

## *Implementation and coloration technology of Stucco formations in Baron palace*

تقنية تنفيذ وتلوين التشكيلات الجصية في قصر البارون

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### **Abstract:**

Baron Empain Palace is one of the most remarkable monuments in the Capital, and one of its unique silhouettes that located in the road connecting the center of Cairo to the airport. The villa Empain situated at high point of the plateau in Avenue Al-Uruba, which was 'Avenue des Palais' previously. The Palace was established by Belgian businessman Eduard Empain, the founder of Heliopolis district, in 1907-1911 by the architect Alexandre Marcel 1860-1928 and the interior designs were made by georges-Louis Claude. Baron Empain built his own palace in a completely different style as a Hindu temple fantasy in reinforced concrete. The building style was inspired by the Angkor vat temple from 12th century in Cambodia. The idea of introducing the Indian style in Heliopolis was suggested by Alexandre Marcel who already built a Cambodia pavilion for the 1900 EXPO in Paris

### **stucco implementation technology.**

By looking closely, we can see the exquisite details of the decorations., as in Hindu constructions, are full of statues and inscriptions, but moderately, in a way that distinguishes this pattern from stacking. These decoration elements were often implemented in advance and then it is transferred. The molds themselves were implemented in reinforced cement. Finally, to give the whole a tone, the architect decided to make this building in Siena, with layers of burnt Sienna color. The result was obtained by using colors based iron oxides , and by spraying the parts to be tinted by means of pumps. The given effect is satisfactory and the process, as original as it is. , in this way we dealt with the technology of implementing cement plaster formations by molding in addition to coloring those formations.

### **Investigation and analytical study .**

it is known that the Baron Palace restoration project was started in 2017 and was completed at the beginning of 2020, and the Palace's restoration project sparked widespread controversy in the way of the restoration works implement , and in this paper we will shed light on the method of finishing, especially the colors and on what scientific basis a Restoration project of the palace came out We will show Historical studies about the building technology in the palace in addition to the scientific study will be addressed through analyzing the components of the Stucco formations and the colors used by founder, using X-ray diffraction analysis and using scanning electron microscope supplied with the EDX unit ,

through these analysis and investigation we find the presence of more than one material in these stucco formations like cement and other minerals , and the presence of the colors basically iron oxides. Mixed with gum Arabic media.

### Aim of study

shed light on the technology of (cement and gypsum stucco formations and its color ) by Investigation and analytical study, for a unique Indian style in Empain Palace . segmented molds have been used in large-sized designs, a concrete structure is made and the precast parts are installed on this structure. And the colors that were applied through examinations and analyzes confirmed that the colors are ferric oxides mixed with gum Arabic.

### Key words :

Heliopolis district, Hindu temple fantasy , Angkorvat temple , Hindu constructions , reinforced cement , Siena , Stucco formations, X-ray diffraction, scanning electron microscope , cement, iron oxides

### المخلص:

قصر البارون إيمان أحد أبرز المعالم الأثرية في العاصمة ، وواحد من الصور الفريدة التي تقع على الطريق الذي يربط وسط القاهرة بمطار القاهرة. ويقع قصر البارون إيمان في أعلى نقطة من الهضبة في شارع العروبة ، والذي كان في السابق "شارع القصر". تم إنشاء القصر من قبل رجل الأعمال البلجيكي إدوارد إيمان ، مؤسس منطقة هليوبوليس ، في ١٩٠٧-١٩١١ من قبل المهندس المعماري ألكسندر مارسيل (١٨٦٠-١٩٢٨) والتصاميم الداخلية بواسطة جورج لويس كلود. حيث بنى البارون إيمان قصره الخاص بأسلوب مختلف تمامًا مثل معبد هندوسي من الخرسانة المسلحة. أسلوب البناء مستوحى من معبد انكوروات من القرن الثاني عشر في كمبوديا. حيث اقترح ألكسندر مارسيل فكرة إدخال النمط الهندي في مصر الجديدة ، بان قام بالفعل ببناء نموذج كمبودي في معرض EXPO ١٩٠٠ م في باريس .

### تكنولوجيا تنفيذ الجصيات بالقصر:

من خلال النظر عن كثب، يمكننا رؤية التفاصيل الرائعة للزخارف. ، كما هو الحال في الإنشاءات الهندوسية، مليئة بالتمائيل والنقوش، ولكن بشكل معتدل، غالبًا ما تم تنفيذ عناصر المبنى الزخرفية هذه مسبقًا ثم تم نقلها. حيث تم تنفيذ القوالب نفسها في الإسمنت المسلح. أخيرًا لإعطاء التميز والتفرد ، قرر المهندس المعماري صبغ هذا المبنى بأحمر سيبينا، حيث تم الحصول على النتيجة باستخدام ألوان تعتمد على أكاسيد الحديد ، ورش الأجزاء و تلوينها بواسطة المضخات.

### دراسة الفحوص والتحليل:

مشروع ترميم وتأهيل قصر البارون تم البدء فيه عام ٢٠١٧م وانتهى العمل به في بداية ٢٠٢٠م واثار مشروع ترميم القصر جدلا واسعا في طرية انهاء اعمال الترميم به وفي ورقتنا البحثية هذه سنلقي الضوء علي طريقة الانهاء خاصة موضوع الالوان وعلي اي اساس علمي خرج مشروع ترميم القصر بهذا الشكل وهنا تم تناول تكنولوجيا تنفيذ التشكيلات الجصية عن طريق القولية اضافة الي تلوين تلك التشكيلات وسيتم تناول الدراسات التاريخية التي تتبعت تكنولوجيا البناء بالقصر اضافة الي الدراسة العلمية من خلال فحص وتحليل مكونات التشكيلات من حيث خامة التشكيلات والالوان المستخدمة بها عن طريق استخدام تحليل حيود الاشعة السينية واستخدام الفحص باستخدام الميكروسكوب الالكتروني الماسح المزود بوحدة الاديكس وتحليل الاشعة تحت الحمراء لمعرفة الوسيط المستخدم مع اللون ومن خلال تلك التحليل تثبت وجود اكثر من خامة في تنفيذ تلك التشكيلات علي راسها الاسمنت ومكون الجبس الذي استعمل لتنفيذ تشكيلات اخري ووجود الوان قوامها الاساسي اكاسيد الحديد، مخلوطة بوسيط الصمغ العربي

**هدف الدراسة:**

لقاء الضوء علي تكنولوجيا تنفيذ الجصيات والتي اتضح انها تمت عن طريق استخدام القوالب المجزأة لتنفيذ التشكيلات الصغيرة الحجم وفي حالة التشكيلات الكبيرة الحجم يتم عمل هيكل خراساني ويتم تركيب الاجزاء سابقة الصب علي هذا الهيكل. والالوان التي طبقت عليها من خلال الفحوص والتحليل لهذا النموذج الهندي الفريد في قصر البارون إمبان، والتي اتضح انها الوان اكاسيد مخلوطة بالصمغ العربي .

