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METHODS OF A BUILDING STONE INTERNAL STRUCTURE STUDY

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Abstract: *Building stone is during its "life" influenced by actions of weathering processes which usually lead to changes in the internal structure of the stone which influences its durability. For this reason, studies of a stone internal structure are very important. There are many methods to determine effective porosity and provide porosity values in a percentage, nevertheless, these methods do not enable visualization of the internal structure. The visualization can be useful for better understanding of the durability phenomenon. Therefore, the methods of X-Ray microtomography and microscopy in ultraviolet light were used in our research of three Czech sandstones. Both methods also provide different values of porosity which are given due to their limitation. The main aim of this contribution is to present basic information about both methods and to compare their results, advantages and disadvantages.*

Keywords: Building stone, Internal structure, X-Ray microtomography, UV microscopy, MicroOpis.

1. Introduction

Building stone is during its "life" influenced by actions of weathering processes which usually lead to changes in the internal structure of the stone. According to studies by many authors (e.g. Fitzner & Kalde, 1991; Kovářová, 2012), once these changes are initiated they influence the stone's durability. For this reason studies of a stone internal structure are very important. There are many methods to determine effective porosity, such as mercury porosimetry, helium pycnometry and determination of open porosity according to the national standards. These methods provide porosity values in a percentage (by helium pycnometry after the conversion of the gained material real density); however, they do not enable the visualization of the internal structure. The visualization can be useful for better understanding of the durability phenomenon.

For these purposes we used the methods of X-Ray microtomography and microscopy in ultraviolet light (UV) in the research of three Czech sandstones. Both methods are described and the obtained results are mentioned and discussed in this article.

2. Experimental Material and Methods

2.1. Experimental material

Three types of commonly used Czech cretaceous sandstone were studied in our research – Božanov, Hořice and Kocbeře. Although all quarries are situated relatively close to each other, each type looks macroscopically as well as microscopically different. The Hořice and Kocbeře sandstones are fine-grained, mostly formed from quarz grains, whereas the Božanov sandstone is coarse-grained and contains higher amounts of feldspar. Each type has a different mineralogical composition of cement binder and also a different organization of the pore space, i.e. the internal structure. Finally, each type also reacts to the weathering action in a different way from the point of view of physical-mechanical properties changes (Kovářová, 2012).

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2.2. Methods

2.2.1. X-Ray microtomography

The method of X-ray microtomography belongs to non-destructive test methods, which were used to obtain information about porosity and organization of internal structure in general. X-Ray microtomography is a characterization method based on the investigation of internal sample structure by image analysis (e.g. Appoloni et al., 2007). X-Ray microtomography is composed of two basic steps - acquisition of projections and volume reconstruction. In the phase of acquisition the object is turned around the rotation axis at a selected small angle and so called X-ray projections are measured. The absorption of X-ray beams as they pass through a material is a logarithmic function of the absorptivity of the material and the distance through which the light must travel (so called Beer's law).

Projections are X-ray attenuation images which are created on a two-dimensional detector after the beam transmission through the object. To accomplish the measurement, the sample can be rotated at 180º or 360°, the latter being used in our case. In one turn the selected number of projections is captured. The three dimensional image of the object is reconstructed after obtaining all projections, when two-dimensional detector is used as in our case (Hain et al., 2011). This method enables to create 3-D video and so a detailed visualization of pore space is possible.

Small cylinder samples with the diameter 1 cm and the height 1.5 cm were prepared from every sandstone type. Samples were measured by microCT phoenix|x-ray nanoton180 with 5 Mpx 2D detector at 90 kV, 100 μA with timing 2 s and 2880 projections. Voxel size was 5 μm (Kovářová et al., 2012). This experimental arrangement enables to evaluate pores with diameter > 5 μm.

