Mediterranean Archaeology and Archaeometry, Vol. 15, No 3,(2015), pp. 249-258

DOI: 10.5281/zenodo.32067

UNDERSTANDING EARLY ISLAMIC MOSAIC PRODUCTION: ARCHAEOMETRIC STUDY OF MATERIAL FROM QASR MUSHATTA

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Received: 10/02/2015
Accepted: 30/09/2015

ABSTRACT

The discovery of mosaic tesserae at Qasr Mushatta (near Amman) in the absence of any complete mosaics raises a number of questions about the reason for how they got there and what do they tell us. Samples of mosaic stone tesserae and mortar were collected from the site and studied for this reason. Petrographic and Scanning Electron Microscope analysis for the tesserae indicate a local provenance for the stone. Mortar composition shows variation in the preparation techniques, and helps in matching the mortar traces found on the tesserae to wall mortar.

The study shows that Mushatta Umayyad place was intended to be decorated with wall mosaics, produced most probably with local mosaicists using local materials.

KEYWORDS: Mosaic, tesserae, mortar, Jordan, Mushatta, Umayyad, Petrography, Scanning electron microscope.

1. INTRODUCTION

Located approximately 31km south of Amman (figure 1), Qasr el Mushatta is an Umayyad desert palace in the central Jordan plateau. It was built under the orders of the Umayyad Caliph Walid II around 743- 744 A.D., and is most renowned for its elaborately carved façade, which is now housed at the Pergamon Museum in Berlin, Germany.

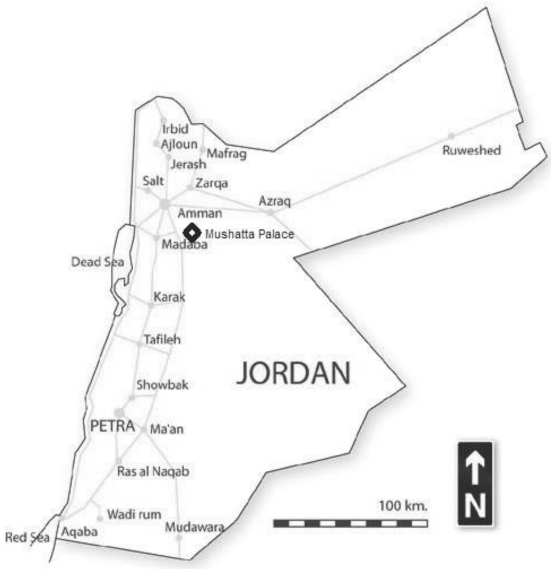


Figure 1: General map of Jordan with location of Mushatta Palace

The earliest western mentions of the site were made by Layard in 1840 and Tristram in 1872 (Creswell, 1958). At the turn of the 19th century, the façade of the palace was given by the Ottoman Sultan, Abdelhamid II, to the German Emperor Wilhelm II, and was thus permanently removed. But it wasn't until the early sixties of the last century when the first excavations were made at the rest of the site. In 2009, a five year restoration project was initiated by the Berlin University of Technology in cooperation with the Islamic Department at the Pergamon Museum as well as with the Department of Antiquities of Jordan, with the aim of conducting a full investigation of the site, in addition to conservation and restoration work.

During the 2010 excavation season, several hundred of mosaic tesserae fragments were found outside the northern wall, within the inner courtyards, and at the entrance corridors to the throne room (figure 2).

Mosaic decorations are common in Umayyad palaces and palace complexes. Qaser Hisham (Khirbat al- Mafjar) in Jericho boasts several meters of mosaic floor, forming thirty eight variable carpet decorations (Creswell, 1958). In addition, the Qastal palace, Qusair Amra, the Umayyad mosque in Damascus and the Holy Dome of the rock in Jerusalem, all have wall mosaics. Thus, the presence of mosaic tesserae at Mushatta is not surprising. It does, however, raise a number of questions. How were these to be used (wall or floor mosaics)? Were they produced on site or brought to the site in a manufactured form? Was it a local workshop with local artisans or were imported skills introduced? What is the provenance of the stone?

Unfortunately, much of the evidence was ignored and lost by archaeologists who excavated the site early on. Excavations went further down to the original floors and the original wall masonry was moved from its original falling location, thus posing a real challenge towards investigating the origin of the mosaic inlay.

