

Original article

CHARACTERIZATION AND RESTORATION RECOMMENDATIONS OF
SOME ADOBE SHRINES AT EL-BAGAWAT CEMETERY, KHARGA OASIS,
WESTERN DESERT - EGYPT

Abd El-Hafez, M.

Conservation dept, Faculty of Archaeology, Cairo Univ., Giza, Egypt

E-mail: hafezm762000@yahoo.com

Received 14/6/2017

Accepted 13/9/2017

Abstract

The existing research focuses on an important type of early Christian architecture, which was common in Kharga oasis, western desert, Egypt. Kharga oasis includes the largest cemetery dated back to the late third/early fourth to the seventh century A.D. this cemetery called "El-Bagawat cemetery". All shrines in this cemetery were built of mud brick "adobe" blocks and mud mortars. Most of walls and facades of those shrines covered with mud and/or lime plasters. This study focused on two shrines at El-Bagawat cemetery, they are shrines numbers 66 and 90. The study showed the main factors of deterioration. All building materials; adobe, mortars and mud plasters were studied, characterized by using different methods and techniques such as; optical microscopy (by USB digital microscope), scanning electron microscopy (SEM-EDX) and X-ray diffraction (XRD). Also, physical and mechanical properties were studied on selected samples. The results referred that the main deterioration factors affected the historic adobe shrines at El-Bagawat cemetery are: the major climatic changes, biological factors and lack of comprehensive restoration/management plan. Using modified adobe blocks and mortars for the purpose of completion and reconstruction (mainly this bricks contained 65 % kaolinite-rich soil + 17 % salt-free sand + 15 % slaked lime + 3 % fiberglass) and provide a sustainable development plan; is the main way to keep this heritage saved and protected.

Keywords: *Adobe (mud brick), El-Bagawat cemetery, Kharga oasis, Restoration, shrine*

1. Introduction

There is an important type of early Christian architecture, known as "funerary churches" at Kharga oasis, located in the western desert, Egypt. This type of architecture clustered mainly at El-Bagawat cemetery, Kharga oasis. The shrines numbers 66 and 90 of the most important shrines at El-Bagawat cemetery. These shrines were built mainly of mud brick "adobe" blocks, fig. (1-a, b). The deterioration factors of these shrines basically due to mechanisms of desert environment, (i.e. great changes in temperature, wind, sandstorms, rain and floods, sand dunes and sediment, etc.), biological factors, especially termites, but the most important

factor is the negligence and absence of management plan for this heritage. All of these above factors caused different types of deterioration aspects such as; cracks, separating of plaster layers, distorting brick features, undercutting of walls, partially or totally collapse, etc. Being the site far to some extent, also due to continuing environmental changes and the weakness of building materials; there were no adequate interventions to save this architectural heritage, except for limited interventions by restoration works; included: reconstruction of some shrines, treatment of cracks and renewing mud plasters.



Figure (1) Shows the main Façades of **a.** shrine No. 66, **b.** shrine No. 90

El-Bagawat cemetery is located at Kharga oasis in the Egyptian western desert, fig. (2), El-Bagawat cemetery is the most significant excavated Coptic cemetery in Egypt in terms of the numbers of remaining tombs, as well as the contents of the painted decorations on a number of the tombs. The site was excavated by the Egyptian Egyptologist; Ahmed Fakhry [1]. Historically; in the Late Roman period, Kharga witnessed the spread of Christianity that left substantial traces, both archaeological and textual. Throughout the fifth century A.D, cemetery of El-Bagawat was one of the most famous monuments of the oasis; nearby, the slopes of “Gebel Al-Teir” behind the monastery of

“Mustapha El-Kashef” are covered by thoroughly documented Coptic graffiti [2]. El-Bagawat cemetery occupies a surface area about 10,000 m². It is 3 km from the center of Kharga city. Notable, that Kharga Oasis is located to the west of the Nile valley, 550 km to the Southwest of Cairo, 232 km to the Southwest of Assiut. Kharga Oasis is located between latitudes 24° 15' and 26° 00' N. and longitudes 30° 00' and 30° 30' E. El-Bagawat cemetery is perhaps the oldest major Christian cemetery in the world; it is dating back to the 4th century A.D (the late 3rd/early 4th), which was built over the site of an earlier Egyptian necropolis of pit graves [3-5].



Figure (2) Shows location map of Egypt, Kharga Oasis between the circle (<https://www.google.com/eg/>)

El-Bagawat cemetery contains about 263 funerary shrines/chapels of which the Chapel of Exodus (Chapel No. 30 - 5th or 6th century) and the Chapel of Peace (Chapel No. 80 - of mid-4th century) have wonderful frescoes [6]. Shrines No. 66 and 90 are clear models of the funerary churches “*funerary churches are those small churches erected for burial*”. Both shrines are dating back to

the fourth century A.D. The church of shrine No. 66 was built on a little-high hill. A square burial well is in front of the apse, fig. (3-a) shows plan and sections of the shrine No. 66). The church of shrine No. 90 is located in the southern part of El-Bagawat cemetery, its entrance located in the southern façade. A deep; rectangular burial well was dug in the floor in front of the apse, fig. (3-b) shows

plan and sections of the shrine No. 90). It is clear that there is some similarity in planning between the two shrines. The current paper focuses, mainly, on detecting the damage and its causes on two of unstudied adobe shrines at El-Bagawat

cemetery, Kharga oasis by using the methodology of field observation and determining the main factors of deterioration and aspects as well. Physical and mechanical properties of selected samples were also studied.

