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Ancient restorations at *Hierapolis of Phrygia* (Denizli, Turkey): Interdisciplinary research on materials and technologies

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ABSTRACT

The restoration of architectural monuments constituted a common practice in the ancient Mediterranean world and the use of artificial binders in repairing blocks is attested both by literary sources and archaeological evidence. However, the knowledge on the use of these ancient binders and their components is limited, due to the shortness and indefiniteness of the ancient recipes and the difficulty of obtaining and analyzing samples from blocks that have remained exposed to atmospheric agents and have undergone degradation.

The paper focuses on the exceptional context of Hierapolis of Phrygia (Denizli, Turkey), where many ancient binders used in the restoration of Roman Imperial-era buildings (Sanctuary of Apollo, Theatre, North Agora and *Ploutonion*) have been identified. Thanks to the good state of conservation of these materials, the paper offers the unique opportunity for studying the role of organic additives used in the ancient bonding mortars and understanding the technologies adopted in the architectural restoration. Several analytical methodologies (Pyrolosis and Gas chromatography coupled with Mass Spectroscopy; X-ray diffractometry and Optical Microscopy) were applied to identify the organic and inorganic components.

The mortars sampled in Hierapolis showed the presence of casein, animal glue, beeswax and *Pinaceae* resin, in agreement with the survived ancient recipes on bonding mortars. However, the archaeometric data revealed the use of complex mixtures, which are also attested by the literary sources. In particular, the use of calcite together with various organic additives appeared to be a common practice. Criteria of selection and use of the different mixtures have been discussed.

1. Introduction

Functionality, static efficacy and aesthetic qualities (*utilitas*, *firmitas* and *venustas* according to Vitruvius perspectives) were essential components of the public architecture of the Roman city. To maintain these architectural principles, public body and private donors were requested to invest funds in the reconstructions and repairs of the buildings forming the urban landscape. Although archaeological, epigraphical and literary evidence points out the outstanding cases of complete reconstructions, the systematic observations of architectural materials reveals the importance of individual and limited repairs, which occurred both during the original building process and the long life of buildings over time. In these restoration activities, economic needs recommended not to discard the defected or accidentally broken blocks but induced to repair and reuse them after a careful restoration. Broken blocks could be simply reattached using metal clamps and dowels; otherwise the greater part of the block was conserved, while the damaged portion was mechanically removed, a special hollow was carved out and a new replacement part (in Greek *emblema* - ἔμβλημα) was inserted (Ismaelli, 2013).

In this process, to secure the joining of the pieces artificial adhesives were used. With the term artificial, we mean a mixing of natural compounds (organic and inorganic) realized to obtain a new material dedicated to specific use. The components of these mixtures are still not well known, for the following reasons. The difficulty of obtaining good samples from blocks that have remained exposed to atmospheric agents

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played a great role, as well as the limited attention paid to this technological know-how by modern scholars and even by Greek and Roman authors. In fact, selection, combination and manipulation of ingredients were part of a tacit knowledge that was orally and visually transmitted by masons over time in workshops and building sites, attracting little attention from ancient architects and art-historians who described us the Greek and Roman architectural practices.

To shed light on this topic a strongly integrated approach, combining archaeology, study of literary sources and archaeometry, was applied. Such study was realized during the "Marmora Phrygiae Project" (Ismaelli and Scardozzi, 2016a) dedicated to the reconstruction of Roman Imperial and Byzantine building sites of Hierapolis in Phrygia, one of the greatest and most studied cities of western Asia Minor, modern Turkey (Scardozzi, 2015). For the ancient inhabitants of Hierapolis architectural restoration was unavoidable (Ismaelli, 2013). In fact, the city lies in a highly seismic region, where the grabens of the Meander and Gediz rivers meet and the settlement was struck by many disastrous earthquakes. The geological context of the site, the well preserved architectural heritage and the advanced state of the archaeological research on the city monuments yielded much information on ancient restoration (Cantisani et al., 2016).

During the archaeological campaigns of 2014 and 2015, fragments of ancient bonding mortars were sampled in the main monuments of Hierapolis, such as the Sanctuary of Apollo, the North Agora, the Theatre and *Ploutonion*. The nine samples presented in this paper constitute the complete set of ancient materials for restoration available in Hierapolis and they represent the result of a painstaking analysis of its monuments. In this framework, it should be noted that the limited number of bonding mortars, in the face of the incredible number of traces of restoration measures on the monuments, obviously depends on the dynamics of deterioration of material and the numerous events occurred to the artefacts, such as displacement, rework and destruction. Moreover, the extreme environmental conditions of the site, due to the gases and thermal waters from the seismic fault (Marabini and Scardozzi, 2015; Vettori et al., 2016), greatly affected the state of conservation of the ancient artefacts. In this regard, it should be pointed out that no residual bonding mortars have been preserved on monuments which, despite being subjected to repeated reconstruction, such as the Gymnasium and the Marble Stoa (Ismaelli, 2016a), have remained immersed for centuries in a marshy environment.