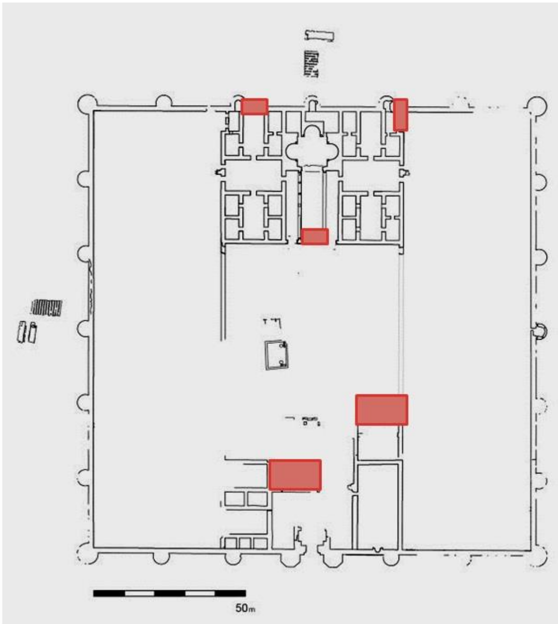


Figure 2: Location of trenches where mosaic tesserae were found

Despite the obstacles faced, this research was initiated to explore these questions. Using standard lab and field approaches, samples were collected and analyzed to gain insight into the secrets of these tesserae and the mosaics to which they should have belonged.

2. MATERIALS AND METHODS

Several hundred scattered mosaic tesserae were found lying outside the northern wall, the inner corridors, the arched entrance to the throne room in addition to the wall of room adjacent to the mosque and in the corridor's leading from the main entrance to the central room

Figure 3: Scattered tesserae at the site (copy right of Dr. Barbara Berlich)

Traces of mortar were found on some of the tesserae sides (varying from one side to three sides; figure 4). Most tesserae had a thick amount of mortar on their sides, while the reverse sides had only traces.

Figure 4: Shape of the mosaic tesserae: (from top to bottom) monocline, wedge, cube rectangular, chips, and triangles.

Four samples of tesserae were chosen for petrographic analysis, one tesserae of each color. Three samples of mortar were taken from the mosaic tesserae found, while another four were collected from floor mortar pavement, the brick wall and from the stone wall layers.

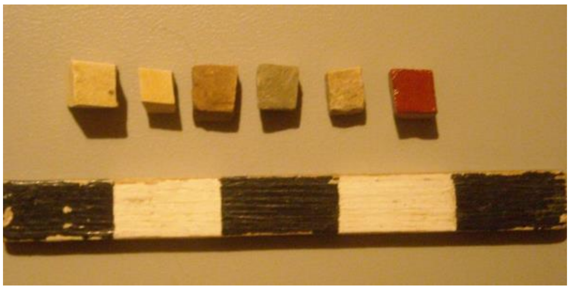


Figure 5: Color of mosaic tesserae.

The tesserae and mortar were examined using a combination of techniques. First there was direct measurement and description of all of the available teaerrae (using a caliper and a Munsel Chart for colours). Thin sections of tesserae samples were prepared to study under polarized microscope (Leica DM 3000), equipped with digital camera type (Canon). The thin sections were colored using (Alizarine Red S). The study was conducted under both XPL and PPL.

Mortar samples were studied under an X-Ray diffractometer Inspect F50, with Schottky Field Emission Gun. The samples were scanned from 3 to 60 degrees at a rate of two degree per minute. The x-ray diffraction spectra were analyzed using attached peak matching software containing mineralogical JCPDF data. Manual checking of the peak matching results was undertaken as well.

Mortar samples for SEM were prepared by placing them on stubs and applying platinum plating. The samples were analyzed using a Cameca SEM device coupled with an energy dispersive x-ray fluorescence attachment for micro chemical analysis. This system is available at Jordan University. The SEM was used for analysis of the texture of the mortar material, whereas the attached EDX was used for the study of chemical and mineralogical characteristics of the samples of mortar under investigation.