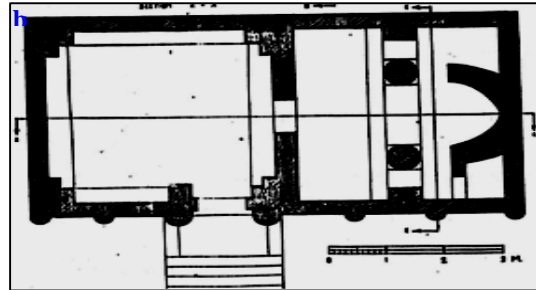
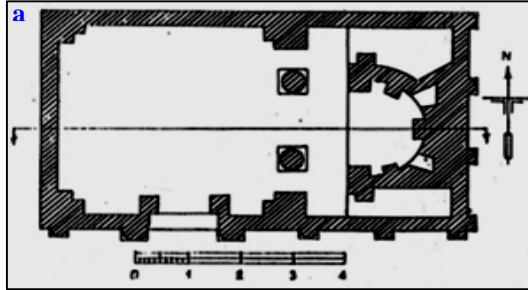


Figure (3) Shows plan, of the shrines **a**, No. 66, **b**, No. 90 at El-Bagawat cemetery, after (Fakhry, 1951).

1.1. Building materials and construction

The two studied shrines were built of mud brick (adobe) blocks attached to each other by mud mortar and, earlier, covered by mud plaster and/or lime plaster. It is well known that adobe architecture is considered the oldest architecture in the world in comparison to stone architecture [7]. The material of earth was used in construction since ancient times in Egypt and almost all regions of the world. There are many techniques of building in adobe architecture, such as; “*pisé de terre*” (or rammed earth), adobe (sun-dried bricks) [8], tuff, etc., the last two types are the

most common techniques in the Egyptian adobe architecture. The walls of shrines No 66 and 90 at El-Bagawat cemetery were built by technique known as the English Bond; it's mean that the first layer of bricks are placed as "headers", the next course of bricks are placed as "stretchers", the thickness of mortar jointing between the bricks on average; in finger size [5,8]. Arches, domes and vaults are common in construction at El-Bagawat cemetery as a distinctive feature of Roman and Coptic architecture, fig. (4).

Figure (4) Shows general view showing the front of El-Bagawat cemetery with many shrines that have arches and domes.



1.2. General considerations and main risks

There are many basics to be clarified the geology and soil of El-Bagawat cemetery, in addition to many deterioration factors detected by field observation; that can be summarized as follow:

- * The geological formations found in Kharga oasis belong to the following rock units from top to bottom, fig. (5-a) [9]. Travertine and loess deposits; Thebes formation; Esna shale; Chalk; Dakhla shale; Phosphatic beds; Purple and variegated shales; Nubia sandstone.

- * No doubt that the bed rock in the archaeological site of El-Bagawat cemetery, and maybe in all archaeological sites at Kharga oasis, was one of the most influential reasons of damaging these sites.
- * The soil of Kharga oasis contains high salt content.
- * The dominant formation of the oasis land is the clay (or shale) formation “known as Dakhla Formation”, contrary to what some believe that the desert soil is only sandy land.

- * In fact, the main material of most depressions lands is shale, sandstone and limestone.
- * The origin shale or clayey soil of the oasis was transferred and deposited since ancient times. A sandy layer; transported by wind and various in thickness from a few centimeters to a few meters; was deposited over the previous clay-based soil.
- * There are mutual layers of shale and sandstone (limestone) forming the majority of the soils in archaeological sites at Kharga oasis, such as El-Bagawat cemetery site, fig. (5-b).
- * The sandy layer; mentioned above; spreads throughout the oasis, and sometimes forms huge sand dunes that affect the archaeological buildings and sites, fig. (5-c).
- * It is worth mentioning, according to the field study, that the main deterioration factors of shrines No. 66 and 90 are represented, *from the researcher's point of view*, in the

following three reasons: environmental “climatic” hazards, biological hazards and lack of heritage management plan. As for *climatic hazards*, these are very significant so much so that they cannot be ignored, because the studied site is located in the western desert, which is considered the most arid area in the world. The prevailing climatic conditions are represented in: large variations in temperature rates, windstorms and unexpected sudden torrents. Table (1) shows the temperature rates during the year at Kharga oasis; also, it shows August is the warmest month of the year. The temperature in August averages 31.2 °C. January is the coldest month, with temperatures averaging 13.9 °C [10]. In fact, these values were recorded during the year and represent the ideal conditions inside the cities and villages, but in the deserted archaeological sites, these temperature values greatly increase. Likewise, rains sometimes fall profusely and devastatingly.

