced deformation and temperature induced deformation was measured in the equipment (Figure 1, [5]) using LVTD sensor located into zerodur closed loop measurement frame which provides the resolution of the length changes 10^{-4} mm, repeatability in the temperature range from -15°C to 105°C and from 10% to 95% relative air humidity. The sample holder is made from stainless steel. The measurement process is PC controlled. The measured sample has shape 1D rod (15cm x 2cm x 2cm). The process of moisture diffusion is an inert one, and therefore the experiments of investigation of deformations are time-consuming. Obtaining of one measured point lasted five weeks.

The moisture induced deformation as a function of moisture content was experimentally determined at temperatures $10°C$ and $40°C$.

The temperature induced deformation as function of temperature was measured upon 40% environment relative humidity.

Fig. 1 *Dilatometer for measurement of moisture and temperature induced expansion.*

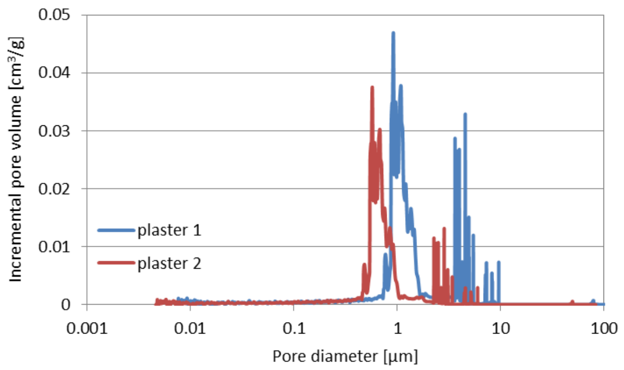
3. Results

Basic material parameters of studied lime based plasters are in the Table 1 and the pore distribution curves are in the Figure 2. We can see that difference between plasters in open porosity is clearly related to the lower bulk density of plaster with the greater pore volume.

Table 1: *Basic material characteristics of lime plasters.*

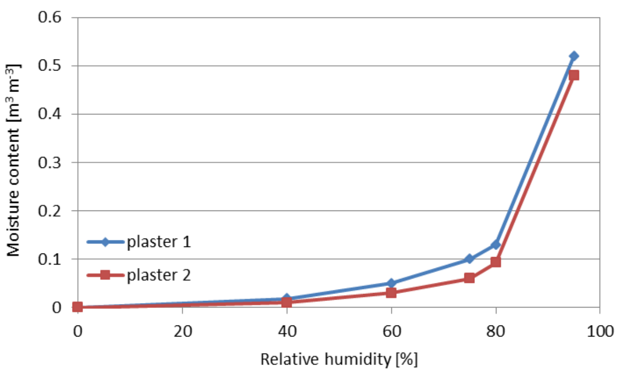
Material	Bulk density [kg.m^{-3}]	Matrix density [kg.m^{-3}]	Open porosity [%m^{3}m^{-3}]
Lime plaster 1	1410	2510	39,1
Lime plaster 2	1670	2430	34,7

Fig. 2: *Pore size distribution curves of lime plasters.*



At the Figure 3 we can see that the sorption isotherms of studied plasters are different, they correlate with basic material characteristic in Table 1 and with the pore size distribution curves at Fig. 2. The highest value of water sorption was achieved by the lightweight plaster 1.

Fig. 3: *Sorption isotherms of studied lime plasters.*



The measured moisture-induced strains ε ($\varepsilon = \frac{\Delta l}{l_0}$, where $\Delta l = l_u - l_0$, $l_0 [m]$ - basic length of a specimen, $l_u [m]$ - measured length of a moist specimen) for both plasters are at the Figure 4 and Figure 5. At the comparison of the moisture dependent moisture induced strains at Figure 4 and Figure 5, we can see both, that the plaster1 reached higher values of strains upon temperature $20°C$ and also under temperature $60°C$ and strains were lower under temperature $20°C$ in the cases of plaster 1 and plaster 2.