**الكلمات الدالة :**

حي هليوبولس؛ المعابد الهندية؛ معبد انكوروات؛ الاسمنت المسلح؛ احمر سينا؛ التشكيلات الجصية؛ حيود الاشعة السينية؛ الميكروسكوب الالكتروني الماسح ؛ الاسمنت ؛ اكاسيد الحديد

**Introduction :****The History of the Palace:**

Three generations of Baron Empain's family lived in it until 1954, when its contents were sold in an auction, before the palace itself was sold as well. It was then abandoned, and entered into a long period of neglect during which it was subjected to much destruction and vandalism. In 1993, by order of the Prime Minister, Baron Empain Palace was registered on the Egyptian Antiquities Organization's list of monuments. Coinciding with the celebration of the centennial of Heliopolis in 2005, the owners of Baron Empain Palace were compensated with a plot of land in New Cairo, and ownership was transferred to the Ministry of Housing. The assets of the palace and the land on which it was built were subsequently transferred to the Supreme Council of Antiquities through a donation in 2007.<sup>1</sup> From 2017 to 2020, Baron Empain Palace underwent comprehensive restoration work under the supervision of the Ministry of Tourism and Antiquities and the Armed Forces Engineering Authority, in a project that cost over 100 million Egyptian Pounds in order to breathe new life into it.

<sup>1</sup> EL-ENANY, K., *Heliopolis the City of the Sun*, Zamalek: Ministry of Tourism and Antiquities PRESS 2020, 5.

## The Founder of the Palace :



Figure 1

: Baron Édouard Louis Joseph Empain (1852-1929) source: (Dobrowolska, 2006)

One of the greatest entrepreneurs of the twentieth century, Édouard Louis Joseph Empain 1852-1929, was the oldest of seven children born to a humble schoolteacher from Beloeil in Belgium. He began his career in 1878 as an apprentice draughtsman at "La Metallurgie", a firm involved in railway construction. His work was appreciated and he was quickly promoted. He left to start his own business and began by operating a quarry in the Namur region.<sup>2</sup> In 1889, Empain founded his own Bank – which later becomes the Industrial Bank of Belgium to save capital for his business. In the same year, he founded the "General Company for Railways of the Wide Roads" which was the main stone for his group of companies. This company was able to establish new companies for the first generation.<sup>3</sup> Empain acquired railways in the south of France, and developed others in Russia, Spain and Cairo. He set up networks in Turkey

<sup>2</sup> INST. R., & COLON, B, *Biographies Colonial Belge*, T.II, Brussels: Institute Royal Colonial BELGE, 1951, 357.

<sup>3</sup> TOUSSAINNT, Y., *Le Barons Empain*, France: Librairie Arthème Fayard, 1996, 22.

and the Caucasus.<sup>4</sup> Thus, in 1904, he established the Great African Lakes Railway Company. Wherefore, king Leopold II honored Empain by giving him the title of "Baron" in 1907 for his efforts to develop the colonies. In 1914, the World War I has broken out. Empain, the colonel, was responsible for organizing the rapid transfer of the Front and putting all his work to serve the government. In 1916, he became a general commissioner throughout the war. In 1918, he was appointed as a General and Assistant to the King's Front.<sup>5</sup> In 1905, the Egyptian government granted Empain and his friend Boghos Nubar Pasha a concession on which to construct the suburb of Heliopolis. In 1906, he founded the Cairo Electric Railways and Heliopolis Oases Company, and work began on what would come to be considered an exceptional example of a project to urbanise the desert.<sup>6</sup> He then crowned the new suburb with his majestic palace that is built in the style of Hindu temples.

### The palace:

Baron Palace is one of the most remarkable monuments in the Capital, and one of its unique silhouettes that located in the road connecting the center of Cairo to the airport. The villa Empain situated at high point of the plateau in Avenue Al-Uruba, which was 'town's Avenue des Palais' previously.<sup>7</sup> The architect Alexandre Marcel 1860-1928 built it in 1907-1911, and the interior designs were made by Georges-Louis Claude.<sup>8</sup> Baron Empain built his own palace in a completely different style as a Hindu temple fantasy in reinforced concrete.<sup>9</sup> Its structural design is of a cross-cultural with a combination of Hindu, Islamic and Renaissance architecture.<sup>10</sup> The building style was inspired by the Angkor vat temple from 12<sup>th</sup> century in Cambodia. The idea of introducing the Indian style in

<sup>4</sup> BRUWIER, M., & LOO, A , *fonds mercator* , Brussels, Héliopolis, 2010, 91.

<sup>5</sup> INST. R., COLON, B , *Biographies Colonial BELGE*, 363.

<sup>6</sup> HELIOPOLIS COMPANY FOR HOUSING & CONSTRUCTION, *Daheyat Misr al-Gadida. Madiha wa Mostaqbalha* , MASLAHET ALMESAHA, 1969, 5.

<sup>7</sup> BRUWIER , LOO, *Héliopolis*, 131.

<sup>8</sup> JAKUB G , *Heliopolis City in the city*, ETH Studio Basel Contemporary City Institute, 2010, 170.

<sup>9</sup> DOBROWOLSKI, A. & JAROSTAW, D , *Heliopolis rebirth of the city of the Sun*, CAIRO: The American University in Cairo press, 2006, 87.

<sup>10</sup> BELAL, M. & MAHER, R .: « Baron Empain Palace Innovative Ideas to Accommodate Untraditional Types of Tourism », *International Academic Journal*, Faculty of Tourism and Hotel Management, 2012, 7.

Heliopolis was suggested by Alexandre Marcel who already built a Cambodia pavilion for the 1900 EXPO in Paris. Baron Palace had a commercial function to fulfill as well as being a dwelling. It was supposed to work as a landmark generating attention to Heliopolis. It was considered as an example of the marketing used by Empain for the successful development of his desert city.<sup>11</sup> The palace consists of two floors and a basement, which was for kitchens and servants stay, the two floors contain only seven rooms; its floor is made of Italian and Belgian marble and the parquet was also used to cover the floors.<sup>12</sup> The Palace was located in the middle of a large garden consists of plants collected from all over the world.<sup>13</sup> (Jakub, 2010) The garden is punctuated by several corridors, the largest path leading to the great staircase that leads in turn to the main entrance to the palace. The palace is preceded by a series of ascending terraces, each with its own set of intriguing marble statues.<sup>14</sup> By looking closely, we can see the exquisite details of the decorations. The smallest parts of this construction, as in Hindu constructions, are full of statues and inscriptions, but moderately, in a way that distinguishes this pattern from stacking. The large tower is characterized by its bold and harmonious shape, where we find that it simulates the ancient Hindu temples, but the architecture has changed in a way gave it a modern style.<sup>15</sup> These decoration elements were often executed in advance and then transferred from France and assembled at the site. (figure 2) The molds themselves were executed in reinforced cement resembling pieces of Lego on top of some, it is called Hennebique system.<sup>16</sup> (figure 3)

<sup>11</sup> JAKUB., *Heliopolis City in the city*, 170.