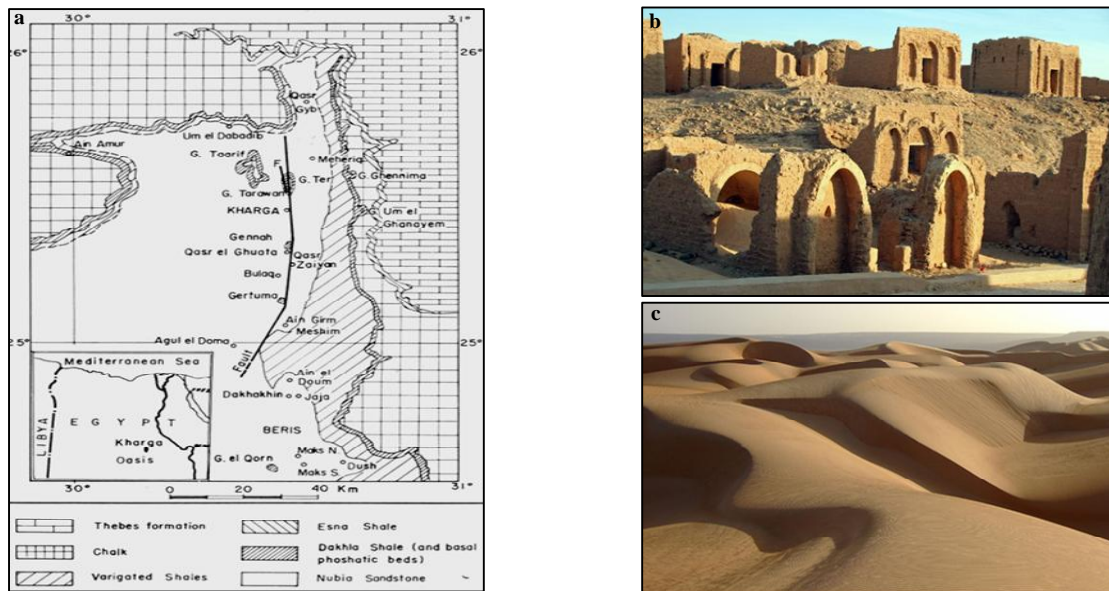


Figure (5) Shows **a.** a map showing geological formations of Kharga oasis “after: Said, 1962”, **b.** adobe shrines that built on the shale deposits/stone formation at El-Bagawat cemetery, **c.** sand dunes spread throughout the oasis.

Table (1) Average temperature rates during the year at Kharga oasis

Temperature (°C)	Months											
	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Avg.	13.9	15.8	19.5	24.2	29.2	30.8	31	31.2	28.8	26.1	20.8	15.9
Min.	5.7	7.2	10.8	15.4	20.7	23	23.1	23	21.3	18.4	13	8.1
Max.	22.2	24.4	28.3	33.1	37.7	38.7	39	39.4	36.4	33.9	28.6	23.8

1.3. Deterioration symptoms

The high values of temperature mostly affected the adobe shrines at El-Bagawat cemetery. It caused increasing in loads, which is called “temperature (or) thermal loads”; these loads appear in the form of cracks/ fine cracks and often weakness and disintegration of plasters. The structural conditions, wind and rain effects play a major role in boosting the action of thermal loads. Wind has the destructive action in El-Bagawat cemetery, so the most façades of shrines were deteriorated by wind erosion and undercutting due to windstorms. The sudden precipitation of rain destroyed many adobe walls and blurred the features of adobe façades of the shrines, fig. (6-a,b,c). The **biological hazards** are playing an essential role in deterioration of most adobe building at Kharga oasis. The white ants “Termites” are considered the main factor in deterioration processes; they feed on cellulose found in wooden elements or in the straw used in mud brick manufacturing. After the termite attacks; most shrines at El-Bagawat became destroyed. The participation between climatic factors and biological agents has led to definite damage to all shrines; specially shrines No 66 and 90. On the other hand, wild bees, beetles and moths have a severe role in deterioration and distortion of the mentioned shrines. For example; wild bees build their solid nests on the building materials, beetles and moths attack the organic building materials; as well as, the organic secretions of these insects are harmful and deforming to the building materials. In addition, bats, rats, reptiles, fierce dogs and wolves are considered an important source of biolog-

ical damage of El-Bagawat shrines; because of the farness of the site from inhabitedness. These animals previously mentioned are digging tunnels and making drillings, holes and scratches due to the direct friction with the building: soil; walls and architectural elements. This severe factor caused a structural dysfunction in many architectural elements of the studied adobe shrines, fig. (6-d). With the same context, the scientific and analytical studies conducted by the researcher proved that the bat excretions; in particular, contribute significantly in the deterioration of historic building materials causing: aesthetic; biogeophysical and biogeochemical damages, as a result of presence of phosphate salts in bats guano which accumulated on the building materials. The main detected salts are: Brushite ($\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$); Whitlockite ($\text{Ca}, \text{Mg}, \text{Fe}[\text{PO}_3\text{OH}/(\text{PO}_4)_6]$) and Newberyite ($\text{MgHPO}_4 \cdot 3\text{H}_2\text{O}$) [11]. Furthermore, there is another kind of risk that affects the studied shrines at El-Bagawat cemetery, which is the *absence of heritage management plan* and lack of future vision for conservation, development and upgrading of the area under the study architectural heritage. The officials neglected these archaeological sites for a long time, this led to make these sites considered lawful by the antiquities thieves; therefore, many of devastation and demolition works were done. On the other hand, there are no paved roads lead to the majority of sites. Recently, the New Valley governorate has established some roads lead to some shrines at El-Bagawat cemetery. As well, there is no documentation of that architectural heritage; these make restoration procedures too difficult.