2.2.2. Microscopy in ultraviolet light

Microscopy in ultraviolet light is usually used for better description of pore space. The method enables to study the pore size, connectedness, pore types and presence of microcracks. Pores and cracks are highlighted by a fluorescence dye contained in the resin which is excited by captured ultraviolet radiation (Jornet et al., 2002). The polarizing microscope Olympus BX-51 with a mercury lamp enabling observation in ultraviolet light was used for the study of stone thin sections.

The program MicroOpis (Kovářová & Kovář, 2011) was used for the study and evaluation of obtained pictures. This software performs color analysis contained in the photo. Photos saved in a raster (dot) graphical format are composed of individual discrete points, pixels. Each point is characterized by a record describing the color of the point. The application MicroOpis passes the photo point to point and counts points which correspond with the selected color condition. The percentage of points complying with the selected condition is calculated from the number of satisfactory points and total points in the photo. The total number of photo points is defined by the photo resolution. The MicroOpis application allows the user to select a "reference color" which is the closest to the desired area in the photo. Consequently, it is necessary to choose the "threshold", the number in the same range as those defined in the representation of each color component, which defines the maximum distance of tested colors from the reference color (Kovářová, 2012).

3. Results and Discussion

The three-dimensional reconstruction of pore space and cross-sections were done by X-Ray microtomography in each stone type (Figs. 1 and 2). The porosity values determined by both methods are given in Tab. 1. As it is obvious from the following figures, each type of sandstone has a different organization of the pore structure. This phenomenon was also confirmed using microscopy in ultraviolet light (Fig. 3). The sample of processed image in ultraviolet light of the Božanov sandstone using MicroOpis application is shown in Fig. 4.

The differences of porosity values determined by both methods are caused by limitations of both methods. Both methods enable the detection of total porosity, i.e. open and closed pores, but each has a different detection limit. The detection limit of X-Ray microtomography in this experimental arrangement is 5 μm and the detection limit of microscopy in ultraviolet light depends on the used enlargement. The results of image analysis using the MicroOpis application also strongly depend on the ability of individual assessors to accurately determine the grain/pore boundary. The analysis of UV images is also timeconsuming. Because of the above mentioned limitations of the methods, it is useful to determine the porosity also by another method, i.e. the mercury porosimetry (Kovářová et al., 2012).

Tab. 1: Porosity values (%) of studied sandstone using both methods of determination.

Sandstone	X-Ray microtomography	UV microscopy
Božanov	***16.00***	***21.14***
Hořice	***22.00***	***30.22***
Kocbeře	***15.61***	***23.15***

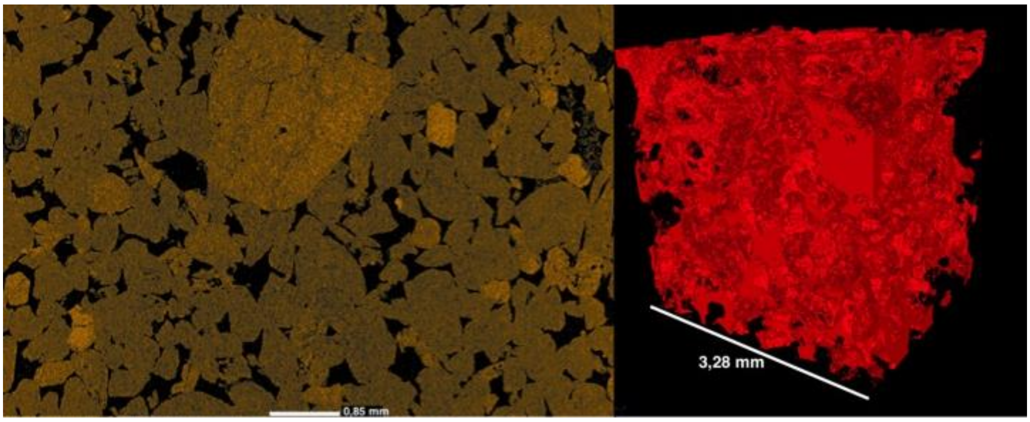

Fig. 1: Cross-section (on the left) and three-dimensional reconstruction (on the right) of Božanov sandstone.

