EVALUATION OF SOME SELECTED GAP-FILLING MATERIALS USED IN RESTORATION OF ARCHAEOLOGICAL POTTERY EXCAVATED FROM TELL BASTA IN SHARKIA: AN EXPERIMENTAL AND APPLIED STUDY

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ABSTRACT

تقييم بعض مواد الاستكمال المستخدمة في ترميم الفخار الأثري المستخرج من تل بسطة بالشرقية: دراسة تجريبية وتطبيقية **[AR]**

الفخار الأثري الذي تم الكشف عنه بتل بسطة بالشرقية هش ومكسور، ومعظم القطع الفخارية المستخرجة من الحفائر تعاني من فقد لأحد الاجزاء مثل البدن أو الفوهة أو المقبض أو الحافة أو القاعدة، ومثل هذه النوعية تحتاج إلى عمليات استكمال حيث تعد من أهم عمليات الترميم والصيانة لتلك النوعية من الآثار الفخارية. وتعتبر عملية الاستكمال بمثابة إعادة احياء تاريخي للفخار بالتعرف على معالمه الاجتماعية والاقتصادية والدينية. وتم إجراء تقييم لبعض مواد الاستكمال المختارة بإجراء العديد من التجارب والاختبارات كتعيين وقت التشغيل ودرجة الانكماش ومقاومة الضغط قبل وبعد التقادم الصناعي المعجل بالحرارة والتقادم الضوئي بالأشعة فوق البنفسجية وتعيين قوة الضغط والخواص الفيزيائية قبل وبعد التقادم الملحي بغرض تقييم مواد الاستكمال المختارة حتى يتثنى اختيار أفضلها وأنسبها في استكمال القطع الفخارية بتل بسطة بالشرقية. وقد اثبتت الدراسة التجريبية نجاح وكفاءة بعض مواد الاستكمال حيث يوصي البحث بضرورة استخدام أحد مواد الاستكمال التي ثبت نجاحها بكفاءة في عملية استكمال الفخار الأثري بتل بسطة وهما: أولا: خليط الميكروبالون ومسحوق الفخار بنسبة 1:2 على التوالي. ثانيا: خليط البولي فيلا ومسحوق الفخار بنسبة 1:2 على التوالي. وتم التطبيق علي طبق فخاري مستخرج من تل بسطة بالشرقية بترميمه وعلاجه واستكماله باستخدام خليط الميكروبالون ومسحوق الفخار بنسبة 1:2 على التوالي، وبعد ترميمه وصيانته أصبح جاهزا للعرض المتحفي بمتحف تل بسطة بالشرقية.

[EN] The archaeological pottery discovered in tell Basta in Sharkia is fragile and broken and most of the pottery objects excavated from Sharkia suffer from loss of one of their parts such as body, rims handle and base. As a result, the pottery needs gap filling, which is one of the most important restoration and maintenance processes. This process is considered a historical revival identifying social, religious and commercial aspects. An assessment of some selected filling materials was done by conducting many experiments and tests such as determining work time, shrinkage degree, compressive strength, accelerated artificial thermal and light (U.V) ageing, salt weathering, compressive strength and physical properties after accelerated artificial ageing for selecting the most appropriate materials in replacement process. This experimental study on filling materials proved successful and efficient loss compensation materials, and it is recommended to use one of the following filling materials: (First: a mixture of microballoon and pottery powder (grog) in a ratio of 2: 1 respectively, Second: a mixture of Poly filla and pottery powder (grog) in a ratio of 2: 1 respectively). In the applied part of the study, restoration, treatment and replacement were conducted on an excavated pottery plate from tell Basta in Sharkia using a mixture of microballon and pottery powder (grog) in a ratio of 2: 1, prior to its museum display at tell Basta Museum, Sharkia governorate.

KEYWORDS: Ageing, grog, microballoon, poly filla, pottery, replacement, shrinkage.

I. INTRODUCTION

Bubastis is one of the most important capitals of ancient Egypt; excavations area had proved that it was inhabited since dawn of ancient Egyptian history. Egyptian historical sources mentioned that Bubastis was the thirteenth province of Delta provinces. Then it became an independent province, and was the eighteenth province, and its capital was Bubastis. Today, the archaeological site is known as tell Basta (Sharkia), it was known in Hellenistic era as Bubastis. Both names (Bubastis - Basta) are derived from ancient Pharaonic name «Br-Bastet», which means «house of goddess Bastet»[1] **[FIGURE 1]**.

[FIGURE 1]: Represents Tell Basta, Sharkia© Taken by the researcher

Damage manifestations of archaeological pottery varied at excavation sites as a result of exposure to various damage factors that may cause cracking or fracture of the pottery body[2], as pottery is breakable by pressures and external soil loads, or as a result of exposure to impact damage, which is irreversible mechanical damage. The fracture may be accompanied by a small or large loss depending on the pressure force. This damage may lead to complete fragmentation[3]. The same mechanical damage can occur because of fault lifting, floods, earthquakes[4], tunneling and reclamation of agricultural land by plows. Damage degree and loss of the pottery body depends on nature of burial environment, whether direct or indirect. The fracture and loss degree increase when the pottery is close to surface soil[5].

After assembling process, some pottery pieces may lose one of their parts. These missing parts differ in their shape and place in the pottery body, so replacement process varies according to missing part shape. This process may be simple or complex because each lost part needs certain filling method[6]. Replacement process is one of the most

[1]NOUREDDINE 2018: 356.
[2]PRICE 2011: 1-4.
[3]RYDZEWSKI 2021:781-790.
[4]SALEH et Al 2020: 97-108.
[5]ZAREMBA et Al 2021:67-81.
[6]WILLIAM 2002: 49-50.

important treatment interventions[7]. A complex replacement process depends on skill of restorer[8]. Filling materials should have various features such as retrieval properties, chemically inactive[9], adequate tensile strength, stability and non-shrinkage[10]. A shrinkage and expansion coefficient should be close to those of the pottery materials. In addition, they should have resistance against microorganisms. It should be easy to shape and have an appropriate work time for modelling. It should not distort the archaeological pottery surface[11], match the pottery body color[12] and be compatible with the charters approved by organizations in this field[13] .

The replacement process always needs a conscious restorer because it is an artwork; its goal is to preserve authenticity of pottery objects. By restoration of pottery that lost shape by filling materials, one can identify social, cultural, religious and commercial aspects for that era[14], therefore, the restorer must focus on historical, artistic and archaeological value during replacement process[15]. Replacement process varies from one country to another according to prevailing philosophy school, technical skill of conservator, nature of the loss part, and filling materials[16]. Many filling materials had varied with progress of chemistry[17] such as dental wax, reinforced aluminum sheets, synthetic rubber, polyfilla, Durofix, some acrylic and vinyl pastes such as **A.J.K** dough[18]. Therefore, conservators should be more specialized in this field[19], with the continuous development of the filling materials[20]. In this study, some filling materials will be evaluated to select the best and most appropriate ones in replacement of some of the archaeological pottery excavated from Tell Basta in Sharkia as an experimental and applied study.

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[7]HASSAN 2021: 879-892.
[8]MONACO et Al 2021:41-50.
[9]FIORENTNO & BORRELLI 1975:202.
[10]DOWMAN 1970:62-63.
[11]CAUPER et Al 2021:311-322.
[12]SANDU et Al 2021:361-390.
[13]ABD AL KAREEM et Al 2021:417-428.
[14]BDRABOU et Al 2021:403-416.
[15]AL SAAD & BATAINEHM 2021:493-506.
[16]HEFNI et Al 2021: 325-334.
[17]IVASHKO et Al 2021:935-960.
[18]LARNEY 1971: 74-75.
[19]HAMAD et Al 2021:105-112.
[20]CAYME 2021:977-986.