<sup>12</sup> SOLIMAN, S., *Qaherat Al-Kosor Fe Al-Karn Al-Tasea' Ashr Wa Matlaa' Al-Karn AL-Eshreen*, Tarek Waly Center Architecture And Heritage. 2013. ( Accessed Dec 3, 2020 <http://bit.ly/2AmGIRU>)

<sup>13</sup> JAKUB., *Heliopolis City in the city*, 170.

<sup>14</sup> BELAL, M. & MAHER, R. *Baron Empain Palace*, 9.

<sup>15</sup> GUENU, EUE, *Le Palais Hindou D'Heliopolis Le Beton Arme*, PARIS, 157, 1911, 82.

<sup>16</sup> TOUSSAINNT, *Le Barons Empain*, 70.



Figure 2

Storage of molded elements at the worksite of the Baron Palace source: (Bruwire, 2010)

The molds themselves were executed in reinforced cement resembling pieces of Lego on top of some, it is called Hennebique system.<sup>17</sup> (figure 3)

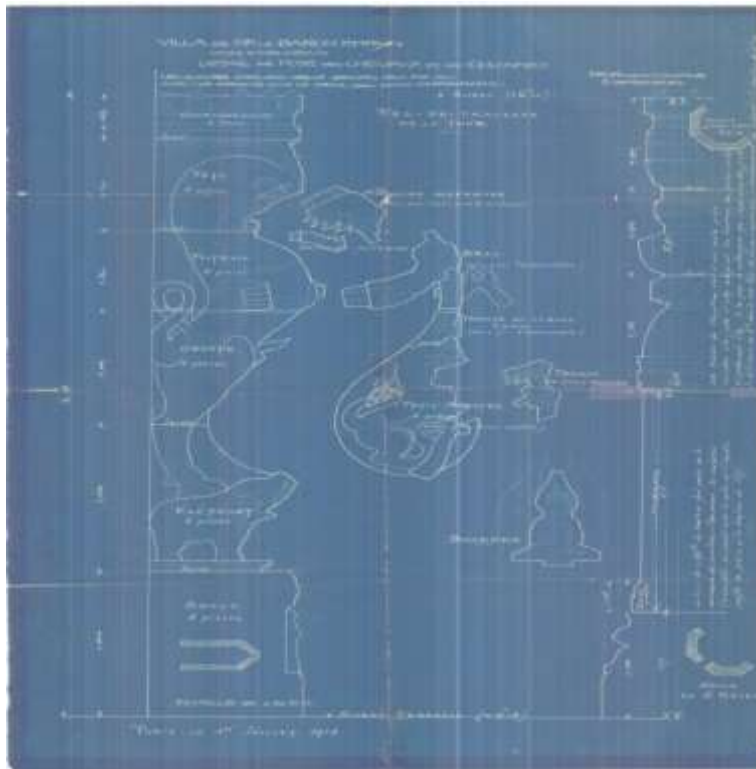


Figure 3

Plan shows one of the decorative elements and the way to group them together Source: (Heliopolis Company for Housing and Construction)

<sup>17</sup> TOUSSAINNT, *Le Barons Empain*, 70.

Finally, to set the tone, the architect decided to make this building in Siena, with layers of burnt Sienna color. The result was obtained by using colors based on iron oxides, and by spraying the parts to be tinted by means of pumps. The effect given is satisfactory and the process, as original as it is.<sup>18</sup> As previously mentioned, these decorative elements were inspired by Hindu temples, as the facades of these temples are covered with a large number of sculptures that depict figures and topics from Hinduism and Buddhism, such as Hindu gods, the Buddha, sacred plants and animals, and fantastical creatures from Hindu mythology. Below are some examples of the subjects of these sculptures

### 1. The Temptation of the Buddha (figure 4):



Figure :4

The Temptation of the Buddha Source: (Photo by Author 2020)

The temptation of the Buddha, depicted here on a plaster panel set above the main entrance into the palace, is a popular topic in Buddhist art. The demon Mara is said to have tried in vain to disrupt Gautama Buddha's meditation to prevent him from obtaining enlightenment by tempting him with his three beautiful daughters.

<sup>18</sup> GUENU, EUE. ,*Le Palais Hindou D'Heliopolis* , 85.



## 2. Shiva the Destroyer (figure 5)



Figure 5

Shiva the Destroyer Source: (Photo by Author 2020)

This reinforced concrete statue of Shiva was cast in a mould. Shiva the Destroyer was the third god in the Trimurti, the Triad of deities in Hinduism, along with Brahma the Creator and Vishnu the Preserver, who is charged with destroying the world. This statue depicts him surrounded by cobras that he would use as weapons, depicted within a fiery oval framework. This is the cosmic circle of fire, which represents the eternal cycle of creation and destruction of the universe.

### 3. Naga (figure 6)



Figure 6

Naga Source: (Photo by Author 2020)

Cast reinforced concrete statue depicting the Naga, divine or semi-divine beings that guard sacred sites. A naga was depicted either as a single cobra, or as a cobra with seven heads that fan out, taking the form of a flame. The naga sculptures adorning the palace of Baron Empain were inspired from those guarding the Angkor Wat temple complex in Cambodia, where they constitute an important part of Khmer architecture.

#### 4. Yali (figure 7)



Figure 7

Yali Source: (Photo by Author 2020)

Cast reinforced concrete statue depicting the Yali, a mythical animal that can often be seen sculpted on the pillars of Hindu temples because of its role as a protector against evil. The archaeological and historical studies of the palace dealt with the method of implementing the decorative stucco elements of the facades, which consist of precast cement plaster, as well as the stucco decorative elements on the main gate of the palace. Another way to find out how to implement the decorative elements is based on extrapolating the nature of the decorated surfaces to see some of the distinctive signs that indicate the method of implementing these elements.