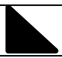
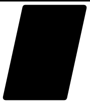
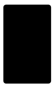
3. RESULTS

A- Qsr Mushatta tesserae description

The shapes of the scattered tesserae varied between cubic, triangular, rectangular, and monoclinic or wedge shaped (figure 5, Table 1).

Many chipped fragments were also found intermingled within the tesserae. The size of each form was categorized as seen in table (1):

TABLE 1: Classification of tesserae according to form of shape

Shape	Shape	Length (mm)	Width (mm)	Thickness (mm)
Triangle		9.64	5.22	10.03
Monoclinic		15.00 left 9. 60 right	9.30	6.61
Cube		13.00	13.00	13.10
Rectangle		18..44	11.80	5.22
Wedge		9.60	6.22 up 3.49 down	7.24

Tesserae colours (table 2) were white (pinkish white, yellowish white), pink, black, grey, red, and brown (very pale brown to brown) (figure 5).

Table 2: Distribution of tesserae according to color

Tesserae color		Tesserae color code	Percentage of distribution
Red		7.5 R 4/6 Red	13.78%
White	Yellowish White	7.5YR 7/3 Pink	49.36%
	Pinkish White	7.5 YR 7/4 Pink	26.50 %
Grey		10 YR 4/1 Dark reddish grey	6.57%
Brown		2.5 YR 5/3 reddish brown	3.35%
Black		5R 2.5 /1 reddish black	0.44%

The mortar was of white to yellowish white color (Munsell Soil – color charts of the year 2009) some tesserae have material resembling a lime wash on their sides of light white color. Some tesserae had mortar of grey to black color, indicating a charred mortar, suggesting exposure to heat or burning.

Table 3: Description of the tesserae samples:

Sample #	Sample color	Sample color code	Dimensions (mm)
Q1	Grey	10 YR 4/1 Dark reddish grey	11.45 X 17.16 X 7.85
Q2	White	7.5 YR 7/4 Pink	18.33 X 17.29 X 6.48
Q3	Red	7.5 R 4/6 Red	8.18 X 11.92 X 7.51
Q4	Brown	2.5 YR 5/3 reddish brown	8.15 X 11.31 X 7.72

Table 4: The description of the mortar samples

Sample #	Sample color	Color Code	Location	Description
QAM – 1 A	White	N white	T12- T13	Located on a small cube tesserae
QAM- 1 B	White	7.5 YR – 1	Entrance	Located on a wedge type tesserae
QAM- 1 C	Grey	10 YR 5/1 Grey	T12- T13	Large cube could be burnt
QAM- 2	White	7.5 YR -/2 pale yellowish pink	Plaster layer of the courtyard	The sample has a smooth surface, which seems compacted , the reverse show both small pores and white lumps of either small stones or lime
QAM- 4	Light pink brown	7.5 YR/ -2 pinkish white	From the side room wall surface plaster	Smooth, shows layering very small.
QAM- 6	White	2.5 Y /- 1	Mortar from the stone wall	Small lump show bedding
QAM- 7	Yellowish white	-	Scrubbed mortar from the surface of a wall break	Powder state

A- Laboratory Investigation

The petrographic investigation has indicated that the materials used for producing the mosaic tesserae were mainly variations of limestone, either micritic limestone with presence of organic matter or marly limestone as described in table 5 (Figures:6, 7, 8, 9).

Table 5: Petrographic Analysis result

Sample #	Sample color	Petrographic Description
Q1	Grey	Limestone, Biomicrite (Folk), packstone (Dunham)
Q2	White	Limestone, Micrite with recrystallization
Q3	Red	Oosparite (Folk), packstone (Dunham)
Q4	Brown	Microsparite, Mudstone (Dunham)

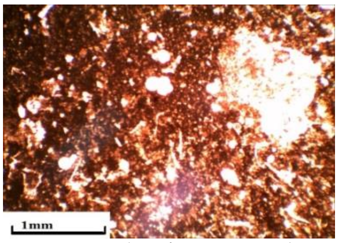


Figure 6: Grey tesserae showing Ostracoda and fragments of Mollusca shell fossils in micritic matrix (PPl, X40)

