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Ancient sandstone condition assessment in relation to degradation, cleaning and consolidation phenomena

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Non-invasive methods for assessing the state of historic stone types rely on measurement of their surface or subsurface characteristics, which are supposed to correlate with objective physical characteristics. Such measurements are influenced by surface conditions of stone, as well as by previous conservation treatments. The authors performed a comprehensive study of characteristics and behaviour of typical sandstone types present in the Charles' Bridge in Prague as a preparatory work for its diagnostic and restoration in order to understand the problem of a large, important, and non-homogeneous (from the material point of view) historic structure, that was intended for repair interventions. The study itself took advantage of the combination of non-invasive, or considerately destructive methods and fully destructive tests, because it was possible to use damaged sandstone blocks, which were extracted from a masonry rail of the bridge before replacement with new elements. Stone characteristics were studied on test specimens prepared from materials in various conditions and after various interventions. Seven types of sandstone were tested in nine sets (degraded surface layer with a crust, degraded surface layer after cleaning, and unweathered core material; all three without any consolidation treatment, and all three after consolidation with two products based on silicic acid ester - Funcosil 100 and 300). The paper will present only selected results of experiments and the most important conclusions taken from the tests and their comparison. During experimental work the following characteristics were investigated: bending strength, modulus of elasticity, ultrasonic velocity, micro-drilling resistance, water uptake, porosity, frost resistance, hydric dilation and thermal dilation. The degraded stone had a rather strong variation of its characteristics along the depth profile from the surface inside the stone ashlar. Therefore, the stone samples were prepared in a form of cubes for non-destructive US tests and micro drilling. Then the cubes were cut into thin plates and they were tested for volumetric change due to hydric and temperature variations. That procedure allowed a comparison of results of the US tests on cubes and destructive bending tests on thin plates. The remains of these plates were used for porosity measurements. The overall test procedure was planned and carried out in a way which ensured testing of appropriately corresponding specimens. The results supplied data for studying efficiency of the consolidation treatment with silicic acid ester products in relation to three pre-treatment stone conditions, as well as to the type of sandstone cementation (the tested stones had mostly a kaolin or silica, rarely a goethit cementation). The tested stone types were documented by macroscopic and microscopic (thin section) descriptions. The results further indicate capacity of individual testing and assessment methods, and help to select methods suitable for in situ diagnostics.