## Results and discussion:

### Implementation and decoration technology of Stucco formations

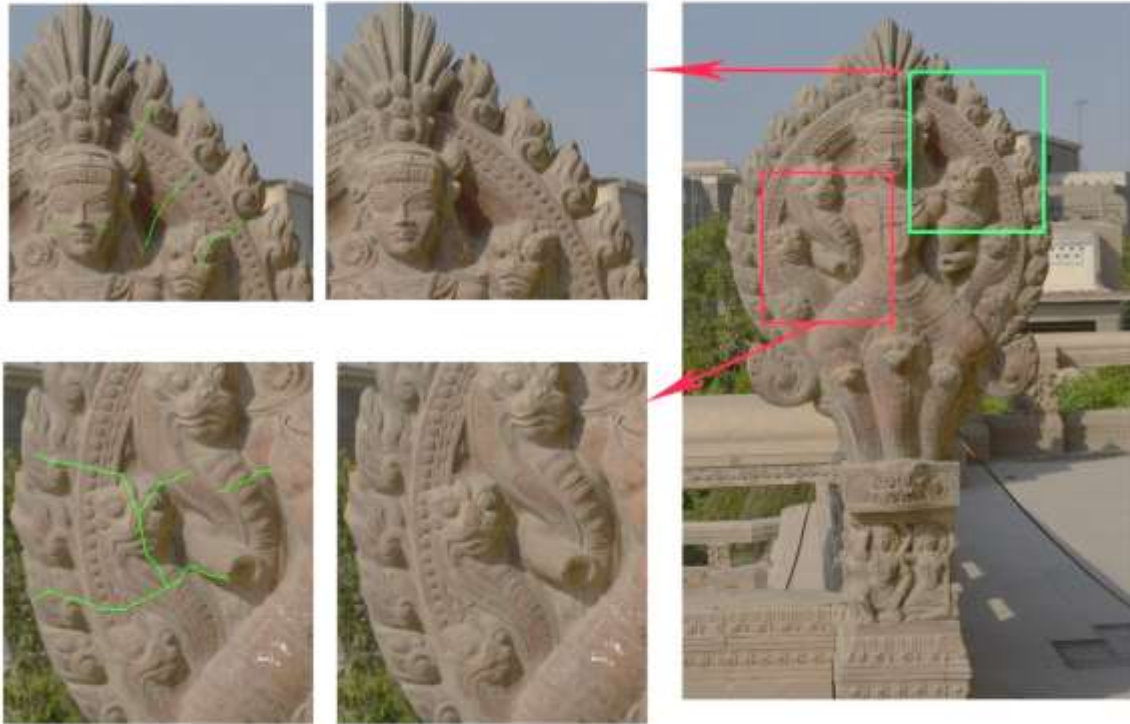


Figure 8

shows Distinctive Signs in Shiva the Destroyer(Photo by Author 2020)

### Distinctive Signs in Shiva the Destroyer :

Figure 8 shows the marks identified in phosphorescent green, which are the marks resulting from casting in the segmented molds, as each part was separated from the adjacent part by something like a thin thread, and these marks remained to bear witness to the technology of execution by casting in segmented molds and these marks were preserved to be Evidence of implementation technology. Here, the stucco element was completely executed by molding and installed. Another way to implement stucco elements in Figure 9 it is Claire that it is a concrete body from the inside and is covered with parts pre-cast in a split mold and installed on the concrete body and the Figure also shows clear remnants of the red

pigment that used to cover all the stucco elements and the color appears here at the base. It has also acidic erosion damage.



Figure 9

show One of the stucco elements that represent a mythical animal

(Photo by Author 2020)



Figure 10

shows the stucco formations on one of the facades of the palace .

(Photo by Author 2020)

Also Figure 10 showing a protrusion that hides some elements, which preserved the original color of the facades, and here the color damaged due to the descent of acid rain. Color residue is a strong evidence of coloring the facades in red pigment. The use of examination and analysis to determine the used materials in the implementation of the stucco elements in the palace. First, the material of the stucco

## 1- Cement stucco:



Figure 11

shows taking a separate sample from one of the damaged stucco formations.

(Photo by Author 2020)

## XRF analyses:

Table 1 showing the composition of cement plaster

|                                |       |
|--------------------------------|-------|
| C.N                            | 5396  |
| D.N                            | B     |
| SI O <sub>2</sub>              | 29.63 |
| TIO <sub>2</sub>               | 0.36  |
| AL <sub>2</sub> O <sub>3</sub> | 3.79  |
| FE <sub>2</sub> O <sub>3</sub> | 2.90  |
| MnO                            | 0.02  |
| MgO                            | 1.52  |
| CaO                            | 36.95 |
| Na <sub>2</sub> O              | 0.03  |
| K <sub>2</sub> O               | 0.30  |
| P <sub>2</sub> O <sub>5</sub>  | 0.03  |
| CL                             | 0.80  |
| SO <sub>3</sub>                | 3.60  |
| LOI                            | 19.78 |

Table 1

showing the composition of cement plaster, which forms the external plaster formations in the facades of the palace, where the presence of calcium and aluminum oxides and a high percentage of sand <sup>19</sup> indicates that the stucco are cement stucco. And it may be the Roman cements , In these natural hydraulic binders the reactive phases are not added as aggregate, but formed in the kiln through the reaction of the clays and the quicklime. They can be considered the precursors of modern Portland clinker. NHL were very popular for building construction and facade decoration in Central Europe in the 19th century. They were, and are still, used extensively for restoration of historical buildings .<sup>20</sup>Portland cement consists of calcium silicate agglomerates with an interstitial matrix of iron-bearing ferrite. The residual texture of the hydrated minerals can be visible within the remaining ferrite. , and can be used to confirm that a binder is Portland cement. <sup>21</sup>So Portland cement, ASTM C 150, <sup>22</sup> serves as the basic active ingredient in our stucco **Gypsum stucco and colors:**

<sup>19</sup> M. S. ALI , KHAN I. A & HOSSAIN, M. I. .: «CHEMICAL ANALYSIS OF ORDINARY PORTLAND CEMENT OF BANGLADESH », *Chemical Engineering Research Bulletin* 12 , 2008 , 7 -10

<sup>20</sup> ARTIOLI, G . & ADDIS, A .: « The Vitruvian legacy: mortars and binders before and after the oman world » , *International Academic Journal*, EMU Notes in Mineralogy, 20 , 2019, 4, 151–202, 169

<sup>21</sup> FIGUERO , G , .: «Mortar Analysis For Archaeological Stratigraphy: The Stadt Huys Block And Seven Hanover Square Sites » *MASTER THESIS*, Graduate School of Architecture, Planning, & Preservation , Columbia University , MAY, 2019 68

<sup>22</sup> MELANDER, J . & FARNY, J & ISBERNERA , *Portland CementPlaster/Stucco Manual* , Fifth Edition Portland Cement Association ( PCA ) , Internet: [www.cement.org](http://www.cement.org) , 130





Figure 12

shows the reddish color of the stucco elements that represent a peacock, and the place where the sample was taken of stucco and colors. (Photo by Author 2020)

