Study of materials and technology of ancient floor mosaics' substrate

Estudo dos materiais e da tecnologia dos substratos de mosaicos de pavimento antigos

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Abstract

A floor mosaic's substrate is composed of a variety of preparatory layers of mortar built on natural levelled ground or on top of a previous pavement. Mosaics' substrates differ one from the other in number, thickness and nature of the mortar layers. In this sense, it has been considered relevant to state how these differences are related with historical period, geographical position, function of the pavements within the building, technology of the substrates. A number of floor mosaics' substrates of Hellenistic and Roman period from archaeological sites in Greece and Italy are under study. The stratigraphy of substrates is recorded in situ, and samples from each mortar layer are analysed in the laboratory by means of different techniques. Results obtained so far indicate that characteristics of the Roman substrates mortar layers are clearly dependant on their position in the substrate stratigraphy, whereas in the case of the Hellenistic substrates, characteristics of the mortar layers are less varying with the stratigraphic position. Furthermore results show that floor mosaics' substrates are different according to the function of the pavement in the building.

Keywords

Mortar; mosaic; substrate.

Resumo

O substrato de um mosaico de pavimento é composto por uma variedade de camadas preparatórias assentes sobre um terreno nivelado ou sobre um pavimento previamente existente. Os substratos de mosaicos podem diferir entre si em número, espessura e natureza das camadas de argamassa. Neste sentido, foi considerado relevante registar de que forma se relacionam estas diferenças com o período histórico, posição geográfica, função dos pavimentos no edifício, tecnologia dos substratos. Um grupo de substratos de mosaicos dos períodos Helenístico e Romano, provenientes de sítios arqueológicos localizados na Grécia e em Itália, estão correntemente em estudo. A estratigrafia dos substratos é registada in-situ, e são recolhidas amostras de cada camada de argamassa para análise em laboratório através de diferentes técnicas. Os resultados até agora obtidos indicam que as características das camadas de argamassa dos substratos romanos dependem claramente da sua posição na estratigrafia do substrato, enquanto que, no caso dos substratos helenísticos, as características das camadas de argamassa variam comparativamente menos com a posição estratigráfica. Os resultados mostram ainda que os substratos de mosaicos de pavimento diferem consoante a função deste último no edifício.

Palavras-chave

Argamassa; mosaico; substrato.

So far, the substrates of sixteen floor mosaics located in five archaeological sites, two of which are in Greece and three in Italy, have been included in this research. Two of these substrates belong to floor mosaics placed in two rooms at the west side of the Palace of Aegae, in Vergina (Greece). The Palace of Aegae was the earliest royal residence in late Classical Greece, dated to the second half of the 4th century B.C.. Five more of the studied substrates belong to mosaics situated in Roman buildings inside the ancient city of Dion (Greece). Dion, located in the foothills of Mount Olympos, was the sacred city of the Macedonians, inhabited continuously from the Classical period to Early Christian times. Two more substrates belong to the remains of a Roman building, dated to the 1st century A.D. situated at a level below the S. Severo's Basilica in Classe, Ravenna (Italy). In the area of the S. Severo's Basilica, the last of Ravenna's great churches to be completed, dated to the end of the 6th century A.D, an archaeological excavation is actually in progress. Two more of the investigated substrates are those of the floor mosaics located in two rooms of the "Villa Romana delle Muracche" in Tortoreto (Italy), a Roman Villa dated to the 1st century B.C.. The last five substrates under study belong to floor mosaics that had been lifted during past excavations in different areas of the city of Florence (Italy) and are currently stored in the courtyard of the Archaeological Museum of Florence, the so called "Cortile Romano".

Analytical methodology

In situ analyses

A characterization of the mosaics' substrates, including recording of layers thickness, description of mortars cohesion and layers mutual adhesion is carried out in situ. The stratigraphy of the substrates is reproduced schematically in order to compare substrates characteristics, especially number and thickness of the mortar layers, among the floor mosaics under study (Fig. 1). Furthermore, information about the sites are collected, especially those regarding the ancient use of the rooms where pavements investigated are located, and an effort to connect these information with substrates characteristics is made [1].

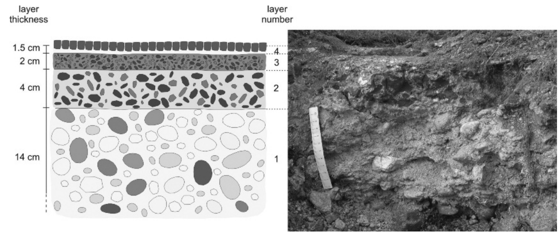

Fig. 1 Roman floor mosaic, ancient city of Dion (Greece), stratigraphy of substrate.