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II. MATERIALS AND METHODS

1. Study Materials

A. Archaeological Pottery

A pottery plate from was selected for the applied study as shown in **[FIGURE 2]**.

[FIGURE 2]: Represents the pottery plate, Tell Basta, Sharkia

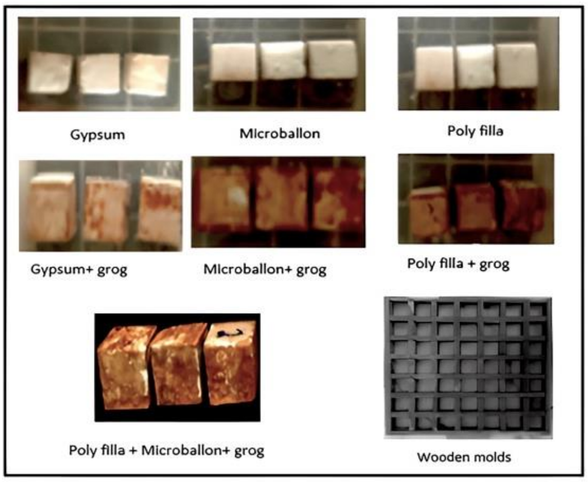
B. Selected Filling Materials

Filling materials selected for the experimental study included poly filla, microballoon, - Italian Gypsum and pottery powder **[FIGURE 3]**.

[FIGURE 3]*:* **Represents some of the selected filling materials**

C. Preparation of the Samples

The samples were prepared to suit tests and experiments that were conducted in the experimental study according to Salah[21], as shown in **[FIGURE 4]**.



[FIGURE 4] : Represents filling materials cubes used in experimental study

[21]SALAH 2019:184.

2. Study Methods

After preparing several samples of the selected filling materials, many experiments and tests were conducted to evaluate filling materials that can be used in restoration and maintenance process. The most important experiments and tests were conducted as follows:

1. Determination of Working Time.
2. Determination of Degree of Shrinkage.
3. Determination of Compressive Strength.
4. Thermal [Heat] Ageing.
5. Light Ageing by U.V.
6. Determination of Compressive Strength after Thermal and Ultra-violet Ageing.
7. Determination of physical properties after thermal ageing.
8. Salt ageing.
9. Determination of Compressive Strength after salt weathering.

3. Results

1. Determination of Working Time of Material

Working time of selected filling materials was observed during the preparation of samples for experiments and tests according to (Rasheed, 2019)[22], and the results recorded are as follows:

A. Poly Filla.

Is mixed with water, is difficult to shape immediately after pouring, and dries within 25 minutes. The material is shaped easily giving a smooth and polished white surface after drying. It can be easily retrieved mechanically.

B. Microballon

It is added to Paraloid B 82 at a concentration of 5%. After casting, it remains in a soft state, it is difficult to shape before 40 minutes, and it dries within 60 minutes. After an hour, the material can be formed and polished.

C. Italian Gypsum

A white substance prepared easily by mixing it with water, it is difficult to form immediately after pouring; and it dries within 6 to 7 minutes.

D. Poly Filla and Pottery Powder (Grog).

Grog was added to polyfilla in a ratio of 1:2 and mixed well, before being added to some water; the working time of this material is 30 minutes.

[22] RASHEED 2019: 195-199.

E. Microballon and Pottery Powder (Grog).

Pottery powder was added to microballon in a ratio of 1:2 respectively, and mixed well. The mixture was added to a solution of Paraloid B 82 with a concentration of 5%. Working time was 60 minutes. It gave a reddish white surface after drying, and can be retrieved.

F. Gypsum and Pottery Powder (Grog).

Pottery powder was mixed with Italian gypsum in a ratio of 1:2 respectively, after that, they were mixed well in water; it dries within 6 to 7 minutes. This material is characterized by its ease for modelling; it gives a reddish-white surface after drying. It can be easily retrieved mechanically.

G. Poly Filla+Microballon+ Pottery Powder (Grog).

Grog was prepared, and then pottery powder was added to polyfilla and microballoon in a ratio of 1:1:1 respectively. They were mixed well in a solution of Paraloid B 82 with a concentration of 5%. Working time is 40 minutes. It gave a reddish white surface after drying and it can be retrieved.

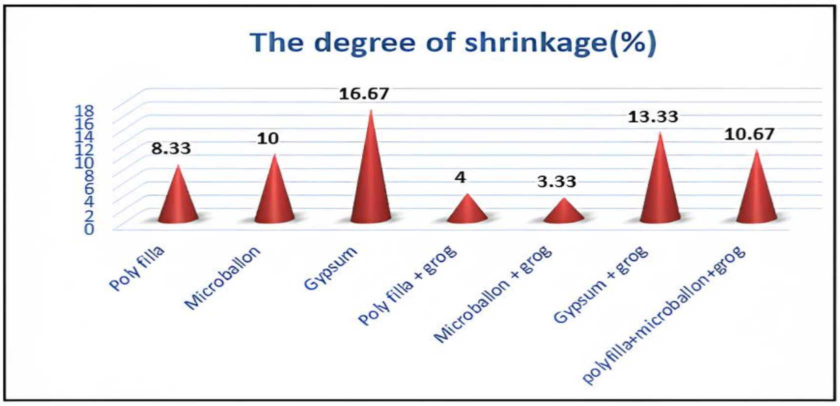
2. Determination of Shrinkage Degree for Selected Filling Materials

Filling materials were poured into molds with known dimensions, and the length of the samples was measured after drying. Thus, degree of shrinkage could be determined, which is a scientific basis for evaluating some selected filling materials. Cylinder-shaped fills were made of certain lengths and a fixed uniform diameter, and then they were left to dry gradually away from the sun's rays. Then, they were placed in a drying furnace at a temperature of 105 °C for 24 hours; the length of samples was measured after drying to obtain the dry length, where drying shrinkage was measured according to (Rice - 1996)[23]. The results are shown in **[TABLE 1] & [FIGURE 5]**.

Material Filling	Wet length	Dry length	The degree of shrinkage (%)
Poly filla	3	2.75	8.33
Microballon	3	2.70	10
Gypsum	3	2.5	16.67
Poly filla + grog	3	2.88	4
Microballon + grog	3	2.9	3.33
Gypsum + grog	3	2.6	13.33
Poly filla + Microballon +grog	3	2.68	10.67

[TABLE 1] : Shows results of shrinkage degree of selected filling materials© Done by the researcher

[23]RICE2015: 70-71.



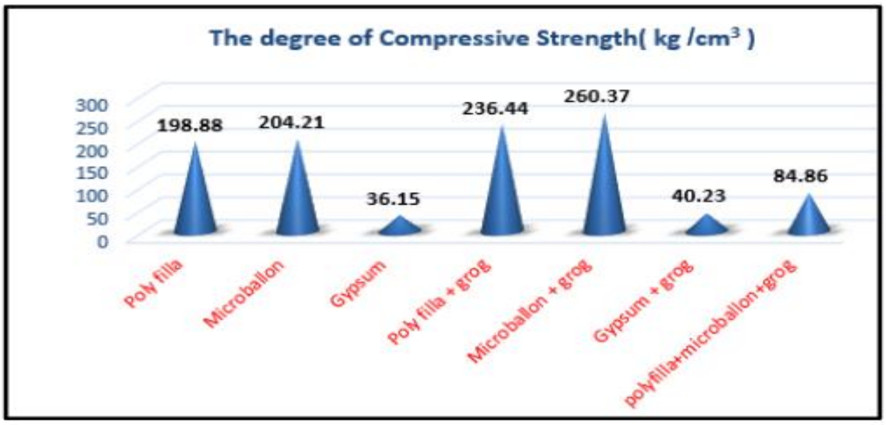
[FIGURE 5]: Represents determination of shrinkage degree of some selected filling materials

3. Determination of Compressive Strength for Selected Filling Materials

Some cubes of selected filling materials were prepared to determine compressive strength for assessing their ability to resistance stresses and loads, which is a guide for assessing the mechanical properties of the selected filling materials. This test was done by German-made device according to ASTM[24]. The results shown in **[TABLE 2] & [FIGURE 6]**.