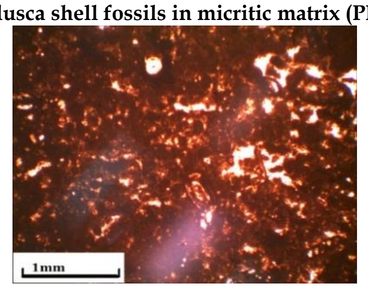


Figure 7: White tesserae, showing dense micrite with presence of pellets. (PPl, X40)

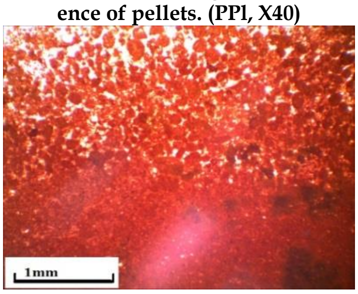


Figure 8: Red tesserae, show dense micrite recrystallization with Pilliodes (PPl, X40).

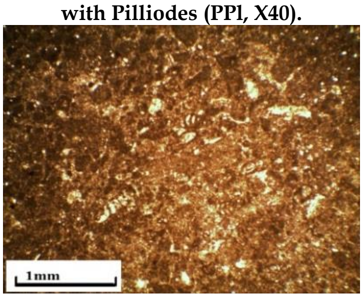


Figure 9: Shows rhombic shape of calcite from the mortar traces found on tesserae fragment under scanning electron microscope).

The analysis of the mortar done by *the Scanning Electron Microscope* found on the tesserae surface (figure 10) was of pure lime, no traces of inclusions were identified. Floor samples (figure 11) showed the presence of aluminum, potassium, magnesium and iron oxides which are an indication of clay materials.

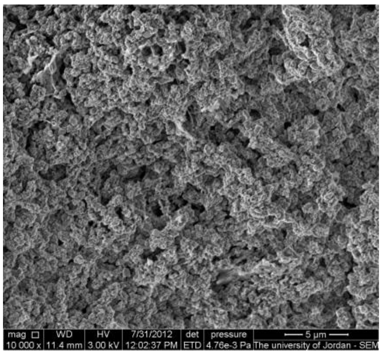


Figure 10: Showing SEM micrographs of the mortar traces found on the tesserae showing well defined calcite crystals (upper)

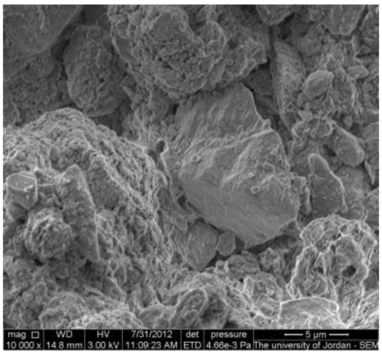


Figure 11: Showing SEM micrographs of the floor mortar (lower)

The wall plaster (figure 12) had showed the presence of silicon, magnesium and aluminum oxide, suggesting the addition of pozzolana or clay. This sample had shown deterioration due to organic growth. The brick wall sample was composed of pure gypsum (figure 13), no other traces of other materials or inclusions were found.

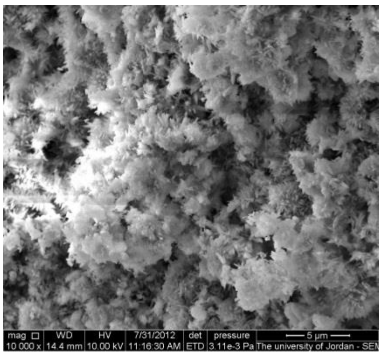


Figure 12: Showing SEM micrographs of wall mortar

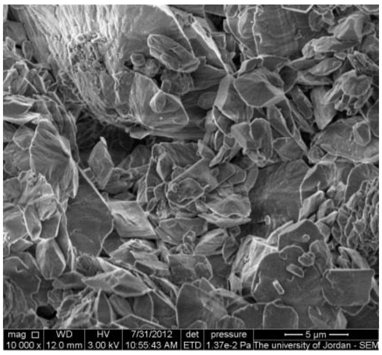


Figure 13: Showing gypsum under scanning electron microscope, from the brick mortar sample.

