pregnated BST rises gradually, in each case with a value of 18 kg/m² after 72 hours (8.5 $h^{0.5}$). It is notable that the water absorption of vacuum treated BST first starts after 6 hours (2.5 $h^{0.5}$) with a value of 2 kg/m², running then almost parallel to the untreated curve (after 8.5 $h^{0.5}$: 11 kg/m²). Due to 5-time impregnation, no water absorption could be determined in the first 48 hours (6.9 $h^{0.5}$), which indicates a denser pore space. Although the pores got denser using other treatment procedures, water transport is still possible for BST (except 5-time treated samples). The effect of a denser pore space can also be seen by the decreasing ability of capillary water absorption of treated SST samples (Figure 3). Due to vacuum and 5-time impregnation, the values after 72 hours (8.5 $h^{0.5}$) are about 0.5 – 0.7 kg/m² respectively 0.4 kg/m².

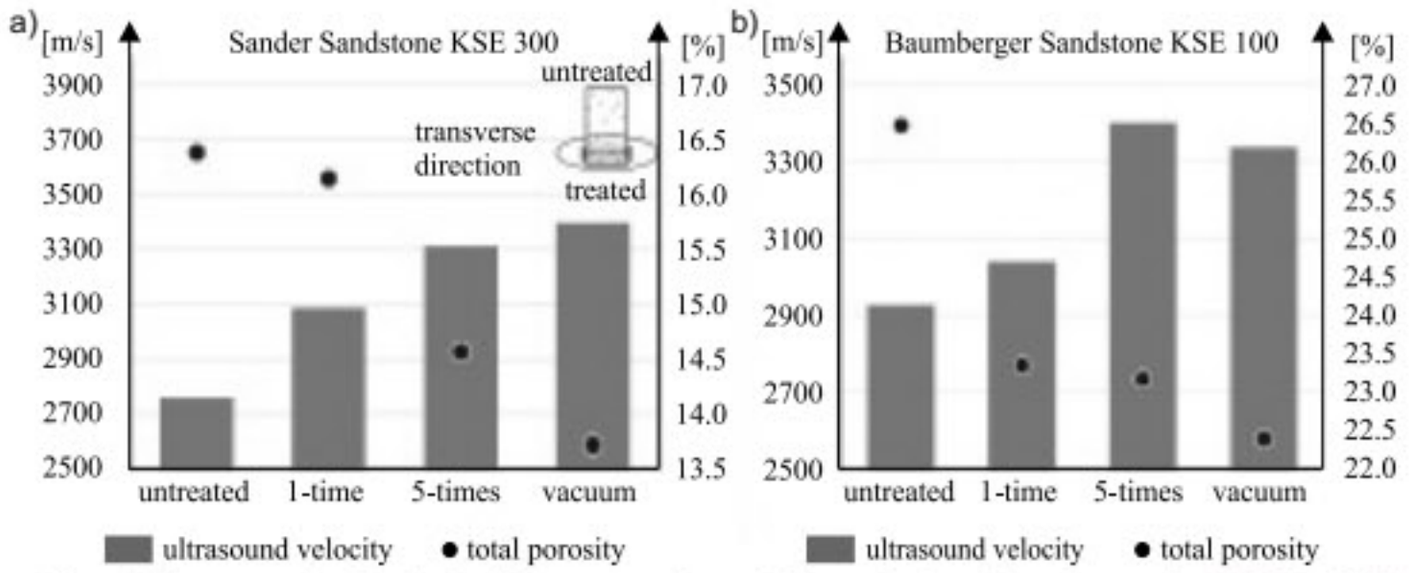

Fig. 4. Ultrasound velocity [m/s] (mean values of 6 samples) and total porosity [%] for SST and BST for different treating procedures, treated with KSE 300 (a) and KSE 100 (b)

Rys. 4. Prędkość fali ultradźwiękowej [m/s] (średnia wartość z 6 próbek) i porowatość całkowita [%] w przypadku piaskowców SST i BST po różnej obróbce preparatami KSE 300 (a) i KSE 100 (b)

SST samples show an increase of 551 m/s from untreated up to 5-time impregnation. Concerning the total porosity of SST (Figure 4), it can be seen that the higher the impregnation rate or the higher the amount of stone strengthener in the pore system of the treated stone, the more decreases the total porosity. The same effect can be detected for untreated up to 5-time treated BST, where the ultrasound velocity increases by 472 m/s and the total porosity is reduced from 26.5% (untreated) to 22.4% (vacuum). The overall decrease in total porosity with continuing treatment action is also reflected in the results of increasing ultrasound velocity. This suggests that the increasing amount of stone strengthener in the stone specimens leads to a denser pore space of SST and BST and might affect the open pore network or even cause a sealing of the pore space. This results were also shown in the reduction of capillary water absorption for both sandstone types.