By the fitting of the measured moisture induced strain data for both plasters and under both temperatures was described the moisture induced strain ε as a function of moisture content by volume $u [m^3.m^{-3}]$:

$$\varepsilon(u) = A + \frac{B}{u + C}, \qquad (1)$$

where A, B, C are fitting constants. This analytical formula moisture induced expansion as a function of moisture content makes it possible the formula for coefficient of moisture expansion $K(u)$ as a differentiation of the $\varepsilon(u)$ function (1) with respect to u . This formula is expressed as follows: $K(u) = -B(u + C)^{-2}$. Measured moisture induced strain values (Figure 4, Figure 5) demonstrate the very fast moisture strain grow with moisture content on low moisture content values, about 50%RH of environment, there is a rupture and moisture deformation rises slightly.

Fig. 4 *Moisture induced strain of lime plaster 1.*

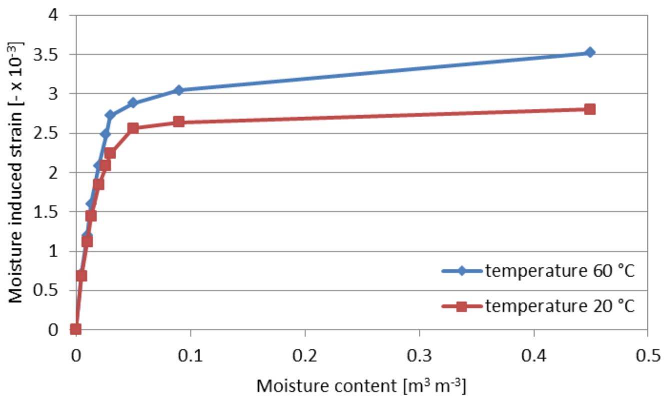


Fig. 5 *Moisture induced strain of lime plaster 2.*

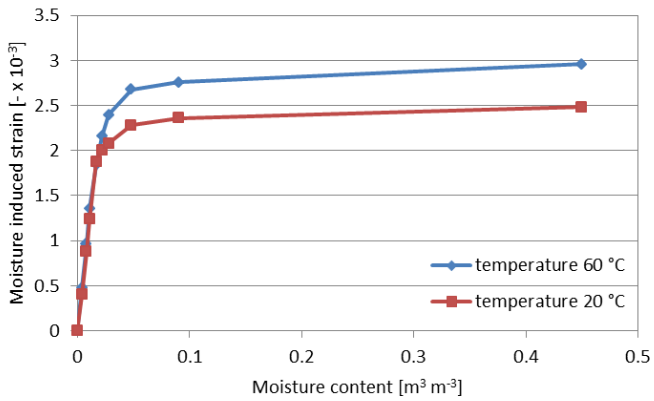
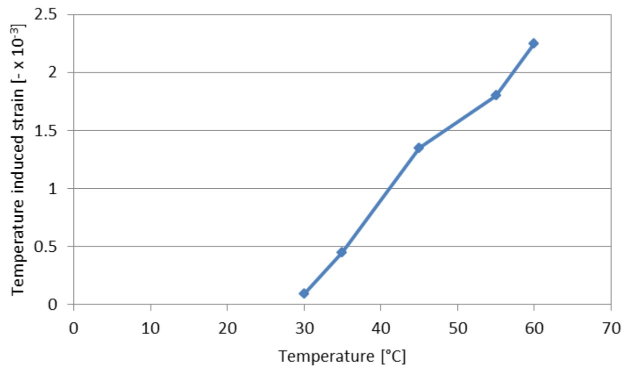


Fig. 6 presents the dependence of the thermal expansion of lime plasters on temperature upon 40%RH of environment. These measured values have the same order as values of moisture deformation. The coefficients of linear thermal expansion for plasters are from the range $6{,}2 \times 10^{-6} K^{-1}$ to $15 \times 10^{-6} K^{-1}$ [6].

Fig.6: *Temperature induced strain of the lime plasters 2.*



4. Conclusions

The moisture and temperature induced strain were established in this study for two lime based plasters. The most important result of the experimental work done in this paper is that the moisture content has significant influence on deformation which might be induced in plasters due to moisture changes. The moisture deformations might be equal as stress caused by temperature changes.

5. Acknowledgement

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6. References

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