Laboratory analyses

According to sampling conditions in situ, collected samples are made up of one or more layers of mortar. In the latter case the different layers of mortar are separated in laboratory by means of scalpel, chisel and rock saw when necessary. Analyses are then performed on each mortar layer of the substrates' stratigraphy. Layers are indicated with increasing numbers starting from the deepest. The mortars are studied by reflected and transmitted light optical microscopy to investigate presence of enclosures, shape and position of pores and cracks, morphology and mineralogy of the aggregate. Observations are carried out on cross sections using a Leica Wild M10 stereomicroscope and on thin sections using a Leitz Laborlux 12 Pol S polarizing microscope. Grain size distribution of the mortar layers is determined by mechanical sieving (ISO 3310 series sieves). The sample, about 80 g, is disaggregated manually, paying attention to not breaking the aggregates, and fractionated in a column of sieves stirred for 10 min, and then the masses of the collected fractions are determined. The granulometric fraction of particle size < 75 μm, containing the binder, is analysed by AAS and HPLC in order to determine the chemical composition and the content of soluble salts. AAS analyses are performed on a Perkin Elmer 3110. For the preparation of samples, 0.25 g of the fraction < 75 μm are treated by wet ashing with $HClO_4$, HF and HCl 6N for the determination of the total oxides content, and 0.25 g are used for the determination of the oxides soluble in HCl 0.1N. HPLC is performed with an Alltech 330 column. Furthermore, a loss on ignition test is carried out on the fine particle size < 75 μm in order to estimate carbonate, organic and elemental carbon content.

The open porosity of the samples is measured following a method based on RILEM CPC 11.3 [2]. Compressive strength of some of the mortars is estimated on samples of approximately cubic shape immerged in moulded gypsum. Before performing the test, gypsum in excess is removed from the four vertical sides of the sample while upper and lower horizontal gypsum surfaces are kept for the application of the compressive stress.

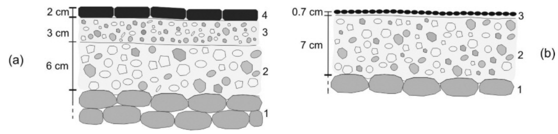

Fig. 3 Hellenistic floor mosaic, Palace of Aegae, Vergina (Greece), stratigraphy of the substrate in the inner area (a) and in the outer frame (b).

Results and discussion

Results obtained so far indicate that mosaics' substrates of a defined historical period located in the same building, either Roman Villa or Roman Domus or Hellenistic Palace, differ one from the other according to the type of room where they are placed. An example is provided by mosaics in the Roman buildings of the ancient city of Dion. The pavements situated in the atrium of a Roman Domus and in the atrium of a Roman Villa have substrates composed of two layers of mortar and a layer of tesserae (Fig. 2 d and c), while those covering the floor of a different room, probably a dining room, in the same Domus, and the floor of a Roman Temple adjacent to the Villa, have substrates composed respectively of three and four layers of mortar plus a layer of tesserae (Fig. 2 b and a).

Furthermore, the analysis of the substrates stratigraphy in different areas of a same mosaic revealed that, in the case of mosaics having an outer frame, the substrate in the area of the frame is different from that in the inner area of the pavement. In Fig. 3 the schematic reproduction of the substrate of a mosaic located in a room serving as banquet hall in the Palace of Aegae, illustrates this case.

Optical microscopy observations indicated for both Roman and Hellenistic mortars the use of materials of local origin. Fluvial sand and pebbles are the main constituents of the aggregates. The use of brick fragments (cocciopesto) as part of the aggregate is recurrent in the mortars of the Roman substrates (Figs. 4 a and 5 a). Brick fragments are always present in the mortars of the 2^{nd} and 3^{rd} layers of the stratigraphy of substrates composed of three or four layers as well as in the mortars of the 1^{st} layer of substrates composed of two layers. Furthermore, in the case of Classe and Tortoreto, brick fragments with dimensions of several centimeters are present also in the 1^{st} layer of substrates composed of three or four layers. Marble dust and fragments were also used for the 4^{th} layer (bedding layer) of the Roman substrates from the ancient City of Dion and the Roman Villa in Tortoreto. In the Hellenistic mosaics' substrates from the Palace of Aegae, pozzolanic sand has been recognized.