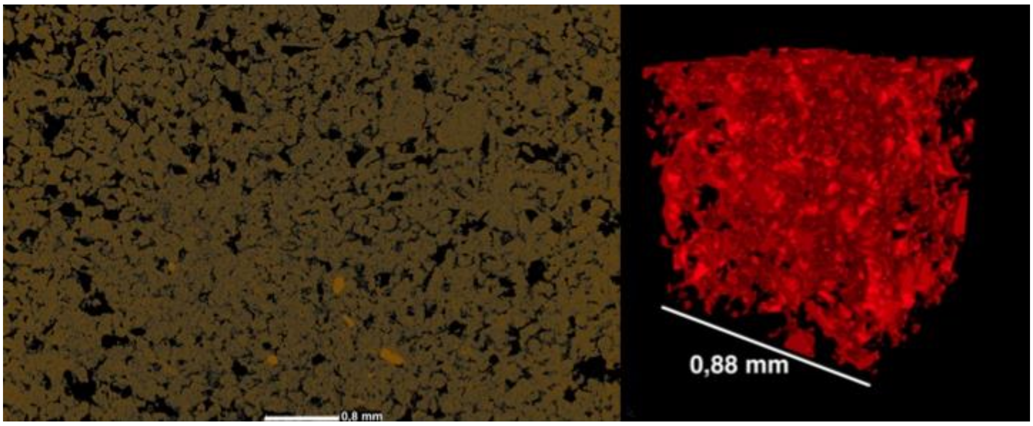

Fig. 2: Cross-section (on the left) and three-dimensional reconstruction (on the right) of Hořice sandstone.

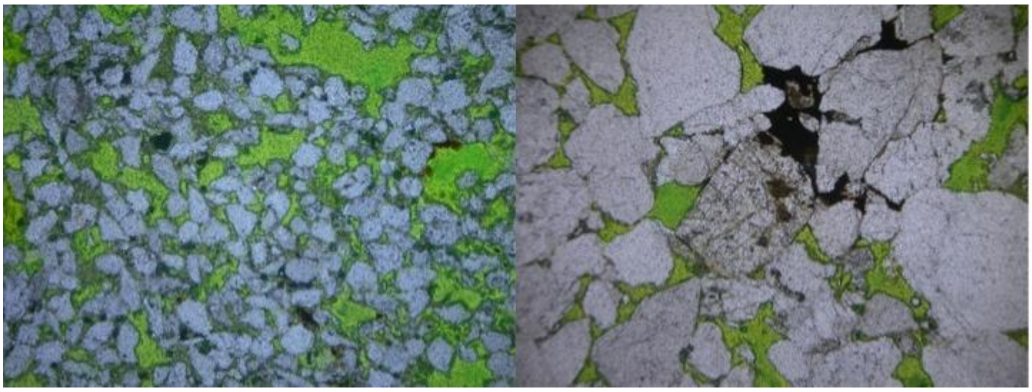

Fig. 3: The Hořice sandstone (on the left) and Božanov sandstone (on the right) in ultraviolet light (4x enlargement).

