Characterization of lime-based mortars from historic aqueducts in Cyprus

*Magdalini Theodoridou[1], Ioannis Ioannou[1]

1. University of Cyprus, Nicosia, Cyprus

The use of composite materials, such as mortars, in construction dates back to prehistoric times. The systematic study of these materials can reveal the technological knowledge of past civilizations. Therefore, mortar studies can be of great importance for material scientists, engineers, historians and archaeologists. With regards to heritage conservation, the interdisciplinary research of mortars is mandatory for the design, production and application of compatible conservation materials.
This work presents results from the study of fifteen indicative mortar samples collected from nine different sites in Cyprus. All samples were collected from the remains of various aqueducts that date back to different historic periods. A thorough documentation of the specimens preceded the systematic analytical approach that was adopted for the investigation of the mortars. Macroscopic and stereoscopic observations, as well as other experimental analyses were carried out, aiming to characterize the samples in terms of their composition, properties and state of conservation. X-ray diffractometry (XRD) was used for the qualitative and quantitative identification of the main mineral crystalline phases of the specimens. X-ray fluorescence (XRF) was performed on pressed pelletized powder samples for the determination of their chemical composition. Differential thermal analysis (DTA) and thermogravimetry (TG) was also undertaken; based on the results of the structurally bound water, the mortar samples were classified according to the extent of their hydraulicity. Mercury intrusion porosimetry (MIP) took place for the determination of their pore structure and volume (i.e. open porosity, average pore size, bulk density). Last but not least, a portable drilling resistance measurement system (DRMS) was used for the micro-destructive assessment of their mechanical state.
The macroscopic and stereoscopic observations of the specimens showed differences in texture, hardness and microstructure, which could be associated with their use in practise (e.g. plaster, joint mortar). The presence of crushed ceramic fragments was also observed; this was more evident in plaster samples. Furthermore, in some plasters, different layers could be observed, indicating changes in the microstructure of the areas close to the exposed surface. The experimental analyses confirmed calcite as the main mineral in all samples. The presence of quartz was also found. Plagioclase feldspars and dolomite were among the minerals commonly found in the mortar samples, as well. Gehlenite was present in all analyzed materials; this mineral is characteristic of the presence of ceramic fragments in the composites. The latter was probably used in the absence of natural pozzolanas on the island in order to enhance the performance of the mortars, increase their mechanical strength, adhesion and hydraulicity and prolong their longevity. The purposeful use of finely crushed ceramic for the production of hydraulic mortars in Cyprus dates back to the Late Bronze Age; this has already been scientifically proven by the authors as the earliest use of artificial pozzolanic material in the history of mortars technology. The presence of clay minerals in all specimens could be related to the composition of the raw materials and/or the presence of subsequent deposits. The gypsum content in some specimens could be associated with secondary salt formation due to atmospheric pollution. The thermal analyses indicated that the mortars under study might be classified as weakly to strongly hydraulic. DRMS and MIP results showed heterogeneity in the microstructure of the mortars, which can be attributed to the different construction methods that were followed at different time periods, as well as to the occurrence of weathering phenomena.

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