Table 6: Results of mortar analysis

Sample #	Sample color	Color Code	Composition
QAM – 1 A	White	N white	Lime mortar, fine and compacted
QAM- 1 B	White	7.5 YR – 1	Lime mortar
QAM- 1 C	Grey	10 YR 5/1 Grey	Lime mortar
QAM- 2	White	7.5 YR -/2 pale yellowish pink	Lime with clay residue, homogenous calcite
QAM- 4	Light pink brown	7.5 YR/ -2 pinkish white	Has cracks, lime mortar with clay residue
QAM- 6	White	2.5 Y /- 1	Calcite, Pozzolana , bacteria
QAM- 7	Yellowish white	-	Showed rhombs, homogenous gypsum composition

4. DISCUSSION

A- Comparative study:

Sear (1967) mentions that the typical length of tesserae used for the wall tesserae varies between ¼ of an inch up to one inch (0.635 – 2.54 cm). In comparison with Umayyad mosaic pavements, Richmond, in his study of the mosaics of the Dome of the Rock mosaics, mentioned that the size of tesserae of the wall mosaic vary from (0.4 cm^3 – $1cm^3$), while van Bercham mentions that the glass tesserae sized varied between 2-3 mm^3 (van Bercham and Ory, 1982). It is unfortunate that some researchers report dimensions and others report volumes. Assuming that the tesserae are cubic, the Dome of the Rock tesserae ranges from 7.4mm to 1 cm, which is similar to the quote by Sear (1967).

Qusair Amra, an Umayyad bath house dating to the middle of the 8th century A.D., in contrast, has floor mosaics made of both multi-colored stone and glass tesserae; forming geometrical patterns. The tesserae had both regular cubic and triangular and rectangular forms. The imbedded tesserae allowed only measuring two of their dimensions: the length and width, the tesserae dimensions vary between (3 – 6 mm) in length, and (5 to 9 mm) in width, the sides of the triangular shaped tesserae measured (9 X6 X 12 mm).

The Qastal Palace complex had both mosaic pavements in the main open courtyard and within the bath complex. The bath complex mosaic pavement is much more sophisticated, and has both glass and stone tesserae, whereas the open courtyard follow a geometrical pattern decoration made out of stone tesserae. The notable aspect within these tesserae is their low thickness, which varies from 3.4-7.4 mm, while their length and width was between 9.4-19.5 mm. They were made of regular cubic and rectangular shapes.

According to the density theory proposed by Avi- Younah (1933), mosaics can be divided into:

a. Coarse pavements: with 4-20 tesserae / 10 cm^2 , these were mostly white cubes

b. Middle quality: with 20- 30 tesserae / 10 cm^2 commonly having 25 cubes

c. Fine pavements: with 42- 100 tesserae/10 cm^2, commonly from 90-100 cubes, sometimes more (Avi- Younah, 1933).

Umayyad mosaic fall within the last category, as the density of Qastal mosaic floor ranged between (48 – 145) tesserae / 10 cm^2 (Bisheh 2000). Qusair Amra mosaic floor has a density of around 155 tesserae / $10cm^2$. The wall mosaic of the Dome of the rock would also fall into this category.

B- Technique of mosaic production at Mushatta

The discovery of the mosaic tesserae at the palace complex and the conducted analysis and investigations were aimed to examine two main theories: were the craftsmen local or foreign, had the materials used been of local provenance and was the tesserae inlay been on the wall or the floor?

"Workshop" in antiquities refers to an improvised gathering site for a dynamic group of artisans, belonging to one family or employees of a master craftsman, settling at the mosaic layering site (Dauphin 1976, Henderson 2000).

Archaeological excavations at different sites dating to the Byzantine period showed evidence of mosaic production workshops in the form of remnants of mosaic tesserae such as chipped fragments of stone, or excess of raw material. These fragments were usually tucked under the mosaic layer, apses or mixed with the mortar (Harding, 1967), although, nothing similar was discovered at an Umayyad site, that does not mean such practices did not occur.

From the evidence collected at the site of the palace, there are strong indications that work was set into embellishing the site with opus tessellatum. The tesserae and chipping fragments found scattered along the building site indicate that a group of artisans were working on cutting the stones at the site and producing the tesserae. The craftsmanship of cutting, consistency of the shape and size indicates an experienced practicing technician. One of the most striking tesserae shapes is the wedge shape. This shape was first used in the production of mosaics during the Roman period. The advantages of this shape that on the surface the tesserae are set in close proximity with each other, while the rest of the body is set in mortar, fixing them firm and making the pavement esthetically appealing. This form had disappeared from the mosaic pavements of the region during the Byzantine period, being substituted with the regular cubic forms (Hamarneh, 2010). Therefore, it is quite interesting to find that shape of tesserae within the discovered fragments at the site is of the wedge shape, indicating that the craftsmen were skilled group with a long experience and tradition of mosaic production.