Material Filling	**Compressive Strength (kg /cm³)**
Poly filla	198.88
Microballon	204.21
Gypsum	36.15
Poly filla +grog	236.44
Microballon +grog	260.37
Gypsum +grog	40.23
Poly filla + Microballon + grog	84.86

[TABLE 2]: Shows results of compressive strength degree of the selected filling materials© Done by the researcher© Done by the researcher



[FIGURE 6]: Represents determination of compressive strength degree of some selected filling materials

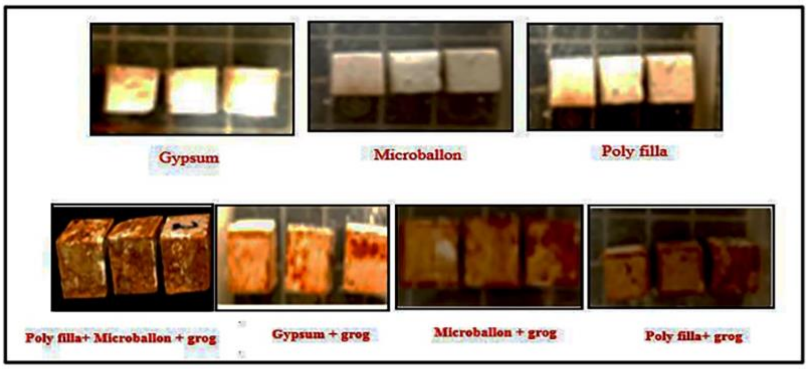
[24] ASTM 2001:118-119.

4. Accelerated Artificial Ageing by Heat for Selected Filling Materials

Filling materials may be damaged and subject to deterioration by accelerated artificial ageing by heat. This deterioration (change in weight or color) is considered a basis for evaluating any material. The more the material is stable and has good resistance, the more material is appropriate for restoration purposes. Thermal ageing was done according to (Brania, 2011)[25]. Samples of cubes were prepared and then left to dry at room temperature for 21 days. They were placed inside a furnace at a temperature ranging from 65-100 °C. Heat temperature was gradually raised, and the cycle period was (30) days for 720 continuous hours. The weight of the samples was measured before placing in the furnace (dry weight), then the samples were weighed several times until the end of heat cycles, the change in color and weight were noticed and recorded. These results are presented in **[TABLE 3]** and **[FIGURE 7]**.

Filling Materials	Heat	Exposure Time	Color before	Color after
Poly filla	100 °C	**720**	**white**	**darkness**
Microballon	100 °C	**720**	**white**	**No change**
Gypsum	100 °C	**720**	**white**	**darkness**
Poly filla + grog	100 °C	**720**	**light brown**	**No change**
Microballon + grog	100 °C	**720**	**light brown**	**No change**
Gypsum +grog	100 °C	**720**	**dark brown**	**darkness**
Poly filla + Microballon + grog	100 °C	**720**	**light brown**	**No change**

[TABLE 3]: Shows results of accelerated artificial thermal ageing for the selected filling materials ©Done by the researcher



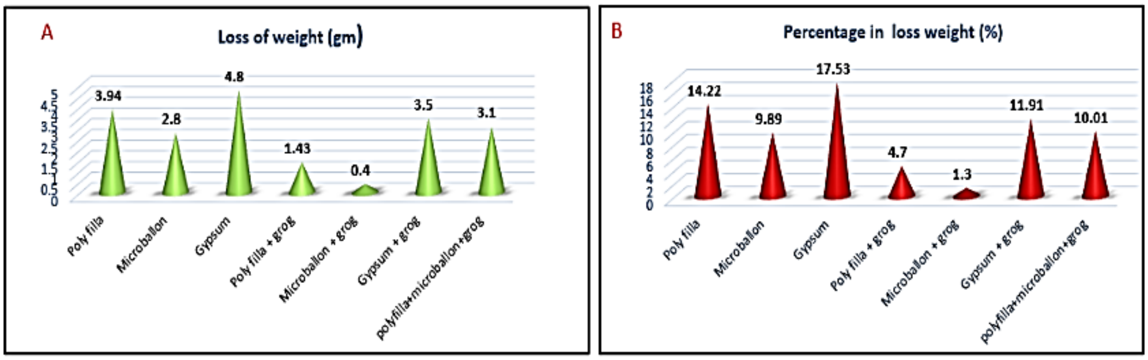
[FIGURE 7]: Represents color change of some selected filling materials by artificial thermal ageing

It has been noticed that most of filling materials samples were subjected to a change in weight in different proportions due to heat temperature; the loss in weight and its percentage are shown in **[TABLE 4] & [FIGURE 8]**.

[25] BRANIA et Al 2011:4.

Filling Materials	Heat Temperature	Exposure Time «hour»	Loss of weight (gm)	Percentage in loss weight (%)
Poly filla	100 °C	720	3.94	14.22
Microballon	100 °C	720	2.80	9.89
Gypsum	100 °C	720	4.80	17.53
Poly filla +grog	100 °C	720	1.43	4.70
Microballon +grog	100 °C	720	0.4	1.30
Gypsum +grog	100 °C	720	3.5	11.91
Poly filla + Microballon + grog	100 °C	720	3.1	10.01

[TABLE 4]: Shows the weight loss and its percentage for selected filling materials by artificial thermal ageing© Done by the researcher



[FIGURE 8]: Represents thermal ageing of selected filling materials A: loss of weight B: percentage in weight loss

5. Light Artificial Ageing of Selected Filling Materials

Light artificial ageing can physically damage the selected filling materials by ultraviolet rays. The samples were exposed to ultraviolet radiation for 30 days at a rate of 720 hours. Light ageing was done according to Elghareb[26]. The results were shown in **[TABLE 5]**.

Filling Materials	Exposure Time «hour»	Color before Exposure	Color after Exposure
Poly filla	720	white	No change
Microballon	720	white	No change
Gypsum	720	white	No change
Poly filla +grog	720	light brown	No change
Microballon +grog	720	light brown	No change
Gypsum +grog	720	dark brown	No change
Poly filla + Microballon + grog	720	light brown	No change

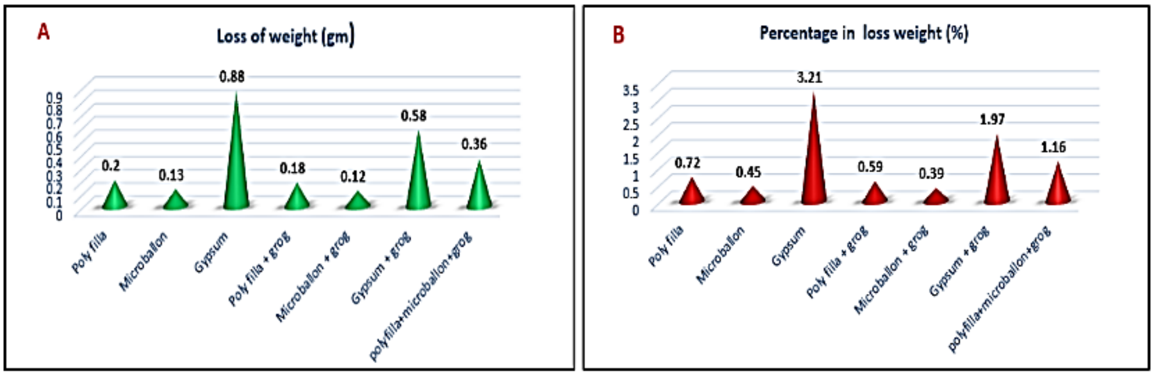
[TABLE 5]: Shows the results of light artificial ageing of the selected filling materials© Done by the researcher

[26]IBRAHIM et Al 2018: 39-48.

