An Evaluation of the Conservation State of the Mosaic Floor of the Virgin Church, Madaba, Jordan

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ABSTRACT

This study aims to diagnose the current conservation state of the mosaic floor of the virgin church in Madaba in Jordan, and to identify the mosaic materials as well as the deterioration forms on the mosaic floor. To achieve these objectives, several investigation and analysis methods were used, such as: visual and optical examination, Scanning Electronic Microscope attached to energy dispersive X-ray spectrometer (SEM/EDS) and X-Ray Diffraction (XRD). These methods revealed that Calcite is the main mineral of all limestone tesserae samples (CaCO3, Calcium Carbonate) and the calcite here is the microcrystalline Calcite which is known mineralogically as (Micrite). All the stones surfaces seem to be inhomogeneous pitted, curviplanar, surface-planar and highly fractured forms. Large areas of the weathering crusts were destroyed and rich in dissolution voids and micro-cracks. Addition to that, other aspects of flaking, and highly fissured nature of decayed crusts were also observed.

In addition, the mosaic floor was exposed to different deterioration aspects such as: lacunae, incrustation, depressions, bulge, detachment between preparatory layers, salt efflorescence, and biological activity. The study confirms that it is necessary to conserve the mosaic floor in order to avoid further damage.

Keywords: Madaba, mosaic, chemical analysis, examination, XRD, SEM/EDS, deterioration, conservation.

1. Introduction

The city of Madaba is located 30km southwest of the Jordanian capital, Amman (Fig.1). It has a deep historical character made up of varied and rich civilizations. The history of Madaba represents a unique and genuine urban and religious heritage that can still be observed in the remaining monuments (Abu Ghanimeh et al., 2010). Archaeological excavations and historical evidence, however, indicate that the city of Madaba was flourished during the Roman, Byzantine and Islamic periods. The virgin church is located in the center of the city of Madaba, along the roman road that crosses the city from east to west. The mosaic of the virgin church was the first mosaic floor in Madaba, known to scholars even before 1890 (Figs.2 and 3).

Figure 1. The map of Jordan showing the location of the Madaba City

In 1972, the Department of Antiquities of Jordan (DOA) acquired the site of the virgin church. In 1973, a short investigation work was performed by the (DOA).
Consecutive seasons of archaeological excavations were conducted from 1979 to 1985, by the Franciscan Archaeological Institute with the cooperation of the (DOA) under the directorship of Michele Piccirillo.

In 1993, conservation works were conducted in the church and a new shelter made of stones and concrete was built over the mosaic. Two access points allow visitors to enter, on footbridges raised about 1.50 meters above the mosaic floor. This has helped not only to protect and conserve the mosaics but also to provide access to them. (Piccirillo, 1984; Puccirillo, 1980; Puccirillo, 1982a). The church is now enclosed by an archaeological park with several byzantine churches.

The church of the Virgin Mary was built above a public hall of the town of Madaba which had been decorated with a beautiful mosaic floor with the myth of Phaedra and Hippolytus and was built in the first half of the Sixth century over a roman temple (Schick, 1995).

Both, the roman temple and the Hippolytus hall are on the south side of a paved courtyard (Fig. 2).

The church of the virgin Mary is a centrally planned church, it consists an internal vestibule, around nave (9.70 m in diameter) and an elongated apsed presbytery (7.10m x 5.80 m) which is supported by two underground rooms with barrel- vaults. There is a courtyard built over a deep cistern on the west side of the church. The façade of the church opens into a narthex. There are three doors in the west wall and one door in the north wall. Also the chancel screen divides the nave from the apsed presbytery. The church was built in the end of the Sixth century A.D. (Piccirillo, 1982b).

The aforementioned mosaic had been laid, a first time at the time of the construction of the church in the end of Sixth century A.D, and redone in the Abbasid period (767 A.D). (Di Segni, 1992; Dauphin, 1975, Piccirillo, 1995).