From the regularity of shapes and their measurements, a conclusion can be made that they were not naturally present. Some tesserae surfaces inclinations varied from 90 degrees to 30 degrees. Tesserae were shaped in a very notable form; they were cubic or rectangular at one side and very elongated, for example their lengths varied between (0.9 – 1.31 cm). This shape is rather novel and differs of the usual floor tesserae which were either regular cubic, triangular or rectangular, or were large on top and narrow down like wedges. The tesserae found at the palace complex were cut in a form indicating that they were to be imbedded deep in a thick layer of mortar, regularly shaped along one side only, where the color is most clear, while the rest of the tesserae were left irregularly cut with chromatic alterations within the long protruding hind part. Their sizes vary in length between 0.93 cm –and 1.63 cm, width between 0.93 and 1.69cm and thickness of between 0.53 and 1.56 cm.

Despite the fact that historic Arab sources inform of the presence of traveling artisans; historic records mention that the Byzantine Emperor (Malik al Rum) dispatching craftsmen to decorate the Mosque of the Prophet on request of Caliph al- Walid ibn ʻAbd al-Malik. The Emperor sent ten skilled mosaicists, and the weight of forty camels of mosaic tesserae (Creswell, 1958). Al – Mas'udi mentions the detachment of mosaics from a church in Sana'a and delayering it on the Ka'ba al Musharafa walls (Al Mas'udi, 1995, Part 3), a process only mastered by qualified mosaicists. The evidence of mosaic tesserae raw materials proves the opposite.

The colored stones used to produce the tesserae were of local provenance, as petrographic analysis correlate the tesserae with local outcrops. The raw materials are similar in character with the what would be found within the outcrops of the area, which belong to the Umm Rijam Chert Limestone formation, Muwaqqar Chalk marl formation, and Al- Hisa Phosphorite formation, and Amman Silicified formation which are either outcropping in the proximate vicinity or located along the wadies (Jaser, 1986; Al- Hunjul, 1995). Muwaqqar Chalk Marl formation is noteworthy for containing pockets of slightly re-crystalized chalk known in Jordan as marble, these lenses are dense with variation of color ranging from whitish grey to brownish red (Khouri, 1989).

The most interesting is the red color sample, the petrographic study shows that it's composed of oosparite, this stone lithology and color was not found in the vicinity of the Qasr site. Similar lithology can be attributed to Eth- Thamad Marl member of Madaba Calc Breccia Formation, comprised in its upper layers of reddish lenses of micritic limestone and in the lower scattered reddish clasts (Al- Hunjul, 1995). This formation is located approximately fifteen kilometers to the south west of the Qasr area, therefore it could have been known to local artisans. This can be interpreted that the artisans collected the stones from the vicinity of the site, also it can be interpreted their already dealt with local stones characteristics, and had already worked with it.

To the north and north eastern part of Qasr Al-Mushatta area lie large outcrops of Umm Rijam Chert- Limestone Formation. This formation is comprised of marly limestone alternated with chalky limestone with chert lenses (Jaser, 1986; Al- Hunjul, 1995). The limestone color mainly is grey white. These outcrops might have well served as the raw material for lime production. To reach a good quality of hydraulic lime, according to Pliny's recommendations, it requires at least two year of slacking (Pliny the Elder, 1962), which leads us to believe that a local workshop would have been responsible for the work, as local craftsmen knew the provenance, quality of local material, method of extracting and preparation. Although no kilns were reported to be found during the excavation process at the palace site, lime kilns were found at other Umayyad Palaces in Jordan such as the lime kiln found at the Umayyad Complex at Amman Citadel (Almagro et al, 2000), evidence of burning can be deduced from the excess of cinder and ash fill in the outer wall mortar. Two small pools found at the east and west of the Qasr Al- Mushatta courtyard show several layers of mortars. These pools could have been used for slaking lime to be used for the mortar layers during the mosaic layering process.