It is clear from results of previous table that the samples showed a degree of stability and resistance to light ageing but they were subjected to loss in weight as recorded in **[TABLE 6] & [FIGURE 9]**.

Filling Materials	Exposure Time «hour»	Loss of weight(gm)	Percentage in Loss weight (%)
Poly filla	720	0.20	0.72
Microballon	720	0.13	0.45
Gypsum	720	0.88	3.21
Poly filla +grog	720	0.18	0.59
Microballon +grog	720	0.12	0.39
Gypsum +grog	720	0.58	1.97
Poly filla + Microballon + grog	720	0.36	1.16

[TABLE 6] : Shows the weight loss and its percentage of the selected filling materials by U.V. © Done by the researcher



[FIGURE 9]: Represents light ageing of the selected filling materials, A) the loss of weight; B) the percentage in weight loss

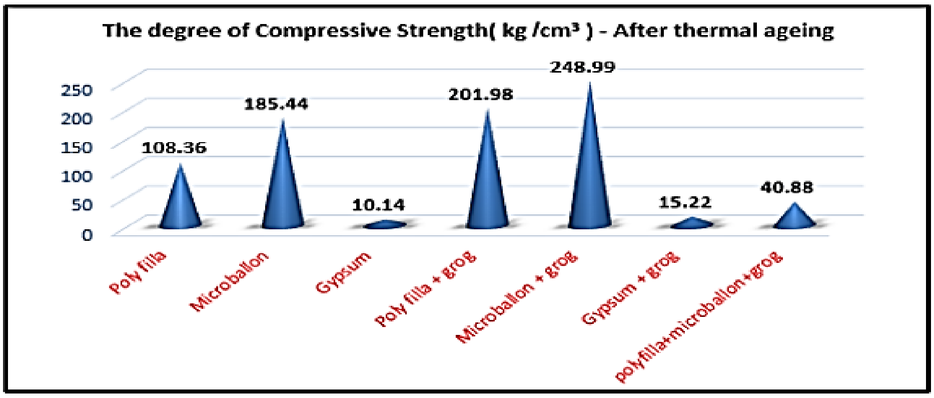
6. Determination of Compressive Strength after Artificial (Thermal-Light) Ageing

A. After Thermal Ageing

Measurements were taken after accelerated artificial heat ageing to determine stability of these materials after exposure to high temperatures. This test was carried out on previously described device. The results are shown in **[TABLE 7]** and **[FIGURE 10]**.

Material Filling	Compressive Strength kg /cm^3
Poly filla	108.36
Micropallon	185.44
Gypsum	10.14
Poly filla + grog	201.98
Microballon + grog	248.99
Gypsum + grog	15.22
Poly filla+ Microballon +grog	40.88

[TABLE 7]: Shows the results of the compressive strength degree of the selected filling materials after artificial thermal ageing© Done by the researcher



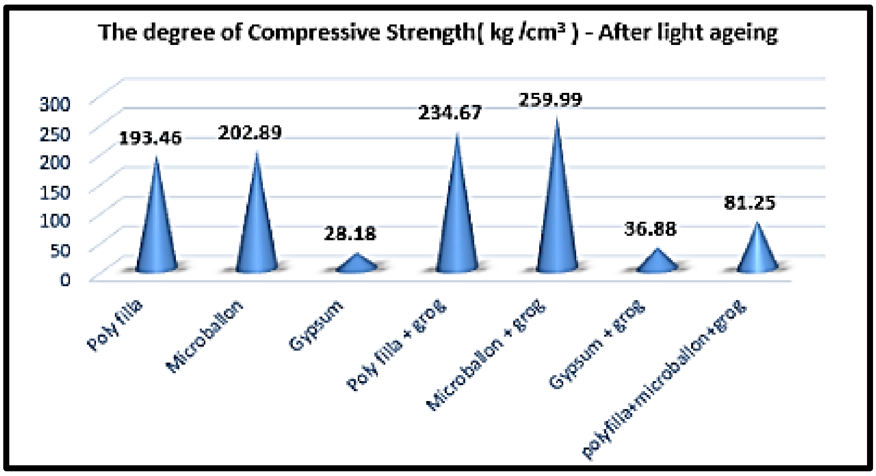
[FIGURE 10]: Represents compressive strength degree after thermal ageing of the selected filling materials

B. After Light Ageing

Test of compressive strength was done after accelerated artificial light ageing to determine the stability of these filling materials .The results are shown in **[TABLE 8] & [FIGURE 11]**.

Material Filling	Compressive Strength kg /cm³
Poly filla	193.46
Micropallon	202.89
Gypsum	28.18
Poly filla + grog	234.67
Microballon + grog	259.99
Gypsum + grog	36.88
Poly filla+ Microballon +grog	81.25

[TABLE 8]: Shows the results of the compressive strength degree of the selected filling materials after artificial light ageing by U.V© Done by the researcher



[FIGURE 11]: Represents compressive strength after light ageing of the selected filling materials

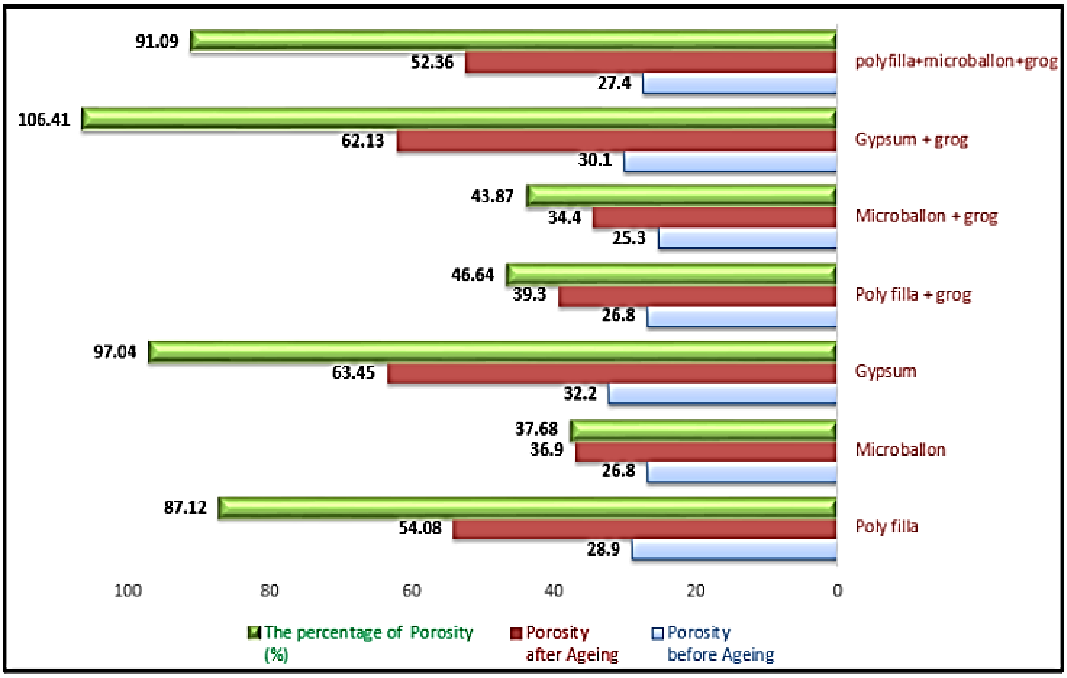
7. Determination of the Physical Properties of the Selected Filling Materials before and after Accelerated Thermal Ageing.