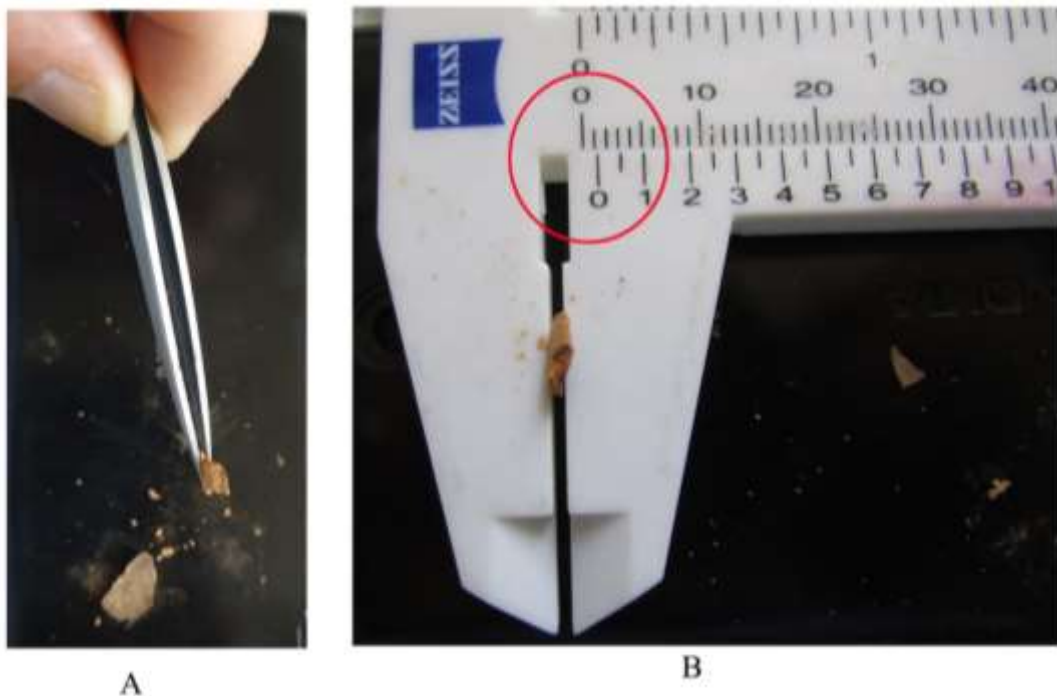


Figure 13

shows A - capture of a veneer of color , B - Measuring the color crust with the Vernier Caliper and The thickness of the veneer inside the red circle

The thickness of the peacock's color scales was measured by Vernier Caliper to determine the thickness of those scales, which reached a thickness of 1.1 - 1.2 mm. Due to the thickness of the color layer, which is somewhat large, its fall was easy due to its being affected by weather factors.

### X-ray diffraction analysis for stucco and pigment :

Specifications of the X-ray diffraction analyzer Technique used  
A PANalytical X-Ray Diffraction equipment model X,Pert PRO with Monochromator Cu-radiation ( $k=1.542\text{\AA}$ ) at 50 K.V., 40 M.A. and scanning speed 0.020/sec. were used. The reflection peaks between  $2\theta = 20$  and 60, corresponding spacing ( $d$ ,  $\text{\AA}$ ) and relative intensities (1/10) were obtained. The diffraction charts and relative intensities are obtained and compared with ICDD files.

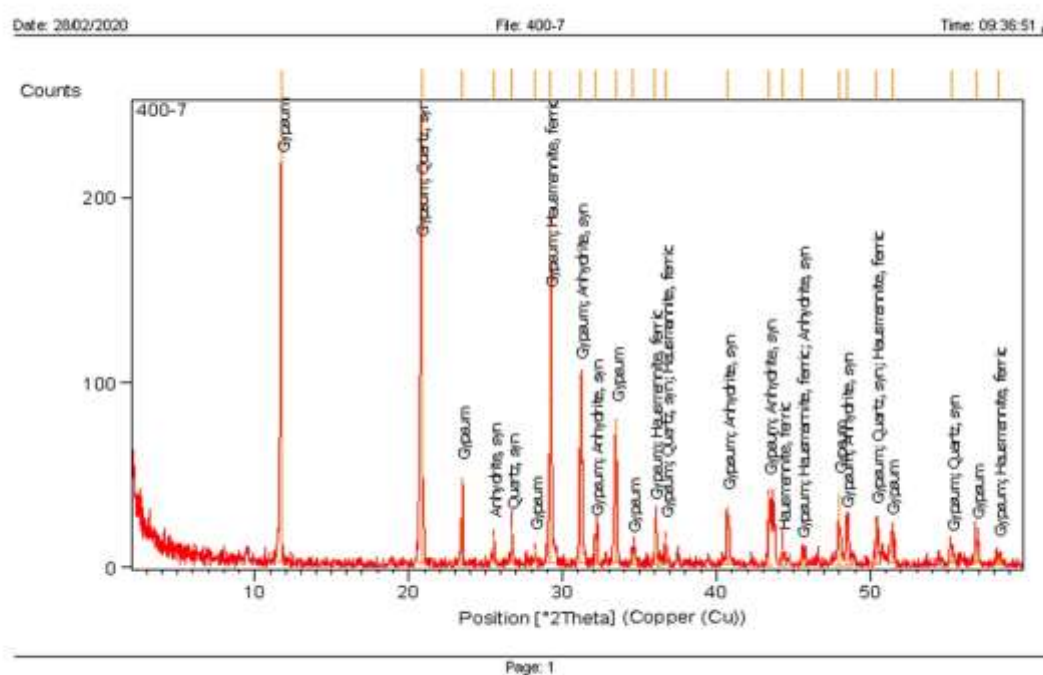


Figure 14

shows the pattern of X-ray diffraction analysis of a stucco sample taken from a peacock

Table 2 shows the minerals that consist the stucco sample

| Ref. Code   | Mineral Name        | Chemical Formula                               | Semi Quant [%] |
|-------------|---------------------|--|----------------|
| 00-006-0047 | Gypsum              | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$      | 81             |
| 01-085-0865 | Quartz, syn         | $\text{SiO}_2$                                 | 5              |
| 01-073-9856 | Hausmannite, ferric | $(\text{Mn}_{2.88}\text{Fe}_{0.12})\text{O}_4$ | 8              |
| 00-006-0226 | Anhydrite, syn      | $\text{CaSO}_4$                                | 6              |

the minerals that consist the stucco sample taken from the peacock it appears that it is a gypsum stucco due to the presence of gypsum by 81% and the anhydrite by 6%, meaning that the gypsum component is about 90% and the presence of Hausmannite, ferric, which is It is mixed with hematite, and small ratio of sand . and the gypsum stucco is a traditional stucco in the majority of archeological sites, the studied stucco samples from the minaret of Shams El-Deen El-Wasty (16century) indicate the following results the intermediate phases (hemihydrates and calcium hydroxide) and the final phases of binders (gypsum and calcite) was used<sup>23</sup>