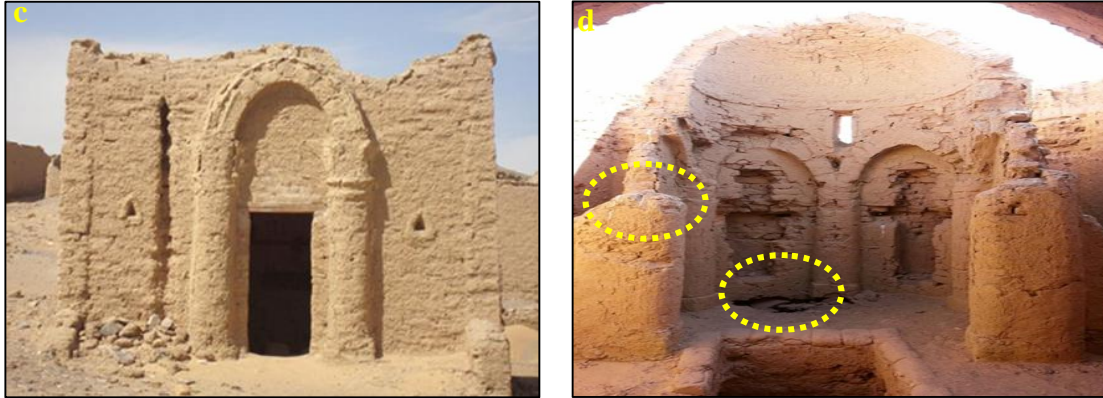


Figure (6) Shows deterioration effects in shrine No. 66 **a.** fine and medium cracks due to thermal changes (thermal loads) and structural reasons, **b.** sand sediments filled and covered the shrines as a result of wind and sandstorms, **c.** loss of façades mud brick features due to the mutual influence between rainfall and severe windstorms, **d.** effects of biological hazards. Rats, reptiles and fierce dogs dug tunnels and holes in the floor under walls causing damage and collapse. Also, the effects of organic secretions of birds contain Nitrates

2. Materials and Methods

Some collected samples from the our site were studied by USB Digital Microscope 500X (*Model pz01*) at various magnifications to characterize the optical features of the samples [12]; SEM (*JEOL JSM S400LV EDX Lin 1 ISIS-Oxford "high vacuum"*), equipped with an energy dispersive X-ray detector was performed in order to investigate the sample surface morphology and study the their elemental compositions [12,13]. Moreover, X-ray diffraction analysis (XRD) with PAN analytical X-Ray equipment (*X'Pert PRO with Seco-ndary Monochromator, -radiation ($\lambda = 1.542\text{\AA}$) at 45 K.V., 35 M.A. and scanning speed 0.04o/sec.*) was used. The diffraction peaks between $2\Theta = 2^\circ$ and 60° , corresponding spacing (d , \AA) and relative intensities (I/I_0) were obtained. The diffraction charts and relative intensities are obtained and compared to ICDD files, (also, Diffractometer PW 1480, Nethe-

rland with analysis program: Match 2014+ PDF4 2015) used to identify the mineralogical composition of studied samples. Additionally, some physical and mechanical properties of some selected samples were studied to evaluate the durability state of the adobe structure. Also, Auto-CAD software 2016 was used to perform a geometric documentation of visible deterioration aspects. Finally, laboratories experiments were carried out for manufacturing two earthen mixtures of new adobe blocks to be used in restoration works. They were subjected to stiff tests to determine their abilities as protective materials for the adobe of shrines buildings and restoration purposes. All the above mentioned procedures were carried out as an applicable integrated strategy for restoration of the studied adobe shrines and all similar shrines at El-Bagawat cemetery, Kharga oasis.

3. Results

3.1. USB digital microscope

USB digital microscope is a modern and advanced technology which can magnify objects up to 500 times their original size. It uses a dynamic image sensor and eight super bright white LED lights for creating detailed images.

This allows seeing even the smallest details, in high resolution, directly on the computer screen [14]. Figure (7-a, b, c) shows the precise surface details of building materials; mud brick, mud mortar and mud plaster. It is very clear

that these building materials have a large amount of sand combined with the desert shale distinguished by red and green colors. The mud brick blocks were well made, but there are many cracks/

micro cracks due to environmental changes; especially large temperature changes, also there is a loss in organic material in some parts due mostly to insect action.

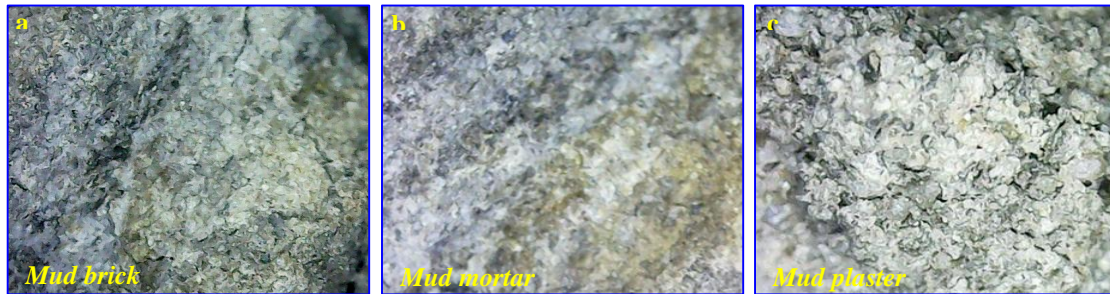


Figure (7) Shows the precise surface details of building materials large amount of sand, also the organic material and micro cracks specially in adobe blocks and mud plaster

3.2. Scanning Electron Microscopy (SEM - EDX)

The results showed that the mud brick samples, fig. (8-a) has many of internal cracks and voids as attested by El-Gohary, (2012) [15]. Also there is some disintegration and rotation in quartz grains, in addition to a weakness in the binding materials (clay minerals) due to environmental weathering especially high temperature and wind erosion. White ants have an important role in degradation processes of the archaeological mud brick in studied shrines at El-Bagawat, they devour the organic material and leave mud blocks weathered and pierced. In a similar way, the damage

occurred in mud mortar, fig. (8-b) and mud plaster, fig. (8-c). Moreover, EDX results of archaeological mud brick, tab. (2) refer to the variety of silica percentage in the different samples, this refers to the increase of sand in some samples (mud blocks) and the decrease in other samples. In addition to the increase of organic material as a result of the existence of Phosphorus element (P), also, all mud brick samples contain a proportion of lime and iron compounds because of the existence of (Ca) and (Fe) elements.