In Fig. 6 a and b, the results of the fractionation and sieving of the Roman mortar samples from the ancient City of Dion are represented as the wt.% of each particle-size range against particle-size range. Three types of grain size distribution have been observed in the granulometric analysis:

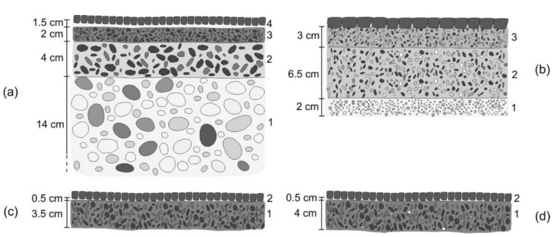

Fig. 2 Roman floor mosaics, ancient city of Dion (Greece), stratigraphy of substrate in a Roman temple (a); dining room in a Roman Domus (b); atrium in a Roman Villa (c); atrium in a Roman Domus (d).

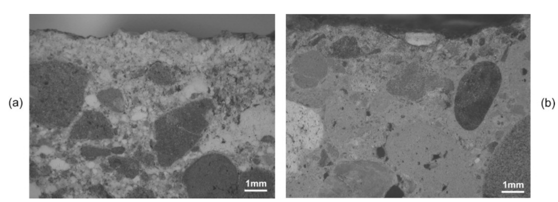

Fig. 4 Cross sections under reflected light microscopy, 3rd and 4th layer of a Roman substrate from the ancient city of Dion (a) and of a Hellenistic substrate from the Palace of Aegae (b).

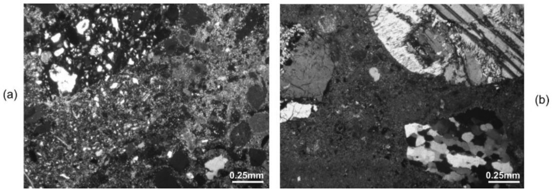

Fig. 5 Thin sections under transmitted polarized light microscopy, 3rd layer of a Roman substrate from the ancient city of Dion (a) and of a Hellenistic substrate from the Palace of Aegae (b).

descending, bimodal and unimodal. In general, substrates composed of at least three layers, besides the bedding layer, showed descending distribution for mortars of the first and the second layer of the stratigraphy and bimodal distribution for mortar of the third layer (Fig. 6 a). On the other hand substrates composed of only one layer of mortar, beside the bedding layer, showed unimodal distribution (Fig. 6 b).

The AAS results for both total and soluble in HCl 0.1 N oxides content show that the chemical characteristics of the Roman mortar layers, with the only exception of those from the mosaics of the Roman Villa in Tortoreto, are related with their position in the substrate stratigraphy. In fig. 7, the total content in CaO + MgO of the mortars is plotted versus the $SiO_2 + Al_2O_3 + Fe_2O_3$ total content. Considering the Roman mortars, those of the

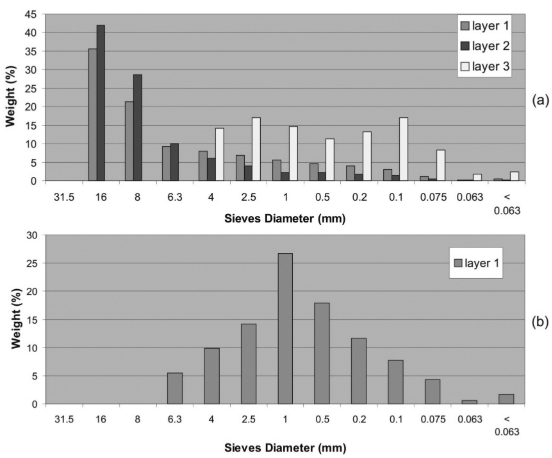

Fig. 6 Grain size distribution of mortar layers of mosaics' substrates in a Roman temple (a) and in the atrium of a Roman Villa (b) in the ancient city of Dion.

1st layer have low percentages of $SiO_2 + Al_2O_3 + Fe_2O_3$ (11-21%) and high percentages of CaO + MgO (46-51%). Mortars of the 2nd layer are characterised by a $SiO_2 + Al_2O_3 + Fe_2O_3$ content between 19% and 42% and a CaO + MgO content between 23% and 37%. Most of the mortars of the 3rd layer have high percentages of $SiO_2 + Al_2O_3 + Fe_2O_3$ (43-55%) and low percentages of CaO + MgO (18-22%). The homogeneity in the chemical characteristics of the mortar layers of the Roman Villa of Tortoreto can be explained considering that an argillaceous limestone was used to make mosaics' tesserae. The same limestone was maybe used also for the lime production process, which would explain why the mortar of the 1st layer, containing neither natural nor artificial pozzolanic materials, showed the same composition as mortars of the 2nd and 3rd layer. Mortar layers of the Hellenistic substrates also showed a substantial uniformity in the chemical characteristics, being characterised by a $SiO_2 + Al_2O_3 + Fe_2O_3$ content between 27% and 32% and a CaO + MgO content between 35% and 40%.