The residues of bonding mortars were sampled from monuments dating back to the 1st to the 3rd century CE, which display different architectural structure, building site features and post-construction events. The case studies have been the object of a careful analysis: the work procedure, the preparation of the contact surfaces, the connection techniques between block and replacement part are carefully described. At the same time the individual cases are discussed in relation to their context, in order to connect the restorations measures to the building history of the various monuments. The samples were then subjected to multiple chemical-physical analyses, for the determination of organic and inorganic components. The results are discussed in relation to the architectural context, the function of the pieces and our knowledge on the artificial glues for stones, which are described in important but little known literary sources. This close integration of archaeological, archaeometric and textual approaches makes it possible to advance some new reflections on the use of bonding mortars, the criteria for selecting ingredients and their concrete methods of use.

2. Materials and methods

2.1. Materials

Fragments of bonding mortars, found on marble blocks belonging to the Sanctuary of Apollo, the Theatre, the North Agora and the *Ploutonion*, were sampled (Figs. 1–2 and Table 1). Dimensional details on the sampled blocks and technical data on the connection system are presented in Table 1.

In general, the difficulty of determining the absolute chronology of restoration interventions should be mentioned, as only some measures can be attributed to the original building site, while others are certainly related to activities occurred at a later time and only exceptionally they are datable thanks to epigraphic or stratigraphic data.

Only the restorations related to samples 7AS, 8T, 6NA can be attributed to the original construction phase. Sample 7AS was taken from a frieze pertaining to an unidentified monument, probably placed to the south of the Apollo Sanctuary and datable to the late 2nd century (Antonine age) on the base of its decoration. Along the upper edge, the egg-and-darts motif has been partly cut to eliminate an accidental fracture of the marble. A recess with a triangular section was created to receive a replacement part, which was held in place only by a pinkish binding mortar. Also to the original construction site can be attributed sample 8T, which has been taken from the third order of the Theatre *scaenae frons*. Its date can be fixed at the late Severan age, under Elagabalus or Alexander Severus (218–235 CE), when the building site reached the top of the scene (Ismaelli et al., 2016; Ismaelli, 2017). There must have been an imperfection in the marble, which was recognized during the carving of the mouldings. The wedged shape (from 3 to 2 cm) of the recess was considered to be insufficient for the stability of the replacement part and a binder was used to join the contact surfaces.

Also sample 6NA can belong to the original phase of the Stoa-basilica, the two-storey portico built on the northern public square of Hierapolis in the second half of the 2nd century CE (Hadrianic-Antonine age) (Ismaelli and Scardozzi, 2016b). During the construction phases, the monument underwent numerous restorations with the use of clamps and dowels to repair fractures of the low-quality marble, crossed by breaks or veins of travertine (Ismaelli and Bozza, 2016). In this specific case, the pillar with two half-columns should have presented a horizontal fissure, in the point where, during the final collapse of the building, the fracture of the block was produced: to keep the lower and upper part connected, an anti-cracking Π-shaped clamp was inserted (18 cm max. × 2.3 cm). To hide the view of the clamp, the metal element was covered with a rather soft white mortar, which seems to have more an aesthetic than a static function.

Certainly, samples 1AS, 2AS, 3AS, 4AS, taken from the Corinthian portico built in the Flavian age (68–96 CE) on the upper terrace of the Apollo Sanctuary can be traced back to restoration work that followed the original construction (Ismaelli and Bozza, 2016; Ismaelli, 2016b). The study of the monument revealed a large number of repairs, which demonstrate a partial disassembly and reassembly of the columns, probably occurred after a seismic event. Targeted repairs of capitals, shafts, frieze-architraves and cornices were aimed at restoring the damaged mouldings, with the insertion of replacement parts. The date of this extensive restoration is difficult to determine: the accuracy of the work and the attention to the restoration of the visual integrity of the blocks suggest a chronology of the work in the 2nd or 3rd century CE at the latest. Samples 2AS and 3AS come from the same column shaft. The white and strong sample 2AS is part of a bonding mortar which fixed a small replacement edge between two flutes. In the case of sample 3AS, part of the shaft was cut, creating a wide and trapezoidal recess, worked with a toothed chisel to facilitate the binder adhesion. Sample 4AS was taken from a frieze-architrave, whose damaged lower edge had been partially removed. The *emblema* was held in place thanks to its slightly trapezoidal shape and the column capital below: further guarantees were offered by the hard mortar that is still preserved at the inner corner of the recess. Finally, sample 1AS has been taken from a Corinthian capital, precisely from the very small cylindrical hollow drilled in the upper part of an acanthus leaf. The top of the leaf that protruded from the calathos should have been irreparably damaged: the leaf was cut, a horizontal contact surface was chiselled and the new replacement part was secured with a metal dowel. The use of bonding mortar should have assured the endurance both of dowel and *emblema*.