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# Execution technique and pigment characteristics of Byzantine wall paintings of Anaia Church in Western Anatolia

Serap Demir, Kerem Şerifaki*, Hasan Böke

*Architectural Restoration Department, İzmir Institute of Technology, 35430 İzmir, Turkey*

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ABSTRACT

In this study, material characteristics of wall paintings executed in 11th Century Byzantine Church located in archaeological site of Anaia (Turkey) were investigated to provide historical information of the painting techniques. For this purpose, physical, chemical and mineralogical compositions of the paintings were determined by X-Ray Diffraction, Fourier Transform Infrared spectroscopy, Scanning Electron Microscopy coupled with Energy Dispersive spectroscopy and Thermo-Gravimetric Analysis. Analysis results indicated that the paintings were executed using lime-secco technique. In this technique, pigments were mixed with lime and applied on a smooth plaster layer. Pigments used were mainly iron oxides for red, yellow and purple paintings, aluminosilicates such as celadonite for green paintings and lazurite for dark blue paintings.

## 1. Introduction

People have decorated the walls of the living places with paintings that reflect their feelings from the earliest beginnings to present. Wall paintings, together with mosaics, are the most common decorative elements in the Byzantine Architecture. Especially in the religious architecture they were used for artistic, spiritual and educational purposes. Depending on the artistic needs of the era, a variety in the painting techniques and materials used in the wall paintings are developed.

In Byzantine era, renderings of wall paintings consisted of two layers, arriccio (rough plaster) and intonaco (fine plaster). The main constituent of the renderings was a mixture of lime and sand or marble dust or sometimes brick aggregates (Mora et al., 1984). The pigments used were mostly natural substances and minerals such as charcoal and carbon black for black, azurite and rarely lapis lazuli for blue, terreverte or malachite for green, iron oxides, caput mortuum, cinnabar, minium, and umber for reddish brown. Gilding of the haloes and nimbuses were made with gold leaf on incised lines (Jeffreys et al., 2008).

Characteristics of wall paintings executed in Byzantine churches were determined to provide historical information and to decide the appropriate intervention methods of the paintings in some studies (Restle, 1969; Schwartzbaum, 1986; Daniilia et al., 2007; Daniilia et al., 2008; Bianchin et al., 2008; Hein et al., 2009; Pelosi et al., 2013; Pelosi et al., 2016; La Russa et al., 2016).

Among the studies, Hein et al. (2009) have studied the characteristics of Byzantine wall paintings of churches constructed in the tenth to fifteenth century, from the Mani peninsula, Greece. They indicated that the earthen pigments were mixed with lime water as a binding medium and then applied on a wet lime substrate.

The painting technique of St Stephen's wall paintings at Meteora from Byzantine to post-Byzantine period was studied by Daniilia et al. (2008). It was indicated that rough lime plaster layer (arriccio) consisted of yellow clay and straw pieces and fine plaster consisted of carbonated lime. In this study, eight earthen pigments were indicated in the execution of the painting colours.

The painting layer stratigraphy and chemical compositions of the binders and the pigments of Byzantine wall paintings in the Protaton Church (Greece) were determined by Daniilia et al. (2007). The experimental results demonstrated that the paintings were executed in both the true fresco and lime-painting techniques and earthen pigments were used in the painting.

The materials used in the preparation of plaster layers and paintings at Kariye Museum (İstanbul) were determined by Bianchin et al. (2008). The results of the study indicated that fresco technique was mainly used but secco was also employed with a tempera based on casein. The painting colours were developed by using natural and synthetic inorganic pigments.

Materials characteristics of the Byzantine wall paintings in the Tokalı Church in Cappadocia were studied by Schwartzbaum (1986). Results of the studies demonstrated that mainly red and green earth pigments were executed on a single layer of whitewash that act as a priming layer over the rock surface in the old church. In the new

* Corresponding author.
*E-mail address:* keremserifaki@iyte.edu.tr (K. Şerifaki).

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church, the use of red ochre, yellow ochre, green earth, carbon black, gypsum white and lapis lazuli over an intonaco composed of lime, river sand and straw was determined. On the intonaco a priming layer of white wash is present. Painting technique of the paintings were determined as fresco but sometimes finished in secco technique with lime and casein binders.

Wall paintings of a group of churches from 6th to 13th centuries A.D. in Cappadocia was studied by Pelosi et al. (2013). Gypsum plaster with traces of organic materials in the churches that belong to 6th–7th centuries and lime plaster with traces of organic material and a thin setting layer of gypsum in the churches that belong to 13th century were determined. Colours obtained from hematite, red lead, lead white, lead oxide, goethite, carbon black, green earth, ultramarine blue, jarosite and indigo constitutes the palette of the paintings.