The importance of this mosaic derives from its late date (after the fall of the Umayyad dynasty), this indicate that there was still a sizable Christian community in Madaba sufficiently prosperous to rebuild the church and decorate it with a new colored mosaic floor( Bisheh, 2000).
square frame and the circular composition are two pairs of geometric-floral motifs. Next to each one of the eastern pair, which are in the form of rosettes, there is a tray of fruit with a knife. A square containing a Solomonic knot in a circle is superimposed on the grid at the entrance from the west. Flowers, leaves, stylized fruit and diamonds fill the empty spaces of the mosaic’s white background. Another eight-line inscription placed within a tabula ansata in front of the chancel screen tells us that the church was rebuilt and beatified by the , “care and zeal of the Christ loving people of Madaba( Piccirillo, 1993; Piccirillo, 1995)( Fig.4).

![Figure 4. General View of the mosaic floor.](image)

**State of Conservation**

To assess the mosaic’s state of conservation, a detailed survey and examination was conducted, all observed deteriorations were photographed and marked on a plan. These deteriorations are presented on the next paragraphs.

The mosaic floor shows a number of lacunae in some areas of the mosaic floor( Fig.5). Two kinds of lacunae were observed (large and small). The lacunae may be caused by several factors, such as detachment between the tessellatum and the bedding layer, water infiltration and deterioration of preparatory layers ( Frankovic, 2008; Farneti, 1993). In addition, a few tesserae are affected by the phenomenon of disintegration. Some depressions in different forms were observed in some areas of the mosaic floor ( Fig. 6), which may be due to the general weakness of the foundation layers or was of the loading or collapse of heavy objects over the mosaic( Ugruyol, 2013). Only a few areas of the mosaic floor are affected by the phenomenon of bulge( Fig.7). This condition is usually associated with the alteration volume of the different components of the bedding layers caused by humidity or change in temperature( Hamdan and Benelli, 2008).

Two kinds of deposits were observed. The first type was a thick hard white mineral crust totally adhered to the mosaic surface. It was found at the southern part of the mosaic( Fig.8). The second deposit was found on the surface of the tesserae in the form of dirt, soil and other hard deposits of brown to white in color. In addition, paint stains and bird droppings were observed in a few areas of the mosaic.
A survey of the state of the mosaic layers was conducted by using manual percussion and rubber hammer. This examination has been detected that many areas of the mosaic have affected by different level of detachment between its layers, which required grout injection. This phenomenon can probably be related to the percolation of rainwater coming from the roof and affected the foundations layers as well as the dehydration of the layers after the excavation (Bicer-Simer and Rainer, 2011; Ferragni et al, 1983; Santopuoli et al 2012).

Different forms of deteriorated tesserae had been detected and can be classified as fracture, exfoliation, pitting and eroding (Fig.9). Moreover, there were permanent color alterations caused by ancient fire in a few areas, especially in white tesserae (Fig.10).

Salt efflorescence was also presented in a few areas of the mosaic mainly along the southern wall. It was probably caused by water infiltration from the outside through the wall.
Microbiological growth in form of small plants and algae were observed in the eastern-southern area of the mosaic floor and in the base of the southern wall (Fig. 11), this phenomenon is associated with the percolation of rainwater coming from the roof, which need urgent intervention.

Finally, some cracks and deterioration on the repair mortar are also revealed (Fig. 12), as well as the deterioration of mortar between tesserae.

![Figure 11. Biological activity](image1)

![Figure 12. Deteriorated repair mortar](image2)

The previous interventions on the mosaic floor were identified; some of them can be attributed to ancient periods while the others were considered modern.

The ancient interventions have been constituted by the restoring of lacunae through fillings with marble slaps and randomly with original tesserae (Figs. 14 and 16).

The modern interventions was took place in 1995. There are no reports of that interventions existed, all the information came from observations made during the assessment process. The interventions include the edging repair with lime mortar and restoring the lacunae. The lacunae were treated in three ways:

- Some lacunae were filled with lime mortar (Fig. 15).
- Some large lacunae were filled with lime mortar with stamping the design.
- Other lacunae were reintegrated with new tesserae surrounded by a frame of glass shards (Fig. 13).