In fig. 8, the loss on ignition (L.O.I.) is plotted versus the CaO + MgO total content in the mortars fraction of particle size < 75 μm. Most of the mortars of the 2nd and the 3rd layer of the substrates stratigraphy showed significant L.O.I. percentages and low CaO + MgO percentages, indicating a possible organic and elemental carbon content.

HPLC registered no relevant concentrations of Cl^-, NO_3^-, SO_4^{2-} in the mortar layers of all the substrates under study except for those of the mosaics of the area of Classe, in Ravenna. In this case, chloride salts have

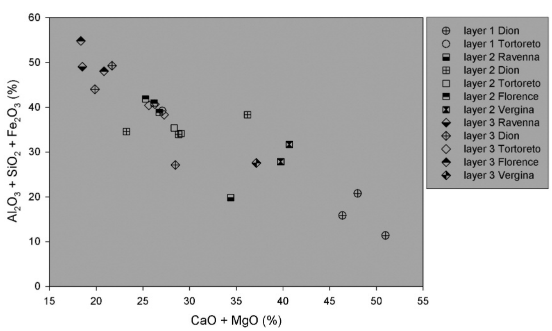

Fig. 7 CaO + MgO total content versus $SiO_2 + Al_2O_3 + Fe_2O_3$ total content of the fraction of particle size < 75 μm of the mortar layers.

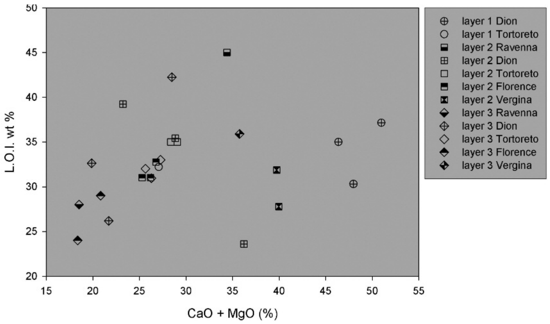

Fig. 8 CaO + MgO total content versus loss on ignition for the fraction of particle size < 75 μm of the mortar layers.

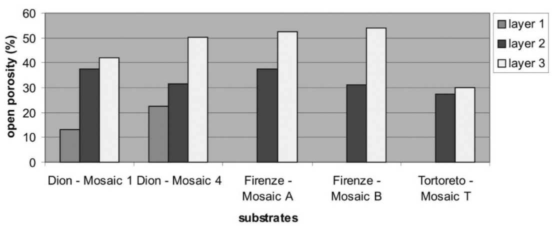

Fig. 9 Open porosity trend for Roman floor mosaics' substrates.

been found, with higher concentrations in the lower part of the substrates stratigraphy. Presence of chlorides in buried structures is probably related, in the area of Ravenna, to underground sea water upraise phenomena.

The results of the open porosity test show that, in most of the Roman substrates, open porosity of the mortars increases from the 1st to the 3rd layer of the stratigraphy (Fig. 9).

So far, results of the compressive strength tests have not shown evident trends in the mechanical characteristics of the mortar layers. Anyway it is noticeable that, in the Roman substrates, layers characterised by higher values of compressive strength are the 2nd and the 3rd. These mortar layers are those containing brick fragments of granulometric size < 1.5 - 2 cm and showing higher content of SiO_2 + Al_2O_3 + Fe_2O_3, as stated by chemical analyses. Furthermore, between the 2nd and the 3rd layer, it is the former that in most of the examined substrates is characterised by a higher compressive strength. This is probably related to the fact that its open porosity is generally lower than that of the 3rd layer [3-4].

Conclusions

The systematic study of floor mosaics' substrate, by means of in situ and laboratory analyses, leads to the understanding of technological aspects involved in their manufacture. The description of the stratigraphy of the studied substrates shows the existence of a correlation between substrates characteristics and ancient usage of the rooms where pavements are located within the building. Furthermore, the same pavement, if composed of more structural elements such as an external frame and an inner area, can have two different substrates below the two elements, in this case the frame and the inner area.

The microscopic, chemical, physical and mechanical characterization of the studied mortars indicates that, in the case of Roman substrates, characteristics of the mortar layers are distinctly related to their stratigraphic position in the substrate [5]. Properties mostly distinguishing mortars of the different layers include granulometric distribution of the aggregates, open porosity and chemical composition of the fraction of particle size < 75 μm. On the other hand, results obtained so far for the Hellenistic substrates from the Palace of Aegae indicate that, although mortar layers differ one from the other in terms of granulometric distribution of the aggregates, other properties, such as open porosity and chemical composition of the fraction of particle size < 75 μm, that demonstrated to be distinctive of the various mortar layers in the Roman substrates, are in this case less varying with the stratigraphic position.

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