Mortars and wall paintings of Forty Martyrs Church in Cappadocia were studied by Pelosi et al. (2016) and La Russa et al. (2016). Mortars used in the church are hydraulic due to the use of volcanic aggregates together with slaked lime (La Russa et al., 2016). A setting layer with high gypsum content is determined in wall paintings (La Russa et al., 2016; Pelosi et al., 2016).

Western Anatolia has had rich historical buildings and monuments from ancient times. In this study, material characteristics of historic paintings executed in a Byzantine church located in archaeological site of Anaia (Kadıkalesi) were determined (Fig. 1). Anaia was an upstate castle situated at the northwest of Davutlar Village in Kuşadası, Aydın. The fortress was erected on a 25 m high hill from the sea level and 250 m away from the sea. Scientific excavations and surface investigations of the site were started at 2001. Archaeological findings during the excavations demonstrated that the castle was erected on a tumulus composed of six archaeological strata. The first settlement on the tumulus is dated to Late Chalcolithic Age (4000 BCE) (Akdeniz, 2007).

A monumental church-monastery complex dated to 11th century was uncovered in 2005 excavations. It is considered to have been a foundation donated by Konstantinos IX Monomachos, the emperor (1042–1055) (Mercangöz and Doğer, 2009). The complex is a magnificent edifice, competing with the huge buildings of Constantinapolis, with its monumental stone artworks and wall paintings (Mercangöz and Doğer, 2009). A great number of painting fragments were found during the excavations in the infill material which shows that once the Church has a comprehensive painting programme. However, at the present a small part of these paintings, which are slowly detaching from their support, are present and needs urgent measures before continuing excavations (Fig. 2).

In this study, material characteristics of the paintings were determined to provide historical information of the wall painting techniques and to choose the appropriate materials to be used in the conservation works of the paintings.

## 2. Methods

In this study, small pieces of wall paintings (Table 1) were provided by Prof. Dr. Zeynep Mercangöz, who is head of archaeological excavation team of Anaia. Samples that represent the palette of the paintings were chosen from the fragments found as detached in the infill material during the excavations.

The initial experimental study was to determine the stratigraphy and the execution technique of the paintings. For this determination, small samples of paintings were cut using a diamond saw (Buehler) and polished by using a diamond polisher and then coated with gold. The stratigraphy and the execution technique were determined using an EDS unit Philips XL30-SFEG Scanning Electron Microscope (SEM) on cross-sectional polished samples.

The bulk density and porosity of the plaster layer were determined by using standard RILEM test method (RILEM, 1980). They were determined by measuring dry, water saturated and hydrostatic weights.

Mineralogical compositions of fine plaster and painting layers were determined by X-ray diffraction (XRD) and Infrared Spectroscopy (FT-IR) analysis. FT-IR analysis was also used for the determination of organic materials in the paintings (Zorba et al., 2006).

XRD analysis performed on powdered fine plaster and on the painting surfaces by using Philips X-Pert Pro X-ray Diffractometer operating at 40 kV and 40 mA, using CuKα radiation in the 5–70° range with a scan speed of 1.6° per min.

FT-IR analyses were carried out on powdered samples. For this analysis, a small amount of sample was taken by scalpel, ground in agate mortar and dispersed in KBr and pressed into pellets by about 10 tons/cm$^2$ pressure. Spectral measurements were carried out on a Perkin-Elmer System FT-IR Spectrum BX. Spectra were acquired between 4000 and 400 cm$^{-1}$ with 4 cm$^{-1}$ resolution. All spectra were collected in absorbance mode and corrected with respect to the spectrum of the KBr.

Elemental compositions of the paint layers were determined by SEM-EDS analyses on the cross sections of the samples. The lime content in the fine plaster layer was evaluated by determining weight loss due to carbon dioxide released during the decomposition of carbonated lime by using a 51 Thermo-gravimetric analyzer (TGA). Analysis was carried out in static nitrogen atmosphere at a temperature range of 25–1000 °C with a heating rate of 10 °C/min.

## 3. Results

### 3.1. Painting technique

SEM analysis on cross-sectional samples indicated that paintings were composed of a fine plaster and a thin paint layer over the plaster layer. The execution techniques of the paintings were identified by examining the boundaries between fine plaster and paint layers. In most of the samples, plaster and paint layers are distinguishable with border


**Fig. 1.** Aerial views of Church and Monastery complex in Anaia (Anaia excavation archive, 2013).