Characterization of mineral building materials from the Fortress of Basthovë, Albania

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Abstract

The ruin of the Fortress of Basthovë, built in the 15th century, is a significant example of the Albanian cultural heritage. In order to gain insights into the material characteristics and state of preservation of the walls, mortar and stone samples were investigated by different methods of microscopy. The results revealed a unique mortar binder characteristic including a general good state of preservation and hydraulic properties caused by a local, impure lime sediment used for lime burning. Based on the results an appropriate mortar system has been elaborated and applied on-site during a conservation campaign.

Aim of the study

In co-operation with the United Nations Office for Project Services (UNOPS) and EU4Culture, the Institute of Conservation of the University of Applied Arts Vienna (IoC UAA) has been supporting three cultural heritage projects in Albania since 2021. One of the projects supervises stone conservation activities at the ruins of the Fortress of Bashtovë in Central Albania (Fig. 1). The medieval quadrangular fortress is located close to the outflow of the Shkumbin River into the Adriatic Sea and was originally constructed in the 15th century when the region was part of the Venetian Empire. The complex building activities at the fortress include among others the partial reconstruction of the destroyed towers, an overall structural enhancement and conservation of the masonries. The role of IoC UUA was to characterize the composition and study the state of preservation of historical and modern mineral building materials at the site and elaborate a suitable mortar system that can be used for re-pointing the joints. In addition to the laboratory analyses, local craftsmen and university students were trained on-site.

Sampling and analytical methods

13 joint and render mortars as well as stone samples were taken from wall sections built in different periods. Observations were done on polished thin sections in optical microscopes (OM) in plane- (PPL) and cross-polarized light (XPL). The measurement of grain-size-distribution (GSD) was performed by the software JMicroVision. Fine-grained, binder-related components were qualitatively analyzed by a scanning electron microscope (SEM) coupled with an EDS detector in high-vacuum mode.

Results and discussion

Building stones

The majority of stone blocks belong to clastic sedimentary rocks which include a series of fine-grained sandstones to conglomerates (Fig. 2 and 3). The clasts are mostly of silicate (i.e. quartz, mica, chert, serpentinite, granite, etc.), ancillary of carbonate nature (i.e. limestone) cemented with fine to coarse-grained calcite (Fig. 3). Additionally, a few dense limestone types and processed white marble, the latter can be considered as spolia, could be identified. Although most of the stone blocks are in good state of preservation, problems occurred in zones where humidity caused, along with the dense joint mortars and/or due to the natural bedding of the stone, extended coving and cavities (Fig. 2). Furthermore, the vicinity of the sea (i.e. wind-driven salts) in combination with strong winds plays also a role in the deterioration processes. Finally, mineral composition, such as the presence of mica and the detachment between altered mineral clasts and the carbonate cement accelerated the above-mentioned processes (Fig. 3).

Mortars

The mortars were produced from a sand of fluvial origin and an air lime binder with a certain hydraulic character. The observed hydraulic binder portions and burnt residues of the original raw material, such as lime lumps containing reacted silica grains and other binder-related inclusions exhibiting diffuse hydration rims, show similarity to natural hydraulic lime binders (Fig. 4 and 5). Therefore, the results suggest that the carbonate raw material used for the mortar naturally contained variable amounts of silica (e.g. quartz) and aluminates such as mica, feldspar and eventually also clay minerals. During the firing process these mineral components formed reactive Ca-silicate and Ca-aluminate phases and became partly hydrated during the slaking process (Fig. 5). The source of raw material might be related to the silty to sandy carbonate rock formations to be found in the vicinity of the castle. Additionally, large lime lumps (Fig. 4) suggest that the mortar mixes were prepared by using the so-called dry-slaking technique. Finally, infiltrating moisture and subsequent leaching left their traces back on the binders provoking a very heterogeneous matrix made up of an impure silica gel and calcium carbonate (Fig. 4).

The aggregates show a very similar mineralogical properties to that of the local sediments and thus it is assumed that the same fluvial sand was taken from the nearby river and/or from an alluvial terrace. GSD varies between 0.05 and 1 mm with a clear dominance of the fractions between 0.2 and 0.4 mm in all samples (Fig. 4). The determined binder-to-aggregate ratios vary between 1 to 2.5 and 1 to 4.

The mortar surfaces are mostly covered with secondary calcite crusts. In a few samples a calcium phosphate layer (Fig. 6) and gypsum crusts were detected. The presence of calcium phosphate can be explained by infiltrating PO_4^{3-} ions originating probably from accumulated guano on the roof terrace. The gypsum was presumably formed due to the reaction between the carbonate components of the original material and sulphate ions washed out from Portland cement-based mortars used during the reconstruction works in the 20th century.