Table 7: Showing the provenance of mosaic tesserae

Sample #	Sample color	Petrographic Description	Provenance (Lithostratigraphy)
Q1	Grey	Limestone Biomicrite (Folk), packstone (Dunham)	Umm Rijam
Q2	White	Limestone Micrite with recrystallization	Amman Silicified Limestone
Q3	Red	Oosparite (Folk), packstone (Dunham)	- Could be Al- Thamad member
Q4	Brown	Microsparite , Mudstone (Dunham)	Marly limestone Al- Hisa Phosphorite Formation Or It could also originate from Muwaqqar Chalk Marl formation pocket of recrystallized chalk.
Q5	White	Limestone: biomicrite (Folk), wackestone (Dunham) with foraminifera.	Umm Rijam chert limestone formation.

There are several differences between wall and floor mosaics. Although the general impression is that wall mosaics are made using glass tesserae, stone was still used for tesserae of white, black, pink, brown and ochre color, with predominant glass tesserae for other colors, particularly gold and silver tesserae, green and blue (van Berchem and Ory, 1982) while in opus tessellatum the predominant material was stone with little glass mosaic mainly for the azure and green colors (Avi- Yonah, 1933) and yellow.

The inlay of the tesserae varied according to the predominant function, as opus tessellatum was a floor made to walk on, its smoothness and levelness was a high requirement, in addition to the necessity of placing the tesserae in close proximity to each other. Unlike opus musivum, which function as a decorative surface, thus irregular shaped tesserae were used to insure the reflection of light, their inlay was made more individually and imbedded into the mortar layers none too firm (Sear, 1967).

Another aspect lies in the mortar, as floor mosaics required a lot of preparations of foundation layers, which comprised the rammed earth, the stratumen; the nuclea, the rudus, and the let de pose layers, which were usually thick preparatory layers reaching up to 50 cm thick (Hamarneh 2010).

While for opus musivum, the mortar was composed of three layers constituting a much lower thickness: a coarse layer with aggregates that could have been 3-5 cm thick, over it a smother layer was applied which was usually incised, and a final layer of lime into which the tesserae was imbedded, thus reaching to a thickness of 10 cm maximum (Haswell, 1973).

In opus tesslatum the application of tesserae inlay could have been made by applying both direct and indirect methods up to double reversed, while in opus musivum a direct method was more commonly used. Haswell even suggests that the golden tesserae location in the design was marked by red paint and then added as the last stage during the production process (Haswell 1973).

Archaeologists discovered of several thousand stone tesserae, taking into consideration the density of tesserae in Umayyad mosaic pavement, we could conclude that the amount of tesserae found at Qaser al Mushatta were enough to cover between 3.5 – 5.5 m^2 of mosaics if it was all intended for the floor. At the same time, we could assume that the design might have included blue, green and yellow colors performed by using glass tesserae. In floor mosaics their percentage of usage was less than the wall mosaics. The limitation of color variation to white, grey brown and red indicated that the stones left behind were of no significance, probably "rare" color tesserae, such as light green or blue, might have been taken by the artisans as they left the building site.

Glass tesserae were mainly used as substitutes for rare colors and for decorations of wall mosaics. Glass tesserae was manufactured in Syria and sold all over the world since the Byzantine period (James, 2006). Jarash had local glass kilns at the lower caves of the North theatre dated to the late Byzantine/ Early Umayyad periods (Meyer 1987). Glass tesserae for the decoration of Qaser al Mushatta could have been ordered for the site to be incorporated in the design, two small glass tesserae were found at the south wall is rather a poor evidence to confirm this hypothesis. Assuming it's true that means that the area covered with mosaics would not change much for the floor pavement, but for the wall it could increase to reach around 9.00m^2.

Upon examining the shape of the tesserae found at the palace site, two main shapes can be identified: the flat surface type and the monocline surface type (30 – 70 degrees). Due to the fact that a large portion of the latter tesserae were found, it could not have been by chance but done on purpose. It is rather clear that the flat surface can be used for floor pavements and wall. The monoclinic forms of tesserae were cut to be used for the wall mosaic decoration.