A. Porosity

The porosity values changed after artificial thermal ageing of the selected filling materials according to ASTM [27], the results are shown in **[TABLE 9] & [FIGURE 12]**.

Filling Materials	Porosity before Ageing	Porosity after Ageing	The percentage of Porosity (%)
polyfilla	28.90	54.08	87.12
Microballon	26.80	36.90	37.68
Gypsum	32.20	63.45	97.04
Polyfilla + grog	26.80	39.30	46.64
Microballon + grog	25.30	34.40	43.87
Gypsum + grog	30.10	62.13	106.41
Polyfilla + Microballon + grog	27.40	52.36	91.09

[TABLE 9]: Shows the porosity of the selected filling materials after artificial thermal ageing ©Done by the researcher



[FIGURE 12]: Represents porosity and its percentage of the selected filling materials after thermal ageing

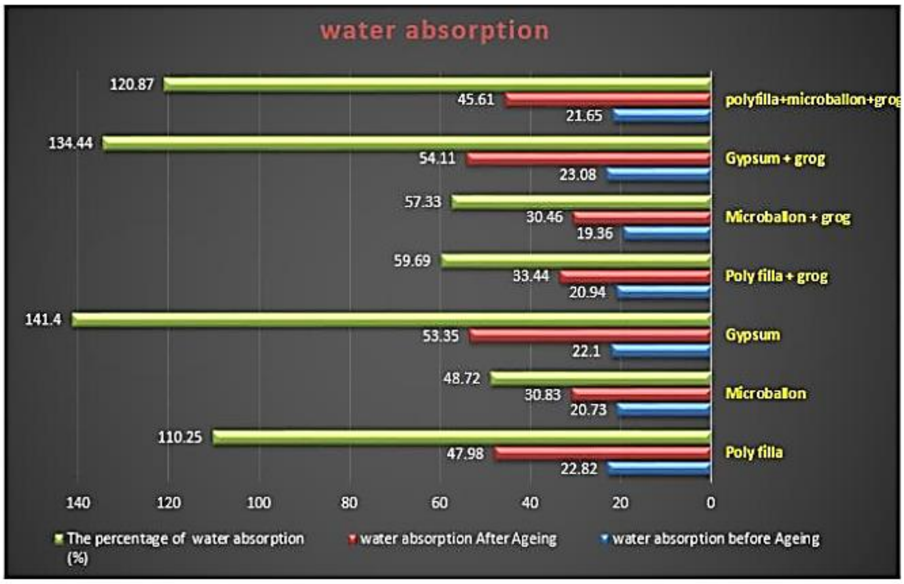
[27]ASTM 2001: 118-119.

B. Water Absorption

Water absorption values changed after thermal ageing of the selected filling materials according to (Kamel, 2012)[28]. The results are shown in **[TABLE 10] & [FIGURE 13]**.

Filling Materials	water absorption before Ageing	water absorption after Ageing	The percentage of water absorption (%)
polyfilla	**22.82**	**47.98**	**110.25**
Microballon	**20.73**	**30.83**	**48.72**
Gypsum	**22.10**	**53.35**	**141.40**
Polyfilla + grog	**20.94**	**33.44**	**59.69**
Microballon + grog	**19.36**	**30.46**	**57.33**
Gypsum + grog	**23.08**	**54.11**	**134.44**
Polyfilla + Microballon + grog	**21.65**	**45.61**	**120.87**

[TABLE 10]: Shows water absorption of the selected filling materials after artificial thermal ageing
© Done by the researcher



.[FIGURE 13]: **Represents water absorption and percentage of selected filling materials after thermal ageing**

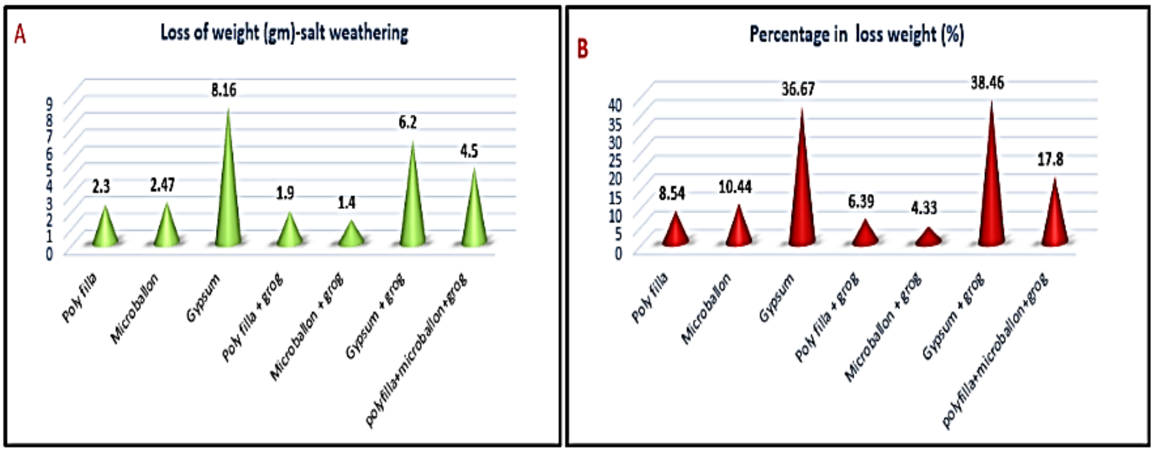
8. Test of Salt Ageing.

Salt ageing was carried out on samples that were prepared in the form of "cubes 3 x 3 x 3 cm" that were left to dry at room temperature for 21 days. After drying, they were placed in a furnace at 105 °C. The dry weight was determined. Then the samples were immersed in a solution of sodium chloride NaCl with a concentration 10% for 8 hours, and then the samples placed for 16 hours in room atmosphere. After that, they were placed in a furnace at about 65°C to 100°C. This cycle was repeated for 30 days according to (Ismail, 2012)[29]. The results are shown in **[TABLE 11] & [FIGURE 14]**.

[28]KAMEL2012: 29-30.
[29]ISMAIL 2000: 70.