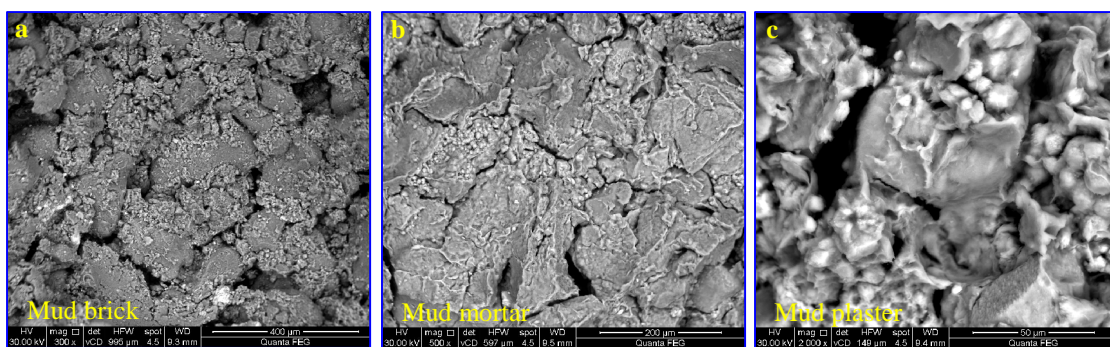


Figure (8) Shows photomicrographs of some weathered and eroded surfaces, internal cracks and voids due to environmental and biological factors

Table (2) SEM-EDX microanalysis of the studied mud brick samples

Samples	Elements (%)				
	Si	P	S	Ca	Fe
1	78.00	20.99	0.21	0.35	0.45
2	40.07	6.01	0.05	0.11	0.16
3	91.30	7.32	0.46	0.47	0.45

3.3. X-Ray Diffraction Analysis (XRD)

The results of collected from the archaeological shrines showed that the two studied shrines were built of mud brick blocks with same mineralogical components. The abundant ingredients of the studied mud brick samples are Quartz, Calcite, Orthoclase and Kaolinite, fig. (9-a). Also, there is a clear similarity in the mineralogical composition between studied mud brick, mud mortar and mud plaster samples. The abundant

minerals of the studied mud mortar samples are Quartz, Calcite, Kaolinite and Montmorillonite fig. (9-b), while the main compounds of the studied plaster samples are Quartz and Orthoclase fig. (9-c). Notable, that the presence of both Quartz and feldspar abundantly in the mineralogical composition of the shrines building materials donates them some of hardness and resistance.

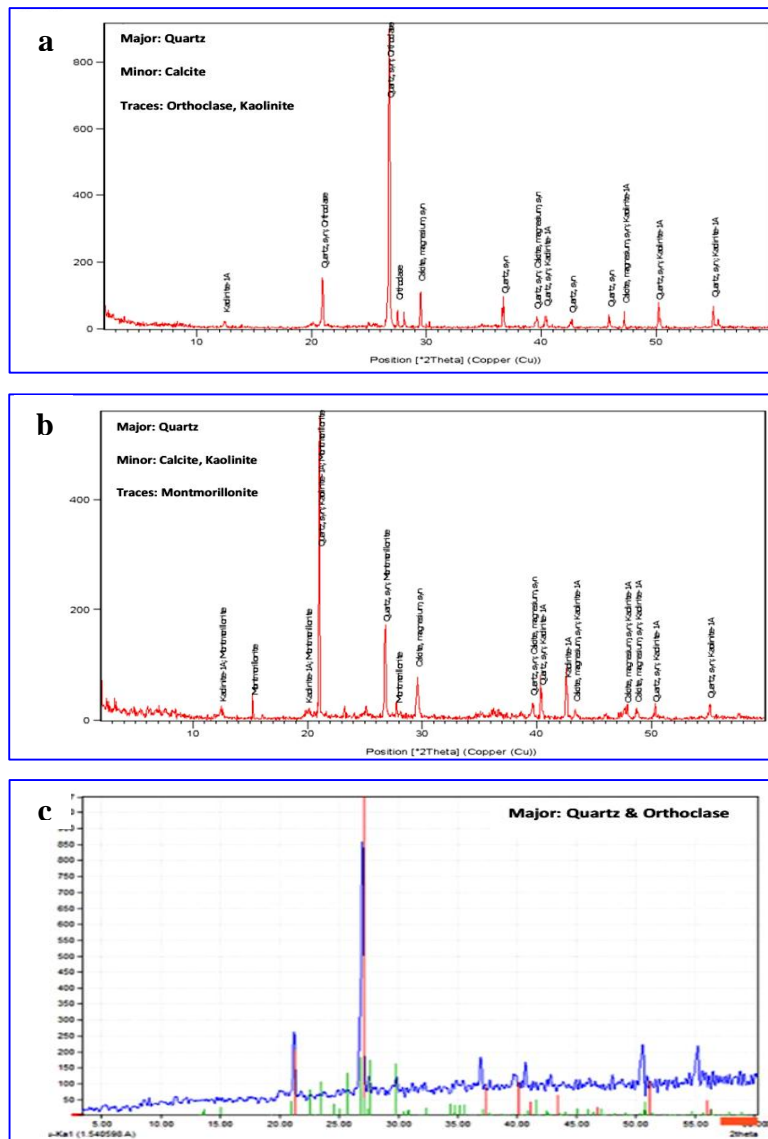


Figure (9) Shows XRD patterns of the studied samples from shrines no. 66 and 90 **a.** mud brick, **b.** mud mortar, **c.** mud plaster.

