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Technology of multilayer mortars applied in ancient floor mosaic substrates

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ABSTRACT

Ancient floor mosaics started to be used from the 2nd millennium BCE, while their structure was established during the Classic Era. From the 4th century BCE they were wide spread and systemized around the Mediterranean Basin, as a mean to decorate public buildings, private houses or open spaces (i.e. atriums). Their substrate, as well as the successiveness of the layers played an important role on their structure, enhancing their durability to environmental factors and external loading. In the present study four multilayer mortar samples from Hellenistic and Roman floor mosaic substrates of monuments from Northern Greece, were analyzed. The methodology concerned in situ, macroscopic and microstructure observation, as well as determination of the physical, mechanical and chemical properties of each layer but at the same time of the structure as a whole. The evaluation of the test results led to the identification of the characteristics of each mortar layer, such as the binding system type, the Binder/Aggregate ratio and the application technique followed. According to the study, all multilayer samples presented similar characteristics, such as: stratigraphy of four very well compacted layers, whose thickness was decreased towards the surface layer, binding system based on lime and natural pozzolan, increase of the Binder/Aggregate ratio upwards and decrease of aggregates' maximum size and porosity. A significant aspect was the good adhesion of the mortar layers, which was attributed to the layers' compaction, as well as to different technological factors.

1. Introduction

Floor mosaics were used from the 2nd millennium BCE as a mean to enhance the aesthetic and architectural value of constructions (Bruneau, 1987; Dumbabin, 1999; Rossi, 1970). An early example was found in Akrotiri, Thera (1700 BCE), decorated with colored, natural pebbles, inserted in a lime-based mortar layer (Palivou, 1999). From the 4th century BCE and on the building materials and techniques applied in floor mosaics were evolved and their construction started to follow specific criteria. Tesserae comprised of natural pebbles or shaped small pieces of stone of various colors (glass or brick tesserae was also used) depicting mythological scenes, animal, vegetal or geometric patterns (Lysandrou et al., 2017; Pachta, 2011; Robinson, 1930).

At the same time, famous mosaic artists were acknowledged, such as Gnossis (4th–3rd cent. BCE), Sossos (3rd–2nd cent. BCE), Asklipiadis (2nd–1st cent. BCE), Dioskouridis (1st cent. BCE) and Aspasios (2nd–1st cent. BCE) (Pachta, 2011). The art of floor mosaics was wide spread during Roman times and started to decline from the 6th century CE (Early Christian times), when the technique of wall mosaics started to be evolved (Pachta, 2011).

Diachronically the substrate of floor mosaics was a significant part of their structure, since it guaranteed their durability. Vitruvius (1960) and Pliny (1971) were the first ancient authors (1st cent. CE), who described floor mosaics' substrate and proposed technical guidelines for their construction (materials, application). Vitruvius (1960) suggested three mortar layers (*supra nucleus*, *nucleus* and *rudus*) layered on a subground of pebbles (*statumen*), above a very well compacted subground. Supra nucleus, in which the tesserae were inserted, consisted of marble dust and fine sand, while nucleus contained crushed brick and rudus coarse aggregates. The thickness of the layers was decreased towards the surface, as well as the aggregates' maximum size. In all cases, lime was mixed with natural pozzolan (rudus, nucleus) and brick dust (nucleus, supra nucleus).

Pliny on the other hand, proposed two layers applied in well-compacted earth (Pliny, 1971). The first consisted of pebbles or crushed brick and the second of lime, sand, charcoal and ash (thickness 15 cm). Later (15th century), Alberti (1965) suggested four layers: a layer of river pebbles (dimension less than a palm), a mortar layer with crushed brick (5–8 cm thick), a layer of tiles mixed with linseed oil and finally a well compacted mortar layer made of lime, pozzolan, sand and brick dust.

The multilayer substrate, as suggested by the ancient authors, has been identified in various floor mosaics located around the Mediterranean basin, dated from the Classic era (beginning of the 4th

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Fig. 1. Studied floor mosaics substrates. a, b: Aiges Palace, c, d: Archaeological site of Pella, e, f: Archaeological site of Dion, g, h: Galerius complex.

cent. BCE) until the Early Christian period (6th cent. CE). Some examples were found at Olynthos, Greece (Classic, beginning of the 4th cent. BCE, four layers) (Robinson, 1930), Pella, Greece (Hellenistic, 3rd cent. BCE, four layers) (Pachta, 2011), Herculaneum and Stabiae, Italy (Roman, 1st cent. CE, three layers) (Leone et al., 2016; Izzo et al., 2016), Histonium, Spain (Roman, 2nd cent. CE, three layers) (Puertas et al., 1994), Pafos, Cyprus (Roman, 2nd cent. CE, six layers) (Getty Conservation Institute, 1991), Jarash, Jordan (Early Christian, 6th cent CE, three to four layers) (Hamarneh and Abu-Jaber, 2017).

The importance of the mortar layers' good compaction, in order to enhance the durability of these masterpieces, has been highlighted by the ancient authors (ICCROM, 1980; Vitruvius, 1960). On the other hand, there are many contemporary research studies regarding the adhesion of multilayer systems that focus on various parameters (i.e. mechanical strength, physical properties, chemical reaction), resuming that it is both a result of inter-layer adhesion and mechanical cohesion of the mortar layers (Botas et al., 2017; Goodwin and West, 1980; Groot, 1993; Stefanidou et al., 2017; Stolz et al., 2016; Thamboo and Dhanasekar, 2015). In most cases, it is pointed out that the enhancement of the cohesion of two or more mortar layers depends on a synergy of factors, such as (Groot, 1993; Stefanidou et al., 2017; Stolz et al., 2016):

- the consistency of the mortar layers
- the high ratio of the effective contact area to the total surface (through scoring of the fresh mortar of the subjacent layer and creating random or ordered lines). Generally the increase of the effective contact area of the layers improves their adhesion.
- the pore system of the subjacent layer (rudus), in order for the covering layer (nucleus) to be able to penetrate, as well as the rheological characteristics of the covering mortar
- the layering (compaction) technique applied.

In the present study, the analysis results of four multilayer mortar samples from Hellenistic and Roman floor mosaics' substrates of Northern Greece are presented and comparatively evaluated. The aim was to identify the materials used and the constructional techniques applied in these special technological artifacts and determine whether their construction followed the diachronic principles given by the ancient authors' instructions. For the better understanding of the results, the analyzed layers were named after Vitruvius, as statumen (substructure layer of pebbles), rudus (lower coarse mortar layer), nucleus (intermediate fine mortar layer) and supra nucleus (upper fine mortar layer that undertook tesserae).

The current state of the substratum's was identified, as correlated to the layers' structural and physico-mechanical properties. The results showed the significant role that the substrate played for the maintenance of floor mosaics that whereas subjected to extreme environmental conditions (i.e. weathering, extreme humidity, loading) are still preserved.