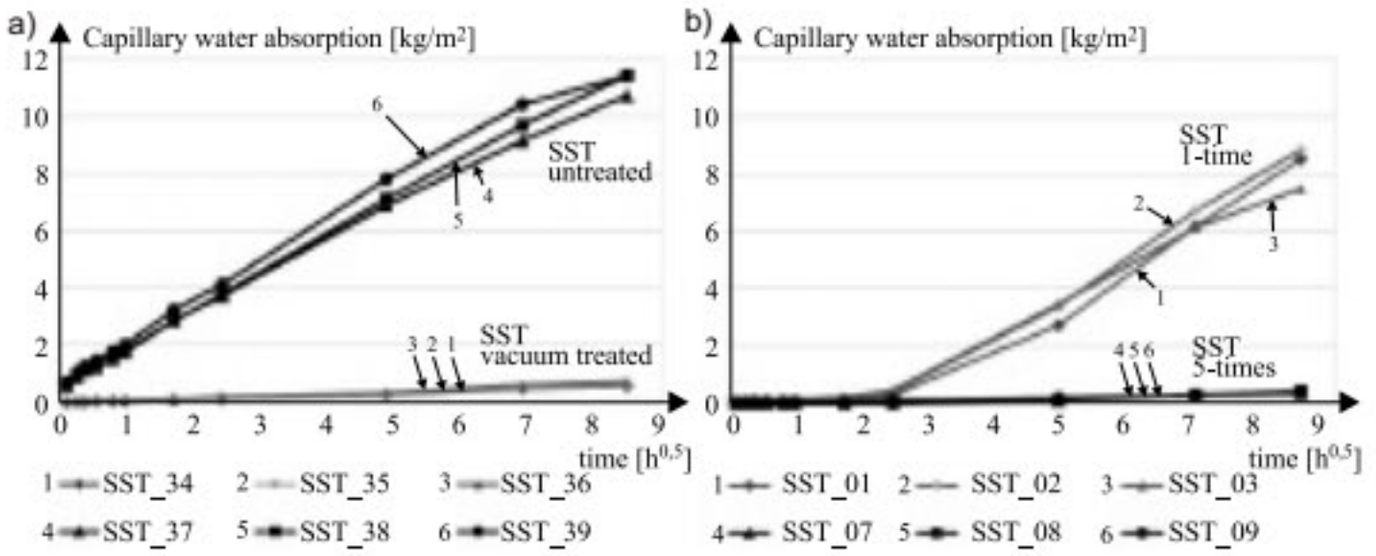

Fig. 3. Capillary water absorption [kg/m²] of untreated and vacuum (a), 1-and 5-time (b) impregnated SST with the stone strengthener KSE 300

Rys. 3. Absorpcja kapilarna wody [kg/m²] piaskowca SST nieimpregnowanego i impregnowanego w próżni (a) oraz impregnowanego 1- i 5-razy (b) środkiem do wzmacniania kamienia KSE 300

This flat curve progression is contrasted by a steeper curve of untreated and 1-time treated SST samples, which reaches values of 11 kg/m² and 9 kg/m² after 72 hours (8.5 $h^{0.5}$). These results clearly show the effect of over-treating stone samples, which inhibits the capillary water uptake and might cause a sealing of the open pore space.

The presence of the stone strengthener and its penetration depth for 1- and 5-time impregnated samples can be detected by ultrasonic velocity tests with a measuring range in transverse direction (Figure 4, illustration of experimental setup of the prismatic stone samples). On the primary axis of the diagrams (Figure 4) the ultrasound velocity [m/s] is plotted and on the secondary axis the total porosity [%].

Discussion and Conclusion

This study shows that the effectiveness of a consolidation action specifically depends on the petrophysical and mineralogical properties of the treated natural stones and that the success of a stone consolidation is also limited by the binding agent of the stone. In case of SST samples (clayey binder), 5-time and vacuum impregnation caused a sealing of the pore space. As a result the capillary water absorption and the water transport through the pore network is limited. Same effects could be detected for 5-time treated BST samples. In contrast, the pore system of 1-time and vacuum treated BST still enables capillary water uptake. 1-time impregnation of BST and SST showed moderate contents of stone strengthener in the stone samples, but it is questionable, if it is sufficient. Using vacuum impregnation it can be ensured that the highest amounts of stone strengthener get into the stone matrix, which leads to an improvement in strength but also increases the possibility of sealing the pores. Therefore vacuum impregnations are not practicable on building sites.

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Przyjęto do druku: 04.10.2016 r.