![Figure 13. Lacuna filled with new tesserae](image3)

![Figure 14. Lacuna filled with marble slaps](image4)

![Figure 15. Lacuna filled with lime mortar](image5)

![Figure 16. Lacuna filled with original tesserae](image6)
Materials and methods

Mosaic samples

Regarding to the main aim of this study is to determine the chemical and mineralogical composition of the stone mosaic tesserae as well as to characterize the binding material or the mortar used. On the other hand the impact of other environmental factors on the chemical deterioration of stone mosaics is detected. From this point, eight stone tesserae of different colors (black, orange, gray, yellow, pink, red, white and brown) were collected together with piece of mosaic original mortar and subjected to different analytical and examination methods. Photographs of these stone tesserae are shown in Figure 17, and Table 1 summarizes the visual description of these samples.

Technical methods of analysis and investigation

X-ray diffraction spectroscopy (XRD)

The mosaic tesserae samples and mortar chunks were crushed and milled in the agate mortar in order to avoid contamination. The powder of the samples was analyzed to determine their chemical and mineralogical composition by using XRD instrument which is available at the Faculty of science Laboratories, The University of Jordan. Powder diffraction patterns were obtained by using a SHIMADZU 7000 - X-Ray Diffraction system, equipped with a copper cathode, under the following conditions: Cu target 40 KV, accelerating voltage 30 mA current, the scanning range of 2θ was from 2° – 60 and the scanning speed was 2°/min.

Scanning electron microscope (SEM) With EDS instrument

Furthermore, to diagnose the structure and morphological texture of the selected samples and determine the micro or elemental composition, a scanning electron microscopy (SEM) attached with an energy dispersive X-ray spectrometer (EDS) Bruker microanalysis with sputter coater platinum target operated at 2.5-10 kV accelerating voltage, 3.66 µA filament current, 7.35×10⁻⁴ Pa vacuum and 16-18 mm working distance, located at the Faculty of science Laboratories, The University of Jordan, was used.

Figure 17. Stone tesserae samples selected for experimental study
Table 1. The description of selected stone tesserae samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Material</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stone tesserae</td>
<td>Black</td>
</tr>
<tr>
<td>2</td>
<td>Stone tesserae</td>
<td>Orange</td>
</tr>
<tr>
<td>3</td>
<td>Stone tesserae</td>
<td>Gray</td>
</tr>
<tr>
<td>4</td>
<td>Stone tesserae</td>
<td>Yellow</td>
</tr>
<tr>
<td>5</td>
<td>Stone tesserae</td>
<td>Pink</td>
</tr>
<tr>
<td>6</td>
<td>Stone tesserae</td>
<td>Red</td>
</tr>
<tr>
<td>7</td>
<td>Stone tesserae</td>
<td>White</td>
</tr>
<tr>
<td>8</td>
<td>Stone tesserae</td>
<td>Brown</td>
</tr>
</tbody>
</table>

Results and Discussion

Mineralogical Results by XRD

The results of XRD analysis of the eight stone tesserae samples are listed in Table 2 and the X-Ray diffraction spectra for representative samples are shown in Figure 18.

The eight stone samples were analyzed by X-ray diffraction. It can be stated that except sample 6 (Red), calcite is the main composed mineral of all limestone samples (CaCO₃, Calcium carbonate) and traces of quartz (SiO₂). However, calcite here is the microcrystalline calcite which is known mineralogically as (Micrite).

It was also observed that sample 6 contains the Dolomite which is the other face of calcite (CaCO₃) as a major component together with calcite. It was previously stated that these stones were locally used in Jordan since ancient periods to construct stone mosaics. (Arinat, 2014)

The mortar sample was analyzed by X-ray diffraction. It can be stated that calcite is the main composed mineral of all limestone samples (CaCO₃, Calcium carbonate) and quartz (SiO₂) are present as minor or trace mineral. The sample is characterized by high hardness of crust layer and its color range from gray to dark. So it can be concluded that the constructed binding mortar is lime based mortar (Arinat et al., 2014).