The location where the mosaic tesserae were found scattered at the northern wall suggest also that the tesserae were laid on the brick portion of wall. The brick wall which had fallen due to earthquake might have scattered the tesserae on the ground.

The nature of the mortar traces indicate that the thickness of the tesserae embedding was the lowest reaching from 2.99 mm up 6.13 mm, judging by the smooth surface, even the elongated tesserae had the smooth, widest surface on top.

The fact that mortar was found at the tesserae sides indicate that these tesserae were imbedded in a mortar layer. The angular sparry calcite crystals are intercalated with some micritic crystals, indicating a prolonged slaking process or a second exposure to solutions, as secondary calcite formulation is observed in some of the pore lattice.

It is evident from the mortar traces found on the tesserae the use of pure lime mortar for their layering. Lime mortar is always used for the let de pose layer, which is the last layer used to secure the tesserae both in the floor and wall mosaics. The laboratory analysis has showed that the mortar on the brick surface is composed of gypsum, which excludes their being laid with mosaic decoration.

The traces of mortar on the tesserae showed well defined calcite crystals, this mortar is made of pure lime putty, showing well defined Portlandite crystals usually resulting of a good calcination process, the calcite rhombic crystals show a long hydration process which allowed the crystals to form, with a large amount of crystals in size < 1μm, showing both oriented and none oriented crystals of Portlandite, a natural occurrence for slow drying hydraulic mortar, which gives the mortar high workability and compactness as few pores were observed. Some mortar samples showed traces of aluminum silicon hydrates.

Both samples of mortar collected from the ashlar stone wall and the floor segment show lime composition, yet their lattice structure is different. The floor mortar shows micritic calcite crystals surrounding clay aggregates inclusions. This could be either a later alteration due to deposition of clay particles by the wind or might have been added to the mixture as a component. The mortar workability is low, showing the formation of clusters probably formed during the slacking process, caused by lack of water and / or lack of mixing during preparation. The sample showed high porosity. The mortar also showed low adherence of the lime binder to aggregated, as some of the clay had single crystals formed on the surface indicating a secondary hydration process.

Unlike the floor sample, the wall sample showed dense micritic calcite with the presence of dense calcium aluminum silicate hydrates, an indication of use of pozzolanic material. This modification increased the adherence and workability of the mortar. The lime putty has formulated a thick layer around some of the grains which makes it hard to identify it counters. The calcite crystal orientation and homogenous sizes indicate a full firing process of the raw material, an elaborative grinding process and the long slacking process for the lime putty.

The wall sample has been exposed to weathering, which lead to the formation of cracks and the colonization of bacteria in some of the pores.

By comparing the composition, quality and the crystalline lattice of the three mortar samples, there is a high match between the characteristics of the mortar on the tesserae with the wall mortar typology.

5. CONCLUSION

The results of this investigation show that the mosaic tradition at the site mirrored the existing traditions of the time. Artisans who labored had belonged to a local workshop with a long tradition and high qualifications, although the evidence cannot dismiss the possibility of local craftsmen working under the supervision of a highly qualified one local artisan. Local materials were used to create what most likely was a wall mosaic for the throne room of the palace. There is slight evidence of using glass tesserae, which was probably taken from the site due to its high coast. The small amount of tesserae with mortar traces found are a small segment which was set on the wall that fell due to natural factors, while the other remnants are probably a reflection of discarding the material at the site due to abandonment of the building project before its completion. Ashlar stone wall mortar analysis has showed its composition being of pure lime, in composition similar to the traces found on the tesserae. This could indicate that wall surfaces were prepared for decorating with mosaic. The most probable location for them could have been the throne room walls, and the arches' spandrels at the main entrance leading to the throne room. Their scattering location might have been due to the destruction of the walls due to natural disasters such as earthquakes.

ACKNOWLEDGEMENTS

I thank the anonymous reviewers for constructive comments. I would like also to thank Prof. Dr.-Ing. Johannes Cramer from Technische Universitat Berlin, head of Mushatta Conservation Project and Dr.-Ing. Barbara Perlich for providing the samples for this research and giving permission to use the pictures. My appreciation goes to the German Jordanian University for providing the grant to conduct the research analysis, and to Mr. Wadah Fares from Jordan University, Hamdi Mango Center for his help with SEM.

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