Specifications of the scanning electronic microscope SEM Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., magnification 14x up to 1000000 and resolution for Gun.1n).gypsum mineral needle crystals are clearly obvious. In the stucco sample taken from the peacock, Figure 15 and that confirm the Xrd results and also EDX analysis of sample taken from the peacock show the presence of silicon and sulfur. So The gypsum is a main component . Figure 16

<sup>23</sup> ABDULLAH, M. & HASSAN, A & HALA, A & MONA, F .: « Mineralogical characterization of Islamic stucco » , *International Academic Journal*, Egypt , Bulaq, Minaret of Shams El-Deen El-Wasty , Construction and Building Materials 101 (2015) 692–701, 699

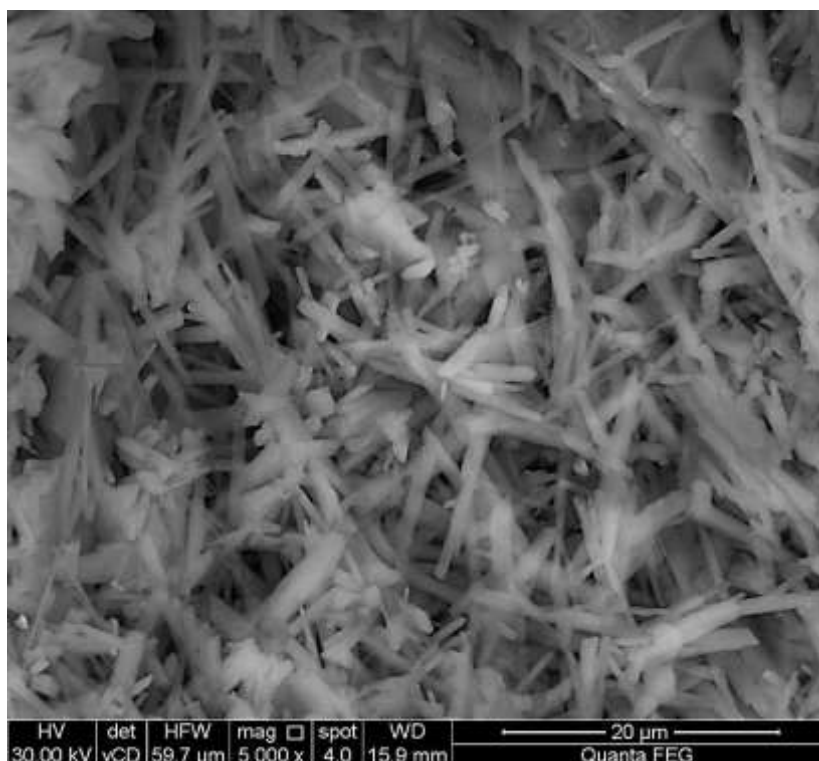


Figure 15

SEM micrograph shows the minerals that consist the stucco sample taken from the peacock, and the gypsum mineral needle crystals are clearly obvious.

### X-ray diffraction analysis of the red pigment sample:

Table 3 shows the minerals that consist the red color

| Ref. Code   | Mineral Name | Chemical Formula                                   | SemiQuant [%] |
|-------------|--------------|--|---------------|
| 01-072-0596 | Gypsum       | $\text{Ca} (\text{S O}_4) (\text{H}_2 \text{O})_2$ | 30            |
| 01-074-3485 | Quartz       | $\text{Si O}_2$                                    | 25            |
| 00-036-0617 | Bassanite    | $\text{Ca S O}_4 \cdot 0.67 \text{H}_2 \text{O}$   | 35            |
| 00-001-1053 | Hematite     | $\text{Fe}_2 \text{O}_3$                           | 10            |

Table 3

shows the minerals that consist the red pigment sample taken from the peacock and it appears that it is gypsum mixed with red color due to

the presence of gypsum by 30% and the Bassanite by 35%, meaning that the gypsum component is about 65% and the presence of hematite, which is the red pigment. with different amounts of impurities especially quartz which the main feature of ochres in general <sup>24</sup> and SEM micrograph shows the distribution of hematite crystals used in the coloration of the stucco peacock formations Figure 18 and EDX analysis for the pigment and stucco sample taken from peacocks, it shows the iron percentage expressing hematite mineral, and also The presence of calcium and sulfur ions confirms the mixture of color with the surface layer of stucco, The presence of silicon and aluminum ions expresses the presence of earthy minerals from dust deposits on the archaeological surface Figure 19

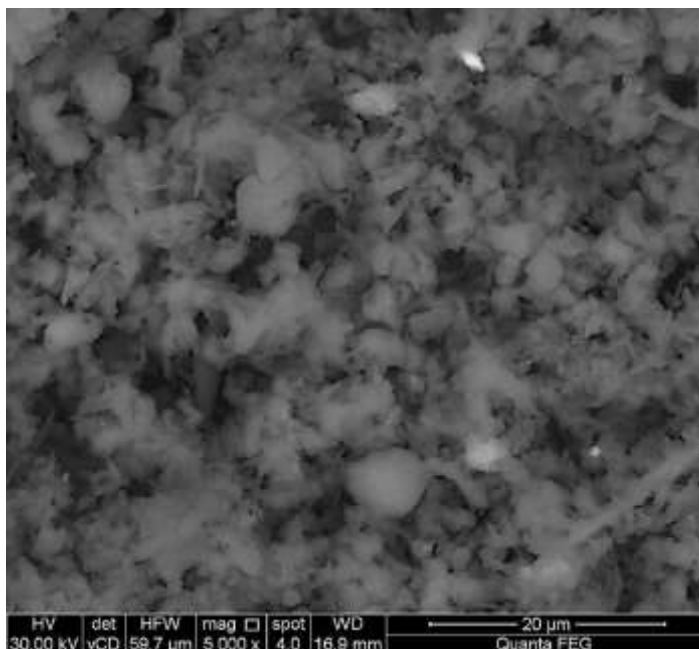


Figure 18

SEM micrograph shows the distribution of hematite used in the coloration of the stucco peacock formations

<sup>24</sup> EL-GOHARY, M. & AL-EMAM, E .: « A closer look at the materials used Mediterranean Archaeology and Archaeometry » , *International Academic Journal*, The paint layers of mural paintings at abydos temples , Egypt15, N°3, 113-121 , 118