However, the mortar sample is free from expected contaminations or clay mineral such as (Kaolinite - Ca - AL2 O3- SiO2) or traces of other minerals such as gypsum (CaSO₄, 2H₂O), cordierite (Mg2Al4Si5O18), muscovite (KA12Si3AlO10 (OH)2), sanidine (K,Na) (Si3Al) O8), anorthite (Ca,Na) (Si,Al) 4O8), beidellite (Na0.3Al2(Si,Al)4O10(OH)2.2H₂O), and talc (Mg3Si4O10(OH)2 ) were not observed which indicated that the purity of the analyzed mortar.

Table 2 The Chemical composition of resulted minerals by XRD of Both stone tesserae and mortar

<table>
<thead>
<tr>
<th>Samples</th>
<th>Color</th>
<th>Minerals</th>
<th>Chem.Comp</th>
<th>Card No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>2</td>
<td>Orange</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>3</td>
<td>Gray</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>4</td>
<td>Yellow</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>5</td>
<td>Pink</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>6</td>
<td>Red</td>
<td>Dolomite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-075-1655</td>
</tr>
<tr>
<td>7</td>
<td>White</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>8</td>
<td>Brown</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-085-0849</td>
</tr>
<tr>
<td>Mortar</td>
<td>white</td>
<td>Calcite</td>
<td>CaCO₃- Calcium carbonate</td>
<td>01-086-2334</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quarts</td>
<td>SiO₂- Silicone oxide</td>
<td>00-001-0649</td>
</tr>
</tbody>
</table>
**EDS identification and characterization**

The micro-chemical analysis carried out by Energy dispersive X-ray analysis EDS for the eight stone tesserae are reported in Figures 19 and 20 and their attached tables. It can be observed that the major components of all the samples are matches with that resulted from XRD mineralogical analysis addition to revealed further elements. The elemental composition of all samples except sample (1) is vary in the following ranges:

- (Ca) from 21.96% to 38.03%,
- (O) from 44.87% - 64.73%
- (C) from 5.91% - 15.6%

However only sample (1) contains traces elements of Na, S, Al and Si.

The stone samples are characterized by low contents of carbon (C) and high content of calcium (Ca). Among the few exceptions, sample (1) is characterized by a higher alumina content, and higher silicon content.

![Figure 18. XRD patterns analysis of stone tesserae samples](image-url)
Figure 19. EDS of stone tesserae samples (1-4)
Figure 20. EDS of stone tesserae samples (5-8)
**Optical Investigation observations**

Micro photographs of stone tesserae obtained by magnifying lens X10 (Fig.21) show that the texture of the stone tesserae, has very homogeneous textures, without inclusions. The surface impact of all tesserae are quite homogeneous, with the presence of small micro pits. The black and brown tesserae exhibit a slight spongy texture appearance with inclusions and the presence of diffused deformed bubbles and large-size pits. This features are certainly due to the defects of cutting and shaping process or due to weathering attacking in the site.

![Figure 21. Photographs of the stone tesserae](image)

**SEM microscopy observation**

From SEM (X-10-10 000) observation of the some samples that covered with coherent deposits and encrustations, it can be seen that all the stone surfaces seem to be inhomogeneous pitted, curviplanar, surface-planar and highly fractured forms (Fig. 22). Large areas of the weathering crusts were destroyed and rich in dissolution voids and micro-cracks. Addition to that, other aspects of flaking, and highly fissured nature of decayed crusts were also observed (Fig.8: 1, 2 and 3). Furthermore, Figure of sample 1 shows secondary electron images of magnified sections through weathered crusts from inside the sample, showing deterioration proceeding from the surface to the interior(Fig.8:1). On the other hand, dirty layers, soil deposits and encrustations on the stone surface appeared to be inhomogeneous, differ in their thickness and strongly adhered to the stone surface and pitted areas (Fig.8:4). Furthermore, salty grains were observed between dirty crust and inside deep pits (Fig.8:1,2 and 3). The presence of calcite crystals was observed . (Fig.8:1.)
Conclusion

Over all, this study investigated the evaluation of the conservation state of the mosaic floor of the virgin church at Madaba city in Jordan.