3.4. Physical and mechanical properties

The different resulted measurements of laboratory experiments proved that the different physical and mechanical

properties of historic adobe are highly affected by dominated deterioration factors as listed in tab. (3).

Table (3) Average of physical and mechanical properties of investigated historic adobe

<u>Property/ Test</u>	<u>Historic adobe</u>
Density (gm/cm ³)	1.2
Porosity (%)	***
Water absorption (%)	***
Shrinkage (%)	**
Compression strength (kg/cm ²)	5.3
Thermal effect	Vulnerable
Total immersion in water	Highly sensitive

* = Small ratio ** = Medium ratio *** = High ratio

3.5. Documentation of shrines as an important preservation strategy

The most important reason for the loss of architectural heritage at El-Kharga oasis, other than environmental and biological factors aforementioned; being this heritage not documented. For this and other reasons, restoration and preservation procedures have become complicated due to lack of documentation about the previous architectural description of the archaeological buildings. This problem is not only for the studied shrines at El-Bagawat cemetery, but also for all archaeological buildings at the oases. The present study recommends and focuses on the need for architectural documentation

of all architectural heritages at El-Bagawat and El-Kharga oasis. Documentation procedures should include description of the current status and deterioration aspects. In this regard, the researcher used the AutoCAD software 2016 to present a geometric documentation of the deterioration aspects of shrine No. 66, fig. (10) as a model to be applied to all archaeological shrines at El-Bagawat. It is clearly shown that the main aspects represented in the loss of mud bricks in some parts; furthermore, there is a collapse in some parts of the shrine, especially the upper parts exposed to rainfall.

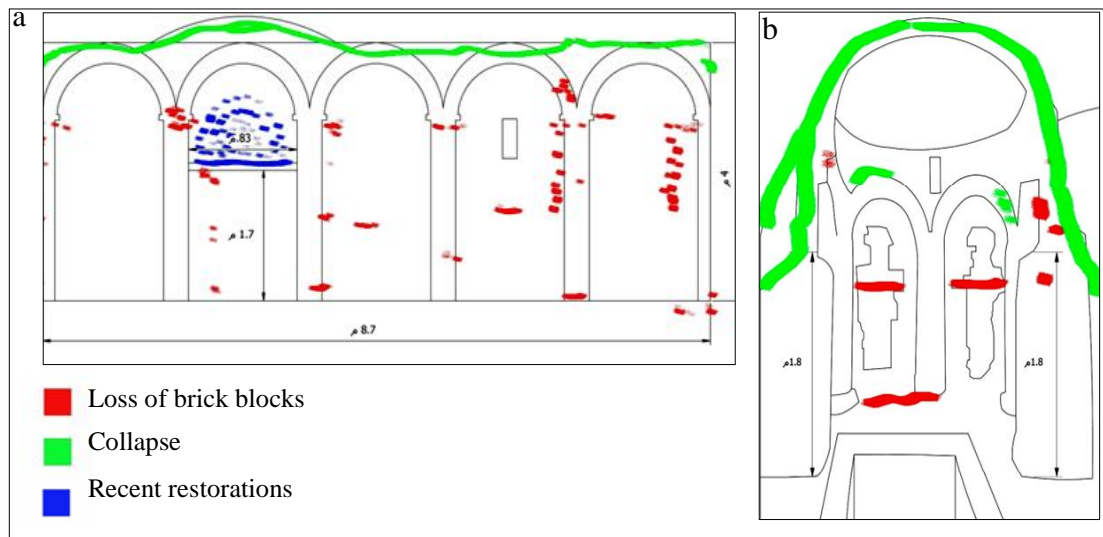


Figure. (10) Shows a geometric documentation of the deterioration aspects of **a.** of southern façade, **b.** of the interior of shrine No. 66, El-Bagawat cemetery, Kharga oasis.

3.6. Manufacturing new mud brick

For the purposes of restoration and reconstruction, two new earthen mixtures were carried out and subjected to stiff tests (exposure to high temperature for several cycles & immersion in water for several consecutive days) to determine their durability; * **1st mix.** consists of (65 % kaolinite-rich soil + 17 % salt-free

sand + 15 % slaked lime + 3 % fiberglass), the **2nd mix.** consists of (70 % clay-rich soil + 15 % salt-free sand + 10 % Portland cement + 5 % chipped straw). The average results of the previous physio-mechanical properties and artificial aging are listed in tab. (4). It is worth noting that the **1st mix.** is a suitable for

use in restoration and reconstruction works of the studied shrines at El-Bagawat cemetery, Kharga oasis. This mixture can be used to manufacture new mud bricks for reconstruction and

reinforcement purposes; it can also be used to make resistant plaster layers or protective layers for ceilings due to their high resistance to heat and moisture.