Filling Materials	Loss of weight(gm)	Percentage of Loss weight (%)
Poly filla	2.30	8.54
Microballon	2.47	10.44
Gypsum	8.16	36.67
Poly filla +grog	1.90	6.39
Microballon +grog	1.40	4.33
Gypsum +grog	6.20	38.46
Poly filla + Microballon + grog	4.50	17.80

[TABLE 11]: shows the results of artificial ageing by salt weathering with sodium chloride (10%) for the selected filling materials



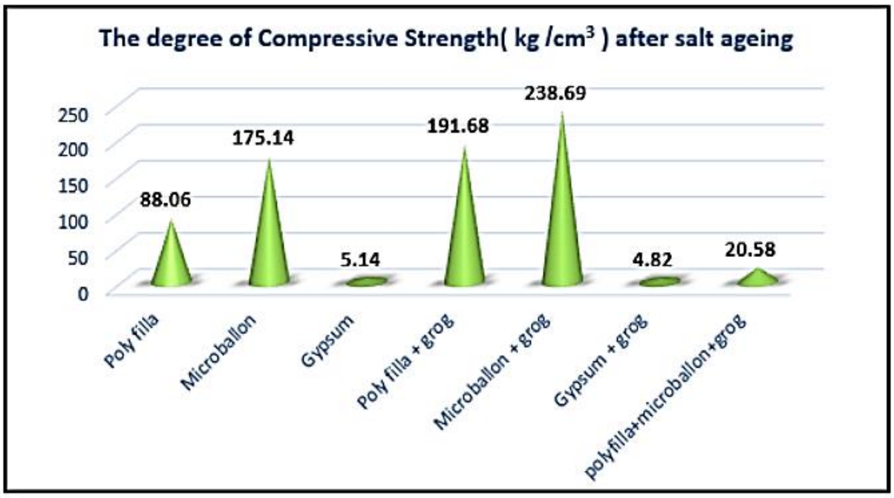
[FIGURE 14]: represents weight loss and its percentage after salt weathering for the selected filling materials, A: loss of weight, B: percentage of weight loss

9. Determination of Compressive Strength of Selected Filling Materials after Accelerated Artificial Ageing by Salt Weathering with Sodium Chloride Salt NaCl (10%).

These measurements were done after salt weathering with sodium chloride salt 10% to recognize the stability of these materials for salt weathering. This test was done on the aforementioned device, and the results are shown in **[TABLE 12] & [FIGURE 15]**.

Filling Materials	Compressive Strength (kg /cm^3) after
Poly filla	88.06
Microballon	175.14
Gypsum	5.14
Poly filla +grog	191.68
Microballon +grog	238.69
Gypsum +grog	4.82
Poly filla + Microballon + grog	20.58

[TABLE 12]: Shows compressive strength degree of selected filling materials after salt weathering (NaCl 10%)© Done by the researcher



[FIGURE 15]: **Shows compressive strength after salt weathering with NaCl (10 %)**

III. DISCUSSION OF RESULTS

The experiments and laboratory tests in this study gave different results depending on nature of each material. Polyfilla is a white material[30], which is easy to prepare by mixing with water[31], is difficult to form immediately after pouring, dries within 30 minutes, and is formed easily and gives a white surface[32]. Microballon, is a white substance that is easy to prepare by mixing with Paraloid B 82 at a concentration of 5%[33]. It is difficult to shape before 60 minutes, and after complete drying, it is difficult to polish and shape.

Italian gypsum consists of semi-aqueous calcium sulfate $CaSO_4.2H_2O$, and has a specific gravity of 2.32. There are two types of gypsum, the first is alpha plaster, and the second is beta plaster. They differ in their physical properties, alpha one needs less water than beta gypsum[34]. Some of the main gypsum defects are its low working time, its expansion and water absorption[35]. It is easy to prepare by mixing with water. It is difficult to form immediately after pouring, it dries within 6 to 7 minutes, and is reversible.

The mixtures of Poly filla and pottery powder (grog), Microballon and pottery powder, and gypsum and pottery powder gave different results in determining working time. It was noticed that during preparation of these mixtures that pottery powder should be finely ground, several pottery powders must be made to select the powder that suits pottery body color[36]. In some cases, color oxide can be added to modify the paste color for matching pottery body. Work time for a mixture of Microballon and pottery powder was 60 minutes, while working time for a mixture of

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[30] Al-SEYOUF,2012162.
[31] AllAM,2005: 202.
[32] HENKEL DÜSSELDORF–CHEMIE 2021: 118-122.
[33] CTS CATALOGUE 2020:153.
[34] SADIQ2005:132.
[35] ATTIA 2003:111.
[36] AL-FATEH 2007:156.

gypsum and pottery powder was from 6 to 7 minutes; working time of a mixture of Polyfilla, microballoon and pottery powder was about 40 minutes.

It has been shown through determining working time for microballon or a mixture of microballon and pottery powder that working time can be controlled by type of solvent where evaporation speed of solvent leads to speed drying, and thus the time of working is reduced and vice versa.

Results of experiments and tests of shrinkage degree gave different results according to properties of each material; it is known that determining shrinkage degree is a scientific basis for evaluating selected filling materials. The lower shrinkage degree, the better in replacement process. A mixture of microballon and pottery powder achieved the lowest shrinkage degree at 3.33%, but Italian Gypsum recorded the highest shrinkage degree at 16.67%. Among them, there were the rest of results of determining shrinkage degree as in **[FIGURE 5].**

The results of determining compressive strength of selected filling materials before ageing showed a difference in degree of resistance sample to compressive strength according to properties of each material. Microballon and pottery powder had the best results recording compressive strength degree about 260.37 kg/cm³, but Gypsum recorded 36.15 kg/cm³, among them, there were the rest of the results of compressive strength as in **[FIGURE 6].**

It was clear from artificial thermal ageing results of selected replacement materials that selected filling materials showed a difference in their resistance to discoloration and weight loss. All replacement materials showed stability to color change except for polyfilla, Italian gypsum, and a mixture of gypsum and pottery powder that had changed to dark color. It is shown from the results of thermal ageing that a mixture of microballon and pottery powder had the best thermal resistance. It recorded weight loss of about 0.4 g and its percentage was 1.30%, while Italian gypsum recorded weight loss of about 4.80 g with a percentage 17.53%, the rest of the results were between the two numbers **[FIGURE 8].**

It is shown from results of light ageing that a mixture of microballon and pottery powder had the best light resistance. It recorded weight loss about 0.12 g and its percentage was 0.39%, while Italian gypsum recorded weight loss about 0.88 g with a percentage of 3.21%, among them there were the rest of the results as **[FIGURE 9].**

Selected replacement materials after artificial thermal ageing showed a difference in resistance to compressive strength. A mixture of microballon and pottery powder had the best pressure resistance results, where it recorded a resistance degree about 248.99 kg/cm³ while gypsum recorded 10.14 kg/cm³. Between them, there were the rest of results as in **[FIGURE 10].**

Regarding compressive strength degree after artificial light ageing by U.V. the mixture of microballon and pottery powder had the best pressure resistance results, where it recorded a resistance degree about 259.99 kg/cm³ while gypsum recorded 28.18 kg/cm³. Between them, there were the rest of results as in **[FIGURE 11].**

The replacement materials showed a difference in porosity degree after thermal ageing compared to the samples before ageing. A mixture of microballon and pottery powder recorded the best results. It recorded the lowest porosity degree before ageing about 25.30, while it recorded porosity degree after ageing 34.40 with percentage 43.87%. Gypsum, as well as a mixture of gypsum and pottery powder had recorded the highest apparent porosity degree 32.20 and 30.10, respectively before ageing, while a mixture of gypsum and pottery powder recorded an apparent porosity degree 62.13 with percentage 106.41, as in **[FIGURE 12].** An increase of porosity in all samples was due to poor inter-granular bonding because of thermal ageing.