Based on the field observation and experimental study results of the deterioration forms on the mosaic floor of the virgin church. It can be noted that Calcite is the main mineral of all limestone tesserae samples (CaCO₃, Calcium Carbonate) and the calcite here is the microcrystalline Calcite which is known minerologically as (Micrite). It was previously stated that these stones were locally used in Jordan since ancient periods to construct stone mosaic. As well as, these methods revealed that the mosaic floor is suffering from different deterioration aspects such as, lacunae, incrustation, depressions, bulge, detachment between preparatory layers, salt efflorescence, deteriorated repair mortar, biological activity.

The current condition of the mosaic floor indicates that the implementation of a conservation intervention is essential to avoid a lot of damage. Moreover, the study confirms that a regular maintenance program of the shelter and the mosaic floor is necessary to preserve this important mosaic floor, which length its survival and thus to insure that this mosaic floor is preserved for future
generations. Therefore, the following recommendations are suggested for the conservation of the mosaic floor:

- Cleaning of all litter, birds debris, paint stains, incrustation and any other extraneous materials from the mosaic.
- Consolidation of both tessellatum and preparatory layers
- Grouting of detached areas and voids.
- Fixing detached tesserae.
- Removal of the deteriorated of repair mortar.
- Filling between tesserae.
- The shelter should be regularly checked for defects such as leaking roof and block drains.
- Documentation, photography and drawings, through all stages of the work.

Acknowledgment

The author would hereby like to acknowledge the Deanship of Academic Research (DAR) of the University of Jordan for funding this research. The gratitude is also extended to the archaeologists in the Department of Antiquities of Jordan (DOA) for their support as well as to the supervisors of the XRD, XRF and SEM laboratories in the faculty of science in the University of Jordan.

Finally, the gratitude should go to Dr. Mariusz Drzewiecki for his help and encouragement during this work.

REFERENCES


Piccirillo, M. 1995. The Mosaic of Jordan, editors: Bikai,
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Tقييم حالة الحفاظ للأرضية الفسيفسائية في كنيسة العذراء، مادبا، الأردن

穆罕默德 عريفات

ملخص

تهدف هذه الدراسة إلى تقييم حالة الحفاظ الحالية للأرضية الفسيفسائية في كنيسة العذراء في مادبا، وتعرف على المواد التي تتكون منها، ومظاهر التلف المختلفة. لتحقيق هذه الأهداف فحصت المكعبات الفسيفسائية والملاط بواسطة رادار الأشعة السينية (XRD) وطريقة التحليل بالأشعة السينية (SEM)، أظهرت هذه التحاليل أن المعن (Calcite, CaCO3, Calcium Carbonate) الرئيس لجميع المكعبات الحجرية هو معن الكالسيت. وقد أظهرت التحاليل أن سطح المكعبات الفسيفسائية تحتوي على العديد من التشظيات والتلف الصغير، بالإضافة إلى أن الأرضية الفسيفسائية تتعرض للعديد من أشكال التلف مثل الثقوب، والترسبات، والهبوط، والانفجار، والانفصال ما بين الطبقات التأسيسية. وتتوفر الأراضي والتنوع في تسبب التلف، وتتوفر الدراسة إلى ضرورة القيام بأعمال الصيانة والترميم للأرضية الفسيفسائية، وذلك لتفادي المزيد من التلف.

الكلمات الدالة: مادبا، فسيفساء، التحليل الكيميائي، الفحص، المجهر الإلكتروني، الأشعة السينية، التلف، الحفاظ.