On-site work, re-pointing of the joints

Based on the results of the laboratory analyses a mortar recipe was elaborated for re-pointing of the joints. The selected binder was a natural hydraulic lime (NHL 3.5) mixed with a local fluvial sand (0-2 mm) using a binder-to-aggregate ratio of 1:3 (by volume). In order to test the pointing mortar, a trial surface was prepared on the southern face of the NE-wall (Fig. 7). As a first step damaged and/or inappropriate mortars were removed and the joints were cleaned. Prior to the application of the mortar the zones to be re-pointed were brushed with a slurry produced from the same, but water-diluted mortar. The re-pointed surfaces were kept moist for a minimum of 16 hours by covering them with wet textiles and plastic foils before their surfaces could be scraped back in order to achieve the final form and overall appearance (Fig. 7). Finally, the joints were continuously kept moist to achieve an optimal strength development.

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Fig. 1 The fortress of Basthovë during the conservation campaign in September 2022

Fig. 2 Coving of sandstone blocks due to dense joint mortars and the influence of moisture

Fig. 3 Center: characteristic wall with sandstone and conglomerate blocks; left: micrograph of sandstone with a microcrack (blue) in the vicinity of a mica grain (arrow, thin section, PPL); right: debonding (blue) between clast and calcite cement in a conglomerate (thins section, PPL)

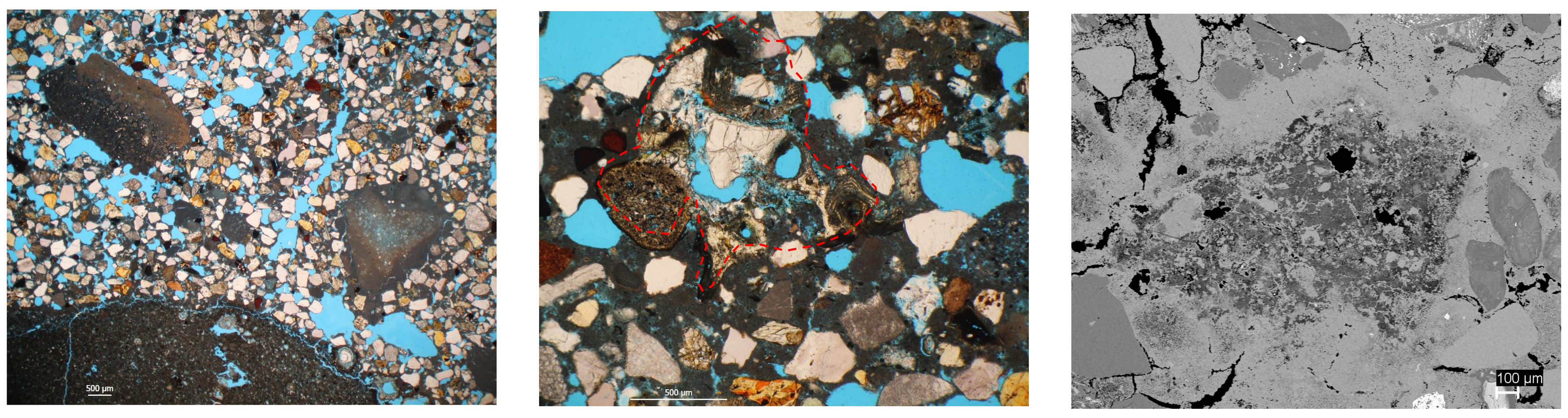

Fig. 4 Left: large lime lumps (brown) in the porous mortar binder (thin section, PPL); center: glassy and Ca-silicate-bearing binder-related inclusion (thin section, PPL); right: hydrated and decalcified binder-related inclusion in a heterogenous mortar binder (SEM-BSD)

