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The Influence of Internal Structure Change on Sandstone Strength

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Abstract: During their "life" sandstones are influenced by actions of weathering processes which usually lead to changes in their internal structure. Porosity and the character of pore space is one of the main factors affecting the resistance to weathering processes and, consequently, to the changes of mechanical-physical properties of these stones. Rock material is generally negatively influenced especially during the winter period. The effect of salt crystals and ice formation depends on the character of pore space, including the pore size distribution. Our research was focused on three commonly used Czech Cretaceous sandstones – Hořice, Božanov and Kocbeře. These stones were exposed to the accelerated durability test and then the change of uniaxial compressive strength was determined. We used the mercury porosimetry and X-Ray microtomography methods to evaluate the changes of pore space properties. Use of these methods enabled more detailed understanding of the processes inside the stone structure and their influence on strength characteristics of sandstones.

Introduction

The weathering processes influence the technical properties of sandstones especially during the winter season thanks to the frost and deicing salt action. These two weathering agents significantly influence the stone internal structure, i.e. pore space, which consequently leads to the deterioration of technical parameters. The uniaxial compressive strength is the most commonly used mechanical parameter enabling the evaluation of deterioration and also durability of a stone.

Experimental material and procedure

Three Czech Cretaceous sandstones (Hořice, Božanov and Kocbeře) were exposed to the accelerated durability test, according to the procedure described by Kovářová et al. [1]. Two sets of cubic stone samples were treated by a cyclic thermal exposition in a climatic chamber with the temperature ranging from – 14°C to 14°C. The samples were soaked for 24 hours in distilled water and in 2.5% solution of NaCl before and during the treatment. The treatment regime consisted of 56 freeze/thaw cycles in total.

To evaluate the rate of deterioration, the uniaxial compressive strength (hereafter UCS) was determined as an arithmetic mean of measured values on ten samples of each sandstone type before and after undergoing both climatic treatments. Hg porosimentry and X-Ray microtomography methods were used to determine the internal structure changes. The total cumulative volume of pores, volumes of meso-, macro- and coarse pores, and the total porosity were determined using coupled Pascal 140 + 240 porosimeters by Thermo Electron – Protec. Small cylinder samples with the diameter 1 cm and the height 1.5 cm were measured by microCT phoenix|x-ray nanoton180 at 90 kV, 100 μA with timing 2 s and 2880 projections. Voxel size was 5 μm and experimental arrangement enabled the evaluation of pores with diameter > 5 μm [1].

Results

Uniaxial compressive strength. The UCS is by many authors considered one of the most important durability indicators. Generally, it is stated that the UCS decreases with an increasing number of freeze/thaw cycles [e.g. 2], however, these statements do not correspond with some of the results we gained, as is obvious from the following table (Table 1). The UCS increased after the climatic treatment with distilled water in Hořice sandstone and also after the climatic treatment with sodium chlorite in Kocbeře sandstone.

Table 1: Average values of UCS [MPa], including percentages changes (in parentheses).

	Hořice sandstone	Božanov sandstone	Kocbeře sandstone
Untreated samples	51	75.2	87.6
F/T cycles + H_2O	54.9 (+ 7.65)	73 (- 2.93)	76.9 (- 12.21)
F/T cycles + NaCl	44.6 (-12.55)	68.7 (- 8.64)	92.4 (+ 5.48)

Mercury porosimetry and X-Ray microtomography. According to statements of many authors [e.g. 2], the decrease of UCS is accompanied by the increase of porosity. The porosity measurement using only Hg porosimetry did not provide convincing results, which would confirm the previous statements. Using the results of mercury porosimetry and X-Ray microtomography, the *residual porosity* of pores with the diameter > 5 μm was calculated [1]. The *residual porosity* consists of closed pores, which are not possible to detect using only mercury porosimetry and other standard penetration methods of porosity determination. Average values of the residual porosity are summarized in the following table (Table 2).

Table 2: Residual porosity of pores with diameter > 5 μm [%].

	Hořice sandstone	Božanov sandstone	Kocbeře sandstone
Untreated samples	7.11	3.31	1.84
F/T cycles + H_2O	5.69	3.11	7.16
F/T cycles + NaCl	9.24	5.56	5.12

Conclusion

The residual porosity development in Hořice and Božanov sandstones explains the reason of increasing UCS after the climatic treatment. For example, the residual porosity in Hořice sandstone increased and the UCS decreased after the climatic treatment with NaCl, whereas the increase of UCS was accompanied with the residual porosity decrease after the climatic treatment with distilled water. Only the Kocbeře sandstone showed a different development and coherency of the studied parameters after the climatic treatment with NaCl. The UCS increased with the residual porosity increase. This can be explain thanks to the X-Ray microtomography detection limit. We can assume, that the internal structure changes occure even below 5 μm and, therefore, it cannot be ruled out, that the residual porosity of pores < 5 μm significantly decreased and this caused the UCS increase.

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References

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