Table (4) Average of physical and mechanical properties of investigated new earthen mixture after artificial aging

Property/ Test	1 st Mix.	2 nd Mix.
Density (gm/cm ³)	1.4	1.8
Porosity (%)	**	***
Water absorption (%)	**	***
Shrinkage (%)	**	*
Compression strength (kg/cm ²)	27.7	22.3
Thermal effect	Resistant	Vulnerable
Total immersion in water	Highly resistant	Medium

* = Small ratio ** = Medium ratio *** = High ratio

4. Discussion

According to the previous studies it could be claimed that the site under the study suffer from severe deterioration symptoms as attested previously by El-Gohary, M., (2012) in similar case [15]. Where, its units indicate that they highly affected by synergetic deterioration factors, especially climatic and biological hazards. The examination by USB digital microscope showed some degradation aspects on the samples, such as: small cracks in mud brick, pitting and cracking of mud plaster due to physical and biological weathering. SEM examination results showed the morphology of the surface of studied samples which seem to be weathered and disintegrated; this is very noticeable in quartz granules [16]. Furthermore, the examination showed mixing clay with sand and lime in mud brick and mud mortar. The elemental composition of studied samples by EDX refers to the presence of (Si, P, S, Ca and Fe) [the main components of sand and lime] in the mud mixture as indicated in XRD results. Moreover, occurring of phosphor (P) is probably referring to the existence of Phosphor [the main component of bird droppings] [17]. Moreover, the soil used in mud brick manufacture was rich in iron and sulfur. XRD results of studied samples (brick, mortar and plaster) indicated the presence of the mineral Quartz (SiO₂) mainly in all sam-

ples, and this is a proof that the brick maker added an adequate amount of sand to the mud mixtures to avoid the problem of cracks after drying. It is also noted that the addition of sand is important to balance the mud mixture because it is inert material, especially that the Kharga oasis soil naturally contains both Kaolinite [Al₄Si₄O₁₀(OH)₈] and Montmorillonite [(Na,Ca)_{0.33}(Al,Mg)₂(Si₄O₁₀)(OH)₂·nH₂O] as is evident by XRD analysis, These types of clay minerals represent the binding materials in the historic mud mixtures [18]. Moreover, the presence of Calcite (CaCO₃) in a moderate amounts in studied samples refers to the intended addition of slaked lime or limestone powder to improve plasticity and durability of the mud mixtures. The mineral Orthoclase [KAlSi₃O₈] is one of the most important feldspar minerals in the earth's crust, it has been found mixed with sand in the soil in the form of very fine grains due to physical weathering. Moreover, it could be claimed that the new mud mixture containing (65 % kaolinite-rich soil + 17 % salt-free sand + 15 % slaked lime + 3 % fiberglass) showed good results in physical and mechanical properties, and this is due to the characteristics of additives. For example sand is an inert material that provides mud brick strength; Kaolinite has a low shrink-swell capacity and a low

cation-exchange capacity, so it is pretty stable on the contrary of Montmorillonite; slaked lime provides good adhesive properties; and fiberglass which is a kind of thermo set plastic with high mechanical properties, furthermore, this material is not affected by water. All of these characteristics made this mud mixture suitable for mud brick manufacture and conservation works. Finally, some special recommendations for restoring and preserving the site under study should be taking into our considerations; they include the following points:

- * supporting the works to protect the shrines from collapse, especially vaults because of their extreme weakness fig. (11-a).
- * covering the shrines and similar mud brick ruins at El-Bagawat cemetery with shelters to keep the adobe shrines out of direct sunlight and rainfall effects, fig. (11-b), with noticing that these shelters should not distort the archaeological site, also; they should have a slope system to drainage.
- * Using the selected mud brick to restore, complete and reconstruct the damaged and lost parts through building one or

two courses on the upper parts of the walls, if possible, to make as protective courses for the lower archaeological parts (*capping*). In addition, narrow strips of plastic sheets (0.9 mm in thickness) between the original surface and capping layer could be used as indicators when additional conservation or intervention is needed, fig. (11-c, d) [19].

- * Applied of mud plaster on wind-exposed façades of the studied shrines using the above-mentioned mixture.
- * Removing sand deposits from inside and outside the archaeological shrines/sites, pave the roads leading to these sites.
- * Applying a concerted plan in which all institutional efforts will be combined to prevent the sand dunes from reaching the archaeological sites.
- * Intensification of scientific studies on Kharga oases, especially studies related to weather changes, environmental impacts, soil and earthquakes. It is worth mentioning that alluvial deposits may result in a high amplification to ground motion (by earthquake) which may result in unexpected high damages [20].



Figure. (11) Shows **a**, applicable technique for prop up the cracked/damaged shrines, **b**, a model for covering by shelters and capping method carried out by the researcher in a similar adobe building **c**, application of plastic sheets, **d**, protective courses.

5. Conclusion

The shrines numbers 66 and 90 of the most important shrines at El-Bagawat cemetery, Kharga oasis, they built originally of mud brick, mortar and plaster. Survey study of the site confirmed that the major factors of damage are environmental "climatic" hazards, biological hazards and lack of heritage management plan. Samples collected from the shrines were analysed by XRD, the results showed that the main components of archaeological mud brick, mortar and plaster are Quartz, Calcite, Orthoclase and Kaolinite with a small amount of Montmorillonite. USB digital microscope and SEM microscopy showed the weathered and eroded surfaces, internal cracks and voids due to environmental and biological factors. EDX results of the archaeological mud brick refer to the variety of silica percentage in the different samples, in addition to the increase of organic material. The studied shrines undergo structural weakness, cracking, partial collapse and disintegration of mud mortar and plaster. The mixture consisted of (65% kaolinite-rich soil+ 17% salt-free sand + 15% slaked lime + 3% fiberglass) proved to be highly efficient in resisting heat, moisture and loads, so it can be used well in restoration and reconstruction works.