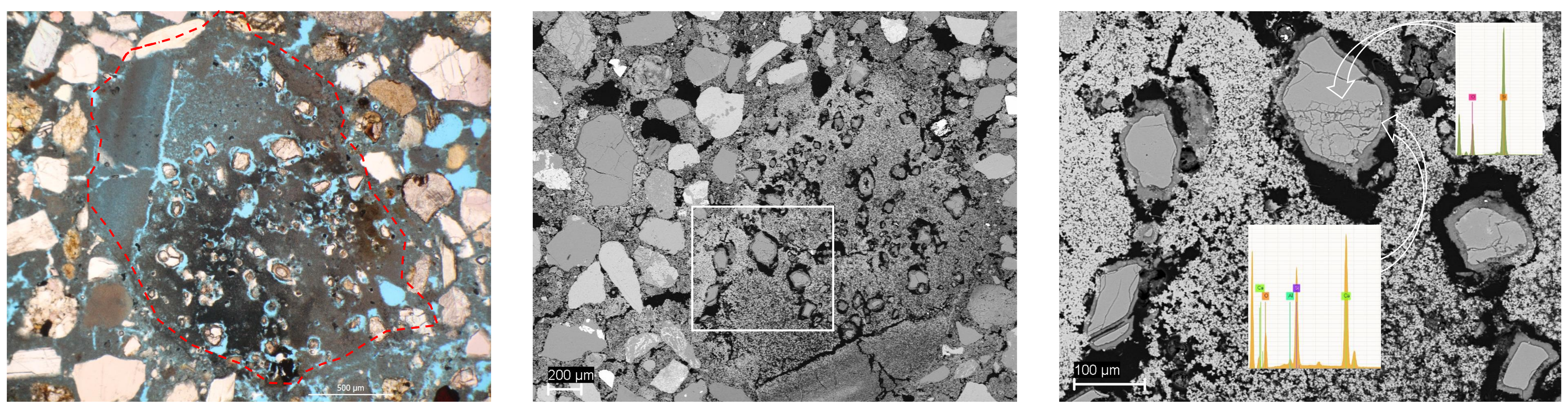

Fig. 5 Left: lime lump (raw material residue) with small silica inclusions (thin section, PPL); center: the same inclusion (SEM-BSD); right: detail of the inclusion with the silica residues exhibiting (hydrated) Ca-silicate rims (SEM-BSD)

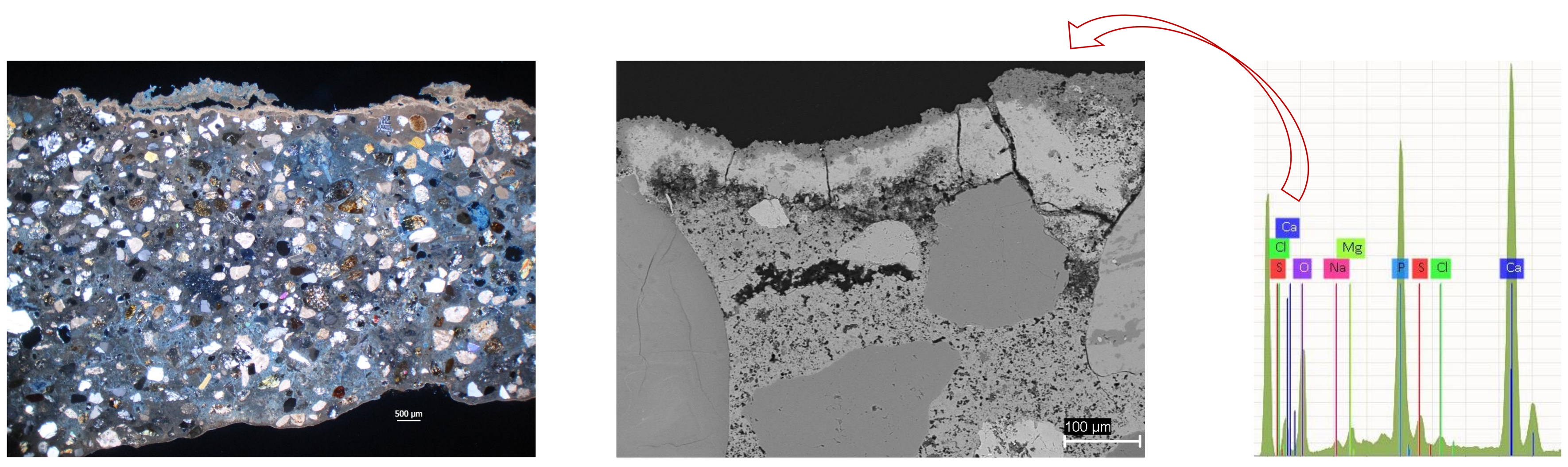

Fig. 6 Left: binder-rich, dense historical joint mortar with a secondary precipitation layer on top (thin section, XPL); center: detail of the calcite and apatite precipitation layer (SEM-BSD); right: EDS spectra of the precipitation layer (SEM-EDS)

Fig. 7 Left: preparation of the NHL-based re-pointing mortar; center: re-pointing of the joints on the test surface; right: scraping back the surface of the pointing mortar after ca. 16 hours of curing