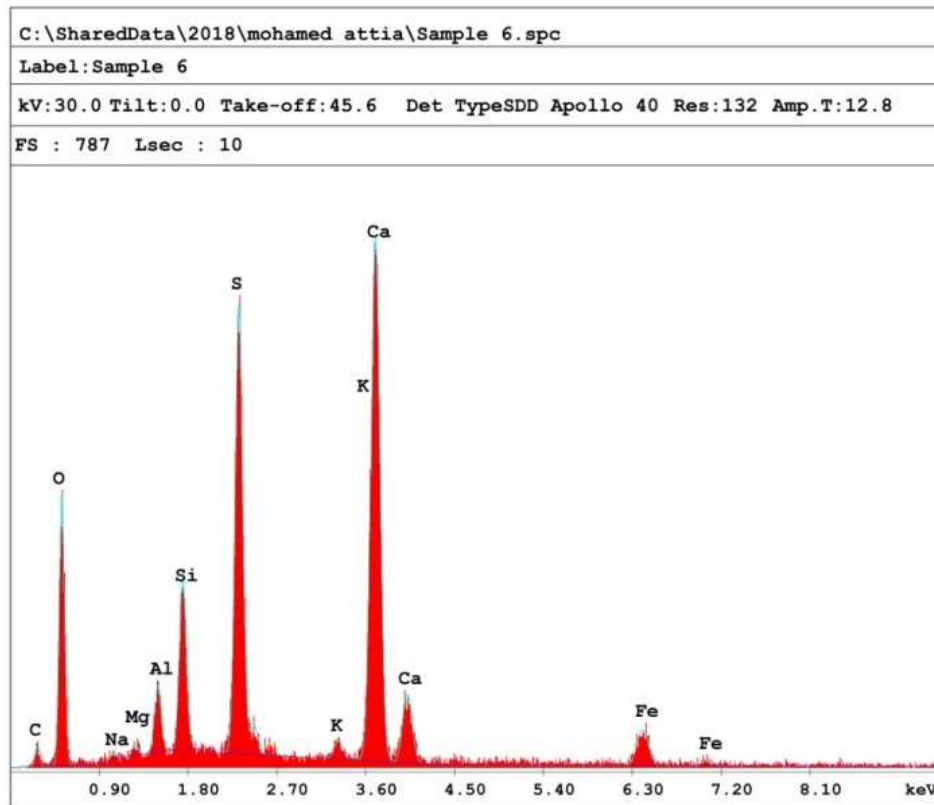


Figure 19

shows the EDX analysis for the pigment and stucco sample taken from peacocks, and it shows the iron percentage expressing hematite mineral.

## Infrared analysis for the media

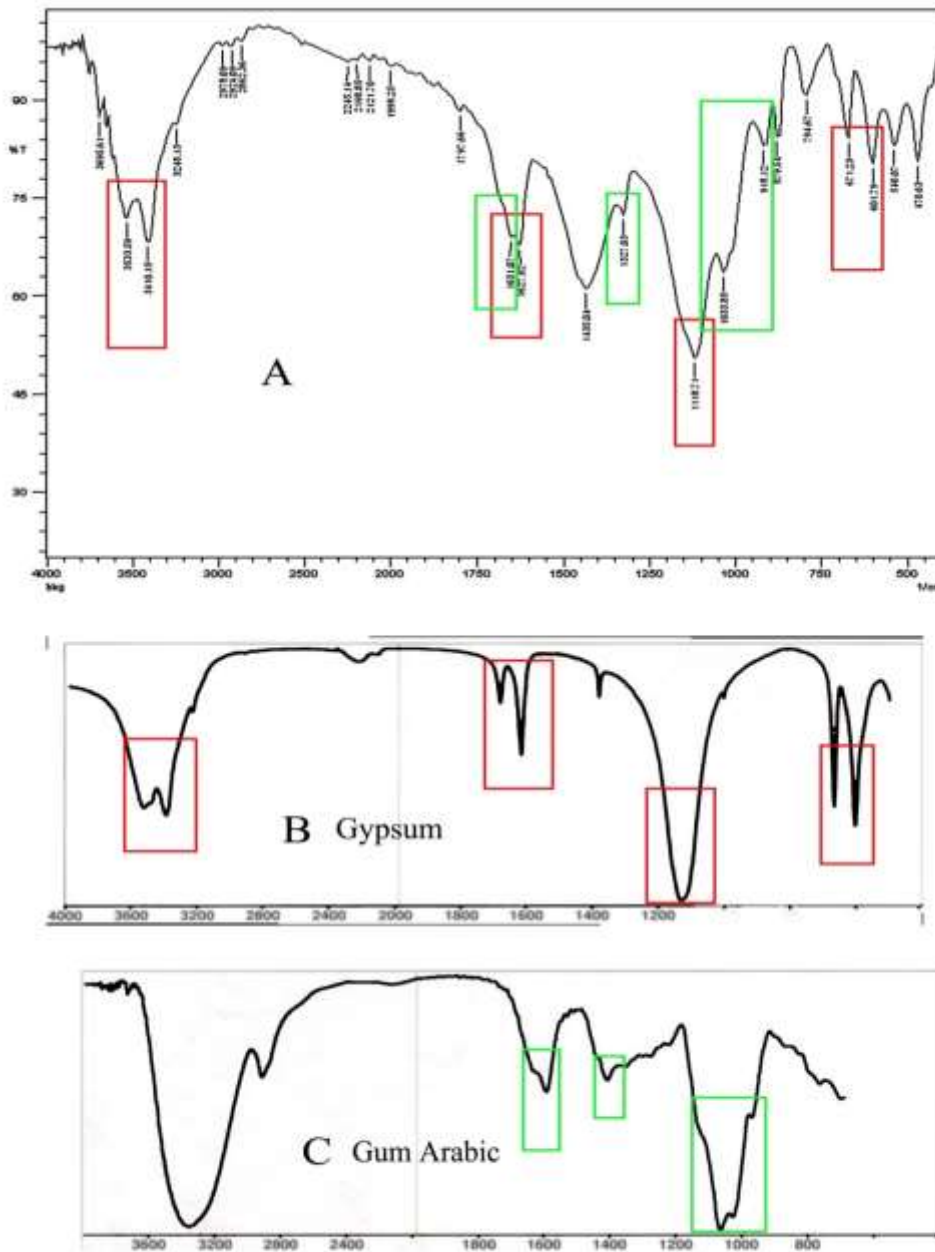


Figure 20

shows the IR spectra for the pigment sample taken from peacocks compared with gypsum B and gum Arabic C stander spectra's

The identification of the media that mixed with iron oxides pigment, a sample of pigment was analyzed using an infrared analysis, and compared with the potential media that used with inorganic pigments. The gum Arabic media used due to the identical presence of the following

functional groups in the analyzed sample compared to a standard sample of gum Arabic and with a standard sample of gypsum<sup>25</sup> (figure 20) and the functional groups are as follows .table 4 shows the functional groups of a sample of pigment compared to a standard sample of gum Arabic and a standard sample of gypsum.