Acknowledgment

The author would like to express his sincere gratitude to Prof. Mohamed El-Gohary, professor of conservation science, Department of conservation, Faculty of Archaeology, Sohag University- vice dean for graduate studies and scientific research, Faculty of Archaeology, Sohag University, Egypt, for his scientific and moral support. The author would also like to thank Dr. Mahmoud M. Masoud and Mr. Mohamed I. Aly, New Valley Governorate, Ministry of Antiquities, for their sincere efforts.

References

- [1] Cruz-Uribe, E., Piccione, P. & Westerfeld, J., (2004). Kharga oasis Coptic graffiti project preliminary report of the 2005 field season, *JSSEA*, Vol. 31, pp: 37-48.
- [2] <http://whc.unesco.org/fr/listesindicates/6067/>, Egypt, (2-5-2017).
- [3] Abo El-Yamin, A., Mahmoud, H. & Brania, A., (2013). Analytical study of Coptic wall paintings in Egypt, El-Bagawat necropolis, Kharga Oasis: A case study, *Periodico di Mineralogia*, Vol. 82 (1), pp: 25-40.
- [4] Fakhry, A., (1951). *The Egyptian desert: The necropolis of El-Bagawat in Kharga oasis*, Government Press, Cairo.
- [5] Abd El-Hafez, M., (2012). *Comparative and analytical study on the deterioration & treatment and conservation of historical buildings of composite building materials at El Kharga & El Dakhla Oases, with application on some selected historical buildings*, PhD dissertation, Conservation dept., Faculty of Archaeology, Cairo Univ., Egypt (In Arabic).
- [6] Chaney, M., Wire, A. & Hearon, H., (2004). *Distant voices drawing near: Essays in honor of Antoinette Clark Wire*. Liturgical Press, USA.
- [7] Abd El-Hady, M. & Abd El-Hafez, M., (2012). Physio-chemical and mechanical deterioration of monumental mud brick in Egypt, *EJARS*, Vol. 2 (2), pp: 103-107.
- [8] Chayet, A., Jest, C. & Sanday, J., (1990). Earth used for building in the Himalayas: The Karakoram, and Central Asia-recent research and future directions, in: Grimstad, K., Agnew, N., Taylor, M., Balderrama, A. & Houben, H (eds.) *Proc. of 6th Int. Conf. on the Conservation of Earthen Architecture (Adobe 90)* , Las Cruces, New Mexico, U.S.A., pp: 29-34.
- [9] Said, R., (1962). *The geology of Egypt*, Elsevier, Amsterdam, New York.
- [10] <https://en.climate-data.org/location/32848/>, Egypt, 2017. (24-6-2017).
- [11] Bakr, A. & Abd El Hafez, M., (2013). Role assessment of bat excretions in degradation of painted surface from Mohamed Ali's palace, Suez, Egypt, *EJARS*, Vol. 3 (1), pp: 47-56.
- [12] Stuart, H., (2007). *Analytical techniques in materials conservation*, John Wiley & Sons Ltd, England.

- [13] Ahmadi, Sh. (2008). *Adobe conservation: Evaluation of silicone and acrylic Consolidants*, MSc dissertation, Department of Art, Queen's Univ., Canada.
- [14] [https://www.seeedstudio.com/USB-Digital-Microscope-p-1406.html?gclid=EAIaIQobChMI_vmg6KKv1QIVTLvtCh2e9QwzEAAYASAAEgKUcvD_BwE,Egypt,\(2-8-2017\)](https://www.seeedstudio.com/USB-Digital-Microscope-p-1406.html?gclid=EAIaIQobChMI_vmg6KKv1QIVTLvtCh2e9QwzEAAYASAAEgKUcvD_BwE,Egypt,(2-8-2017)).
- [15] El-Gohary, M., (2012). The contrivance of new mud bricks for restoring and preserving the Edfa ancient granary-Sohag, Egypt, *IJCS*, Vol. 3 (2), pp: 67-78.
- [16] El-Gohary, M., (2017). Environmental impacts: Weathering factors, mechanism and forms affected the stone decaying in Petra, *African Earth Sciences* Vol. 135, pp: 204-212.
- [17] Bassi, M. Chiantante, D. (1976). The role of pigeon excrement in stone biodeterioration, *Int. Biodeterioration Bulletin*, Vol. 12 (3), pp: 73-79.
- [18] El-Gohary, M. (2011). Analytical investigations of disintegrated granite surface from the Un-finished obelisk in Aswan, *Int. J. of ArchaeoScience*, Vol. 35, pp. 29-39.
- [19] Caperton, J., (1993). Long term preservation issues related to earthen archaeological sites, in: Alcada, M., ICCROM & CRATerre-EAC (eds.) *Proc. of 7th Int. Conf. on the Study and Conservation of earthen Architecture*, Silves, Portugal, pp: 210- 214.
- [20] Fouad, M., Mohamed, A., Salah, H., Khalil, A. & Abd El Hafez, M., (2015). Seismological investigation at mekaad Radwan, Ottoman period - Cairo - Egypt, *EJARS*, Vol. 5 (1), pp: 13-20.