Filling materials showed a difference in water absorption degree. Microballon and pottery powder recorded the best results. A mixture of microballon and grog recorded the lowest water absorption degree about 19.36 before ageing, while it recorded water absorption degree after ageing 30.46 with percentage 57.33%. Then, gypsum, followed by a mixture of gypsum and pottery powder had recorded the highest water absorption degree at 22.10 and 23.08, respectively before ageing, while a mixture of gypsum and pottery powder recorded water absorption degree 54.11 with percentage of 134.44 % but water absorption percentage of gypsum was 141.40 % as in **[FIGURE 13].**

Water absorption degree after ageing was increased compared to the samples before ageing due to poor cohesion of grains by thermal ageing.It is clear from the results of saline ageing that the samples were affected by salt weathering (sodium chloride salt 10%) in different proportions. A mixture of microballon and pottery powder gave the best results of weight loss resistance by saline weathering. Mixture of microballon and grog recorded a weight loss of 1.40 g with a percentage of 4.33%, while gypsum recorded a weight loss of 8.16 g with a percentage of about 36.67%. Among them, there were the rest of the results, as in in **[FIGURE 14].**

From the determination of compressive strength of selected filling materials after salt ageing (sodium chloride salt 10%), a difference in their degree of resistance is clear. A mixture of microballon and pottery powder had the best pressure resistance results, where it recorded compressive strength degree of about 238.69 kg/cm³, while a mixture of gypsum and pottery powder recorded compressive strength 3.82 kg/cm³. Among them, there were the rest of the results, as in **[FIGURE 15].**

IV. APPIED STUDY

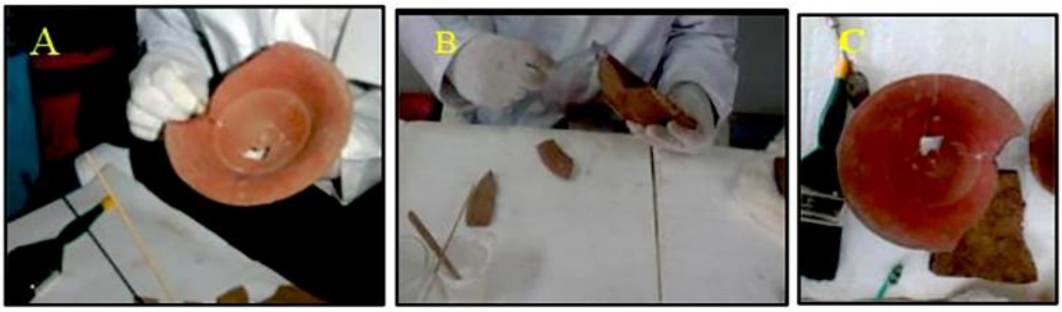
A. Description and Diagnosis of Damage

A pottery piece, which was a medium-sized pottery plate that was broken into three different fragments, was chosen for the applied study. The pottery piece suffers from presence of many different clay and lime soil sediments, as well as crystallization of salts, as shown in **[FIGURE 16].**

[FIGURE 16]: Represents a pottery plate before restoration and maintenance, tell Basta, Sharkia,

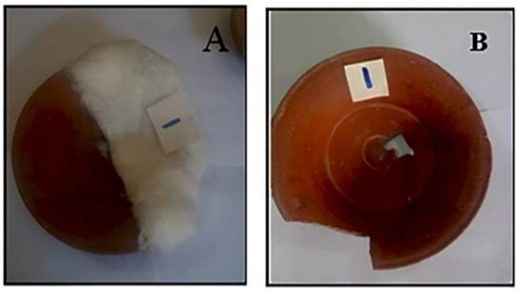
B. Cleaning Process

Soft brushes were used to remove dirt deposits mechanically. In some cases, scalpels may be used to clean hard calcifications carefully, gave excellent results[37], but the pottery plate still suffered from some lime deposits, as in **[FIGURE 17].**



[FIGURE 17]: Represents mechanical cleaning of pottery plate, A) needle cleaning; B) brushing cleaning; C) after mechanical cleaning

The lime sediments were cleaned by EDTA, known as tetra sodium ethylene diamine tetra acetic acid according to Nabil& Ala[38], which gave excellent results as in **[FIGURE 18].**



[FIGURE 18]: Represents chemical cleaning of pottery plate, A) during chemical cleaning; B) after chemical cleaning

C. Bonding Process

After mechanical and chemical cleaning of the pottery plate a preliminary assembly of the plate fragments with each other was carried out in order to locate the lost parts. Then a process of assembling for these pottery sherds was carried out using Paraloid B72 dissolved in toluene at a concentration of 50% according to (Nagwa, 2016) [39], and thus the artifact was restored to its original shape before burial in the soil, as shown in **[FIGURE 19].**

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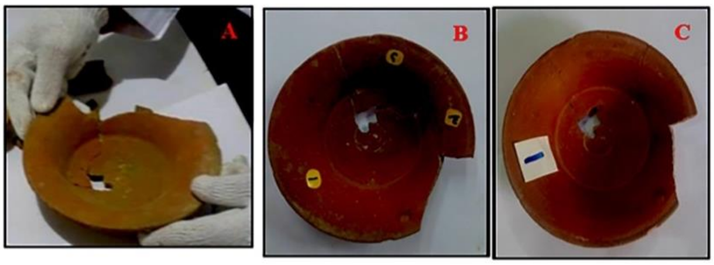
[37]SEASE 1994:111-124.
[38]BADER & MOHAMED 2016: 443-458.
[39]SAYED 2016: 25.



[FIGURE 19]: Represents assembling process of pottery plate, A) preliminary assembly; B) during assembling; C) after cleaning and assembling process

After assembling process, the artifact was strengthened by a mixture of Nano silica dispersed in ethyl alcohol at a concentration of 1% with Wacker H at a ratio of 1: 1 using poultice method according to Elghareb[40], as shown in [FIGURE 20].

[FIGURE 20]: Represents strengthening process by poultice method

D. Replacement of Lost Parts

It was noticed after assembly process, that the pottery plate suffered from missing parts. Aluminium paper was applied under the missing part as a support material. Then replacement material was prepared, which was a mixture of microballon and pottery powder in a ratio of 2: 1. The paste was applied. After an hour, it was shaped and polished. Thus, the pottery object was restored to its original shape before burial in the soil. The pottery object was protected and isolated using Paraloid B 82 with a concentration of 3 % by brush, as shown in **[FIGURE 21].**

[FIGURE 21]: Represents replacement process of pottery plate, A) before replacement; B) after replacement

[40] EL GHAREB 2019:415-428.

V. CONCLUSION

The research proved that most of the excavated pottery pieces from tell Basta in Sharkia suffered from loss of one of their parts. These pottery objects need a replacement process to restore its artistic and archaeological form before breaking. It is considered a historical revival identifying social, religious, commercial aspects. The experimental study proved successful and efficiency of some gap-filling materials in completing of the pottery was achieved. It is recommend to use one of the tested filling materials: (First: a mixture of microballoon and pottery powder (grog) in a ratio of 2: 1 respectively, Second: a mixture of Poly filla and pottery powder (grog) in a ratio of 2: 1, respectively). In the applied study, restoration interventions and treatment were done for a pottery plate. In addition to the completing process using a mixture of microballon and pottery powder (grog) in a ratio of 2: 1 for the pottery object. After restoration, the treated archaeological pottery plate was ready for museum display at tell Basta Museum, Sharkia governorate.

BIBLIOGRAPHY

ABD AL KAREEM, A. & **MOHIE**, M.: «The Conservation of an Oil Painting by Antonio Schranz, 1841 AD», *International Journal of Conservation Science* 12/ 2, 2021, 417-428.

ABDRABOU, A., **EL HADIDI**, N., **HAMED**, S., & **Betiha**, M.: «Experimental Study on the Efficacy of Cleaning Systems for the Removal of Previous Conservation Treatments from Tutankhamuns' Gilded Wooden Bed », *International Journal of Conservation Science* 12/2, 2021, 403-416.

AL SAAD, Z. & **BATAINEHM**, M.: «Preventive Preservation Approach for the Preservation of Unique Early Neolithic Architectural Remains of the Archaeological Site of Beidha-Jordan», *International Journal of Conservation Science* 12/ 2, 2021, 493-506.

AL-FATEH, O.: «An Applied Scientific Study on Treatment and Maintenance of Some Mamluk Pottery Vessels Painted with Colored Slip Layers with an Applying on a Group from the Museum of Islamic Art in Cairo», Ma thesis, Department of Restoration, Faculty of Archeology, Cairo University, 2007.