| functional groups                                 | sample of colors (A) | Standard sample for gypsum (B) | A standard sample of gum Arabic(C) |
|---|----------------------|--------------------------------|------------------------------------|
| anti-symmetric and symmetric O-H stretching bands | 3410 - 3533 cm-1     | 3700-3200 cm-1                 | 3200- 3600 cm-1                    |
| C-H stretching bands                              | 2862 -2970 cm-1      | -----                          | 2800- 3000 cm-1                    |
| O-H bending band                                  | 1627 -1651 cm-1      | 1600 -1670 cm-1                | 1650 cm-1                          |
| C-H bending band                                  | 1327 cm-1            | -----                          | 1300 - 1480cm-1                    |
| COO stretching bands                              | 918 -1033 cm-1       | -----                          | 900 - 1300cm-1                     |
| asymmetric SO <sub>4</sub> stretching band        | 1118 cm-1            | 1080-1140 cm-1                 | -----                              |
| SO <sub>4</sub> . bending band                    | 601-671 cm-1         | 620 cm-1                       | -----                              |

It is clear from the functional groups table that the functional groups in the analyzed sample are the same as the functional groups that consist the gum Arabic stander sample and the gypsum stander sample. Therefore, the media used to fix the color layer is gum Arabic and the presence of sulfate groups representing gypsum mineral the main component of stucco matching X-ray diffraction analysis Results in Peacock stucco sample.

<sup>25</sup> MICHELE , R . & DUSAN , S & JAMES, M. , *Infrared Spectroscopy in Conservation Science*, Los Angeles: The Getty Conservation Institute, Printed in the United States of America , 1999 , J. PAUL , GETTY TRUST , 179-180



## Investigation of Peacock stucco reinforcement material :

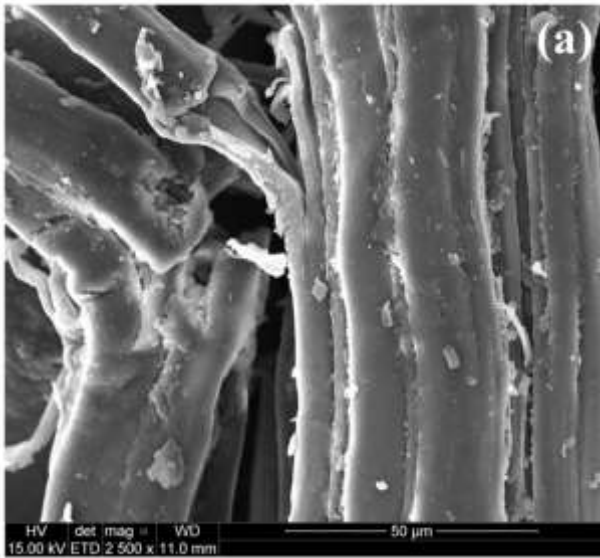


Figure 21

. SEM micrograph of raw (a) jute fibers.<sup>26</sup>

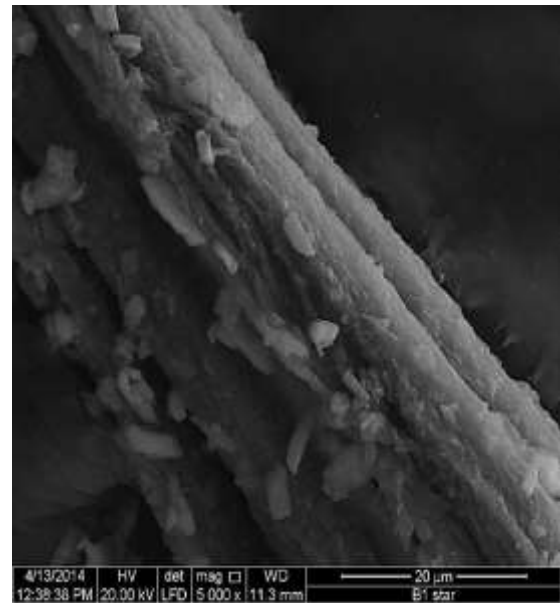


Figure 22

SEM micrograph of a sample of the reinforcement material for the peacock stucco

the reinforcement material for the peacock stucco Investigated under SEM and compared with raw jute fibers SEM micrograph . which is usually in the form of a band of stripes, which is what distinguishes the jute fibers. This confirms the use of jute to reinforce stucco formations.

### Conclusion:

There are various ways to implement stucco formation as follow. Firstly : It is evident from the extrapolation of the distinctive signs of using molds in casting stucco in the palace that segmented molds were used in the implementation of decorations with intricate details. Figure 2 ,3 ,8 Here, the stucco element was completely executed by molding and installed. Secondly : it is Claire that it is a concrete body from the inside and covered with parts pre-cast in a split mold and installed on the concrete body. Figure 9 We can also observe the diversity of the stucco material, where sometimes Portland cement was used XRF analyses Table 1 confirmed that. at other times gypsum was the main component of stucco , which confirms the diversity of components used in casting the raw material. The stucco is appropriate to the complex stucco formations such

<sup>26</sup> CORREIA , C . & OLIVEIRA , L . & VALERA , T . : « The Influence of Bleached Jute Fiber Filler on the Properties of Vulcanized Natural Rubber », Materials Research , *International Academic Journal* , São Carlos 2 , Nº. 20 , 2017 Epub Oct 30 , 2017,3

as the deities mentioned above. the peacock it appears that it is a gypsum stucco due to the presence of gypsum by 81% and the anhydrite by 6%, meaning that the gypsum component is about 90% table 2 the reinforcement material for the peacock stucco Investigated under SEM and compared with raw jute fibers SEM micrograph . which is usually in the form of a band of stripes, which is what distinguishes the jute fibers. This confirms the use of jute to reinforce stucco formations. Figure 21,22 As for the colors used in the palace, Color residue is a strong evidence of coloring the facades in red pigment. Figure 10 and color scales was measured by Vernier Caliper to determine the thickness of those scales, which reached a thickness of 1.1 - 1.2 mm. Figure 13 the X-ray diffraction analysis and the EDX unit confirmed that the presence of ferrous minerals such as hematite and Hausmannite, ferric, leaving no doubt that iron oxides are used in palace coloring. the presence of hematite, which is the red pigment. with different amounts of impurities especially quartz which the main feature of ochres in general. table 3 Infrared analysis for the media ,the analyzed sample are the same as the functional groups that consist the gum Arabic stander sample and the gypsum stander sample. Therefore, the media used to fix the color layer is gum Arabic table 4 , Figure 20 The chemical and mineralogical study of the stucco mortars of the palace shown that mortars is contributing for the knowledge of the construction technologies used in this part of the site.<sup>27</sup>

<sup>27</sup> MORRICONE , A & MACCHIA , A & CAMPANELLA, L & DAVID, M & TOGNI , S & TURCI , M.:«Archeometrical analysis for the characterization of mortars from Ostia Antica», *International Academic Journal*8, 2013 ,231 – 238 , 235

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