21st International Conference **ENGINEERING MECHANICS 2015**
Svratka, Czech Republic, May 11 –14, 2015
Paper **#255, pp. 328–329**

Repair Formulations for Fine-Grained Stone Arte-Facts

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Keywords: repair mortar, biodetritic limestone, mudstone, compatibility

Abstract: Stone restoration practice continuously deals with the problem of the selection of suitable repair materials. In establishing the requirements that guide their specification, the fundamental aim should always be to achieve the best compatibility between the substrate and the repair. When dealing with the restoration of stone, several aspects must be taken into consideration: not only the way in which compatibility influences the durability and structural and environmental resistance of the repair, but also the properties of the stone substrate itself must be considered. Compatibility is a highly complex problem but when considering the above-mentioned aspects, *functional* compatibility – the compliance between physical and mechanical characteristics of the materials – is the most critical in prolonging the sustainability of the repair.

In this work two examples of restoration projects dealing with the development of the repair compounds for two inland stones commonly used as materials for making carvings or sculptures and/or construction building material have been conducted. The first project deals with the restoration of Kutná Hora limestone on sculptures in front of the Jesuit College in Kutná Hora, Czech Republic; the second is aimed at the repointing of the defects and missing parts on the spongolite, the construction material of the main portico entrance pillars to the Liechtenstein crypt at St. Virgin Mary Church in Vranov near Brno. In both restoration projects inorganic "mortar" binders were used for repairs and filling defects, this being the most common repair materials in current stone restoration practice. The material selection of components and composition of the repair mortars were selected in accordance with determined stone mineralogical composition and properties. Kutná Hora limestone can be classified as organodetritic middle to coarse grained limestone whose homogeneity and properties depend on the site and stratigraphic level of the quarry; the original stones of the statues were rather homogenous with a high total porosity determined by mercury intrusion porosimetry of about 18 % (per volume) and bimodal pore size distribution composed of capillary pores varying from 0.1-5 mm and larger macropores. The compressive strength of such limestones may vary from 30-84 MPa. The spongolite stone (in Czech "opuka", and in literature also referred to as a "mudstone") of the pillars in Vranov, comes from local sources and represents Upper Cretaceous sediment of the Czech Cretaceous basin. The rock can be classified as sedimentary, siliceous and fine grained, often fossiliferous, containing traces of carbonate and clay. The deterioration also observed on pillars often takes the form of disintegration, delamination or fragmentation. The pillar stone can be described as highly porous with a total porosity of some 20.8 vol.% , the porous structure consists of capillary pores of 0.2-2 mm in diameter and macropores in a region over 0.3 mm. Although the stone is highly porous it possesses extremely high compressive strength with values varying from 59.0-94.0 MPa. The strength values of both stones used on-site was impossible to determine as only limited sampling was possible. However, the ultrasonic pulse velocity method was used instead which is rapid and easy to use directly on-site or on small samples. Complete characterization of the stone composition and its characteristics help to develop a basis for the repair mortar compounds which were first developed in the laboratory and, after assessment, the best was applied on-site for compatibility assessment in natural atmospheric conditions. Eight mortar mixtures were prepared in the laboratory for the limestone repairs, with aerial lime or hydraulic binders as a binder. The mortar

mixtures were of a home-made formulation as well as premixed commercial binders also used by restorers containing a quite similar spectrum of binders. The binders were mixtures of areal lime, NHL2 and 3.5. For comparison, a mixture with white Portland cement was also prepared. The aggregate and b/a ratio was similar for all mixtures; crushed Kutná Hora stone was used as an aggregate with particle size D‹2 mm, mortars were produced at a volumetric binder to aggregate ratio of 2:1. Such mortar recipes possess good performance properties and workability. All mortars were produced to a constant flow of about 15 cm to ensure similar performance properties. The mortars used for spongolite repair were only of hydraulic origin, as these binders suit the properties of the original stone properties better, especially as regards high strength and porosity. Mixtures of Roman cement, Natural hydraulic lime (NHL5) and areal lime were mixed with standardized sand in a volumetric ratio of 2:1 and applied directly on-site and left for almost one year to harden and age naturally in external atmospheric conditions. After that time the mortars were cut away from the stone substrate and tested in the laboratory. The general focus of this work was to discuss the compatibility of the mortars as regards their compliance from the point of view of selected physical and mechanical properties. These two model examples also help to define the importance of particular physical and mechanical parameters for the assessment of compatibility between the original substrate and repairs, and based on that, help to make a ranking of the importance of a particular property (characteristic). It was found that just a narrow range of critical properties such as water transmittance properties together with the characterization of the pore structure by means of mercury intrusion porosimetry, modulus of elasticity/deformability and ultrasound velocity was found to provide reliable information in order to a make a general choice of safe repair material and provide general instructions for each substitution project. This is a highly positive finding, especially in cases when dealing with cultural heritage properties where only minimum sampling is possible and/or compatibility assessment should be often done directly on-site.

Acknowledgement: The authors gratefully acknowledge support from the Czech Ministry of Culture NAKI Project DF12P01OVV018 entitled "*Conditions and requirements of compatible care of the historical inorganic porous materials*", "Podmínky a požadavky kompatibilní péče o historické anorganické porézní materiály".