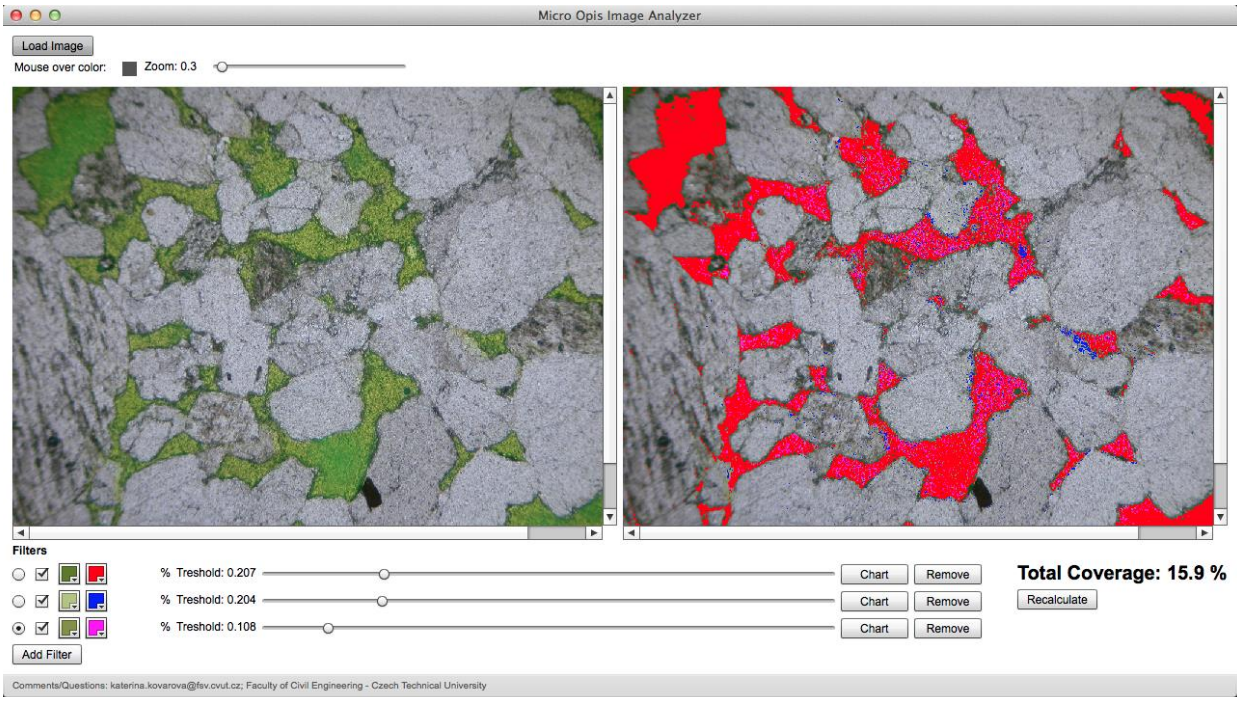

Fig. 4: The processed UV image of the Božanov sandstone using the MicroOpis application – the UV image of the stone thin section (on the left); the image after the color highlight of pore area, incl. their percentage (on the right).

4. Conclusions

To sum up, both mentioned methods enabling the study of the internal structure have their own limitations. The main disadvantage of both methods is their detection limit but the main advantage is the possibility to visualize the internal structure which is not possible using another method.

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References

Appoloni, C.R., Fernandes, C.P., Rodrigues C.R.O. (2007) X-ray microtomography study of a sandstone reservoir rock. Nuclear instruments and methods in physics research A, 580, pp. 629-632.

Fitzner, B., Kalde, M. (1991) Simulation of frost-thaw cycle and salt weathering - nature adapted material tests, In: La détérioration des matériaux de construction, Colloque International, La Rochelle (France), pp. 103-114.

Hain, M., Nosko, M., Simančík, F., Dvořák, T., Florek, R. (2011) X-Ray microtogtraphy and its use for non-destructive characterisation of material, In: Proc. 8th International Conference on Measurement (Maňka, J., Witkovský, V., Tyšler M. & Frollo, I. eds), Institute of Measurement Science, SAS, Bratislava, pp. 123-126.

Jornet, A., Teruzzi, T., Rück, P. (2002) Bowing of Carrara marble slabs: comparison between natural and artificial weathering, In: Understanding and managing of stone decay (Přikryl R. & Viles H. eds), Karolinum, Prague, pp. 161-169.

Kovářová, K. (2012) Influence of weathering processes on physical-mechanical properties of sandstones. PhD. thesis, CTU Prague.

Kovar, J., Kovarova, K. (2011) MicroOpis 1.0.

Kovářová, K., Ševčík, R., Weishauptová, Z. (2012) Comparison of mercury porosimetry and X-Ray microtomography for porosity study of sandstones. Acta Geodyn. Geomater., 9, 4 (168), pp. 541-549.