ALLAM, A.: «A Technical Study and Treatment of Archaeological Faience with Applying on One of the Selected Patterns from the Egyptian Museum», Ma thesis, Department of Restoration, Faculty of Archeology, Cairo University, 2005.

AL-SEYOUF, F.: «A Scientific and Applied Study for Treatment and Conservation of some Silicate Archaeological Collections (Pottery-Glass) in Jordan with Applying on selected patterns », PhD thesis, Department of Restoration, Faculty of Archeology, Cairo University, 2012.

ANNUAL BOOK OF ASTM STANDARDS, Section 15, part 15-02: *Glass, Ceramics and white wares*, U.S.A., 2001.

ANNUAL BOOK OF ASTM STANDARDS, Section 15, part 15-02: *Glass, Ceramics and white wares*, U.S.A., 2001,

ATTIA, A.: *Restoration of Archaeological Mosaics*, Cairo (Dār Al-Fajr for Publishing and Distribution)2003.

BADER, N. & **MOHAMED**, A.: «The Cleaning of the Isis Temple Mural Painting in Upper Egypt Using zinc Oxide Nanoparticles and Non-ionic Detergents», *International Journal of Conservation Science* 7/2, 2016, 443-458.

BRANIA, A., **IMAM**, H. & **ELSAYED**, K.: «Libs Tool to Diagnose the Egyptian Wall Painting During Laser Cleaning Process, An experimental Study», *Egyptian Journal of Archaeological and Restoration Studies* 1/ 2, 2011, 4-5.

CAUPER, L., **CAUPER**, F. & **OLIVEIRA**, L.: «Biosurfactant Production by Rhizobacteria Isolated from Amazonian Soils», *International Journal of Conservation Science* 12/1, 2021, 311-322.

CAYME, M.C.: «Chemistry of Lime Mortared Rubble Masonry in Bohol, Philippines», *International Journal of Conservation Science* 12/3, 2021, 977-986.

CTS Catalogue, Italy: Milano, 2020.

DOWMAN, E.: *Conservation in the field archaeology*, London (Methuen) 1970.

ELGHAREB, W.: «Deterioration and Consolidation of Some Pottery Vessels in Tel Ajrud, Suez, Egypt: Analytical and Experimental Study», *International Journal of Conservation Science* 10/3, 2019, 415-428.

FIORENTNO, P. & **BORRELLI**, V. «A Preliminary Note on the Use of Adhesives and Fillers in the Restoration of Ancient Egyptian Materials», *Studies in Conservation* 20/4, 1975, 202.

HAMAD, R., **ABD AL-RAHIM**, N., **MOGHAZY**, M. & **ABD AL-MONEAM**, H.: «Explosion Effects on Archaeological Glass, Conservation and Protection Strategy», *International Journal of Conservation Science* 12/1, 2021, 105-112.

HASSAN, R.: «A Recently Discovered Corn Mummy In Ibis, South Of Abu Sir, North of Saqqara 2018: A Case Study», *International Journal of Conservation Science* 12/**3**, 2021, 879-892.

HEFNI, M., **ABD AL-RAHIM**, N., **ABD AL-MONEAM**, H., **HAMAD**, R., «Evaluation of Kemapoxy 150 3D IN Restoration of archaeological glass», *International Journal of Conservation Science* 12/2, 2021,325-334.

HENKEL DÜSSELDROF – CHEMIE, West Germany, 2021, 118-122.

IBRAHIM, M., **MOHAMED**, S. & **HEFNI**, Y.: «Nano Materials for Consolidation and Protection of Egyptian Faience form Matteria, Egypt», *Journal of Nano Research* 56, 2018, 39-48.

ISMAIL, B.: «The Impact of Environmental Conditions on the Roman Tombs in Alexandria city», *Bulletin of the Faculty of Arts* 10, 2000, 70.

IVASHKO, Y., **KOROVKINA**, A., **YERMOLENKO**, I. TOVBYCH, V., **KUSNIERZ-KRUPA**, D. & **KOBYLARCZYK**, J.: «Finishing Materials for Facades and Interiors of Art Nouveau Buildings. Examples of Ukraine and Poland», *International Journal of Conservation Science* 12/3, 2021, 935-960.

KAMEL, W.: «Scientific Evaluation of some Consolidation Materials of Excavated Archaeological Pottery from the Region of Tel Pasta, At Sharkia in the East of Delta », *Egyptian Journal of Archaeological and Restoration Studies* 2/1, 2012, 29-30.

LARNEY, J.: «Ceramic Restoration in the Victoria and Albert Museum», *Studies in Conservation* 16/2, 1971, 74-75.

MONACO, M., **FAELLA**, G., & **GUADAGNUOLO**, M.: «Analysis of Pozzolanic Mortars for Restoration», *International Journal of Conservation Science* 12/**1**, 2021, 41-50.

NOUREDDINE, A.: *Ancient Egyptian Antiquities Sites from the Earliest Times Until the End of the Dynastic Ages*, vol.1, *Lower Egypt*, Cairo (Dār al-ʾAqsa for Printing and Publishing) 2018.

PRICE, C.: *Stone Conservation:* An Overview of Current Research, second edition, Los Angeles, U.S.A (Getty Conservation Institute Press) 2011.

RASHEED, M.: «Study of Techniques, Restoration and Conservation of Samarra al-Abbasi Pottery in Iraq Applying on some Selected Models», Ma thesis, Faculty of Archeology, South Valley University, 2019.

RICE, P.: *Pottery Analysis: A Source book*, 2nd (ed.), London (University of Chicago Press, Ltd.) 2015.

RYDZEWSKI, P.: «Between Environmental Protection and Technology: Europeans' Ecological Attitudes», *International Journal of Conservation Science* 12/1, 2021, 781-790.

SADIQ, H.: «A Technical Study, Treatment and Maintenance of Islamic Archaeological Ceramic Lighting Tools», Ma thesis, Department of Restoration, Faculty of Archeology, Cairo University, 2005.

SALAH, M.: «Analytical Study of Techniques of Archeological Pottery in Sinai with Treatment and Conservation of some Selected Objects», Ma thesis, Conservation Department, Faculty of Archaeology, Fayoum University, 2019.

SALEH, A., **MOHAMED** A., **WAEL** S. & **ALAA** A.: «Experimental Study of Gap-Filling of Ancient Completely Corroded Copper Bowl Via Nano-Polymers», *International Journal of Conservation Science* 11/1, 2020, 97-108.

SANDU, I.: «Scientific Conservation of the Outstanding Theaters of the 19th Century and Their Influence on the Creation of Modern Art-Space», *International Journal of Conservation Science* 12/2, 2021, 361-390.

SAYED, N.: «Analytical Study and Conservation of Archaeological Terrasigillata Ware from Roman Period, Tripoli, Libya», *Journal of Applied Science and Technology to Cultural issues* 2/2 ,2016, 25.

SEASE, C.: *A Conservation Manual for the Field Archaeology*, Los Angeles, U.S.A (Institute of Archaeology Press) 1994.

WILLIAM, N.: *Porcelain, Repair and Restoration*, 2nd (ed.), U.S.A (University of Pennsylvania Press) 2002.

ZAREMBA, M., **TRZCINSKI**, J., **SZCZEPANSKI**, T., **BOBROWSKA**, A. & **WELC,** F.: «Influence of Deterioration on the Preservation of Mud Brick Architecture Based on the Monuments from the Tell El-Retaba Archaeological Site», *International Journal of Conservation Science* 12/1,2021, 67-81.