Advanced Research in Conservation Science, Vol. 4, Issue 2, 2023, 13-30.

Advanced Research in Conservation Science

Journal homepage: https://arcs.journals.ekb.eg

DOI: 10.21608/arcs.2023.198234.1036

Evaluation Study of The Fustat Excavations Site Between The Past, Present And Expected Future

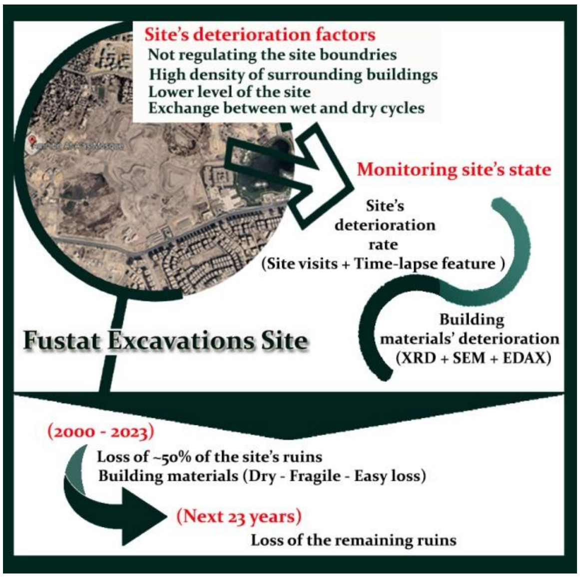
Omar Mohammed Adam Abd El Hameed, Aalaa Gamal Mahmoud Ali*

Department of Architectural Conservation and Preservation of Buildings and Archaeological Sites, Faculty of Archaeology, Cairo University, Giza, Egypt.

HIGHLIGHTS

- Fustat excavations site suffers from many problems related to its local environment and its building materials.
- By tracking the site in the proposed time period (23 years), the site underwent many changes in terms of wet and dry cycles, growth of plants, disappearance of some ruins, increase of population and buildings' density.
- Fired bricks suffer from a weak internal structure, which causes its fragility and easily lost.
- The bonding mortar is dry and lacks its suitable percentages of improving materials.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article History:
Received: 6 March 2023.
Revised: 26 August 2023.
Accepted: 11 December 2023.
Available online: 29 December 2023.

Keywords:
Preservation state, current state evaluation, deterioration rating, building materials analysis, fired bricks, mortar.

ABSTRACT

The city of Fustat which is located in Cairo, Egypt, was the first Islamic city in Africa. The site underwent excavation works that revealed some city and buildings. Excavations stopped in 1975, and from that time the site started to deteriorate. The most important deterioration factors were the urban expansion and the rising of groundwater level, besides lacking any regular restoration or evaluation works.

The study aims to monitor the state of preservation of the Fustat excavations site and track the stages of its deterioration during a specific period (23 years). This helps in monitoring the rate of deterioration during that period, thus

* **Corresponding author:** aalaa_gamal@cu.edu.eg

predicting the condition of the site during a similar future period of time or more. To achieve these aims, the following methodology was suggested: a. monitoring the current deterioration phenomena and its causes, b. determining the state of archaeological building materials by taking small representative samples from the fired bricks and mortar, and c. standard samples of fired bricks and mortar were used for the comparison with the results of the current samples in order to determine the status of preservation of the archaeological building materials at the site.

1. Introduction

Visiting the Fustat excavations site reflects mixed impressions between an ancient city that was famous for its civilization and history, and some ruins that disappeared due to natural and human factors. The Fustat excavations site is considered part of the Fustat archaeological site (Fig. 1) that includes many archaeological sites, such as the Synagogue of Ben Ezra, the Mosque of ‘Amr ibn al-‘As, the excavated remains of the old city of al-Fustat, the Nilometer on Al-Roda island, the Al-Manesterley Palace, and Mohammad Ali Palace in Al-Manyal [1].

The ruins of the ancient city of Fustat are located in Cairo, the capital of Egypt. The city of Fustat is one of the oldest Islamic cities in the world, and the first Islamic city in Africa. It was established by Amr Ibn Al-Aas under the rule of Caliph Omar Ibn Al-Khattab in 21 AH / 640 AD [2], and it is located to the east of the Nile next to the Babylon Fortress [3].

Fustat planning follows the planning of Islamic cities, which includes streets, lanes and alleys, with the presence of the mosque and the Emirate House in the city center, as well as markets named after craftsmen such as Souk Al-Attarin (for selling perfumes) and Souk Al-Sammakeen (for selling fish), in addition to simple facilities known as guards(guardhouses), for neighborhood mediation or located on their borders to guard every tribe [3]. The role of Fustat as an inhabited city has weakened as a result of being exposed to fire more than once and for various reasons, starting in the year 132 AH / 750 AD, while the last fire was 564 AH / 1168 AD [4].

Salah al-Din al-Ayyubi walled Cairo and the remains of Fustat which includes the remains of houses, bathrooms and civil buildings with one wall, the remains of which are still present now [1]. Recently, organized excavations continued at the site beginning from 1912- 1925 (Excavations of Ali Bahjat and Gabriel) [4], [5], and until 1975 AD, which resulted in the discovery of some of the houses' foundations from the Rashidun period (the era of construction) until the Fatimid period, in addition to some remains of pottery and ceramic shards dating back to different periods [2], [4]. The city's buildings were built of adobe bricks, and then of fired bricks and mortar that was a mixture of lime, sand and qasromil [6]. The houses consisted of one floor or more, according to the thickness of the walls' foundations. The elements of the house were gathered around an open middle courtyard [7], also the houses were attached to stores, shops, stables for horses and animals, and a sewage line (made of pottery and bricks). However, not many walls remain to help delineate the streets, lanes and alleys in Fustat.

The climate zone in Egypt is classified as hot and dry climatic conditions with very high temperatures, little rains and variation in temperatures during the year [8].

Urbanization over Fustat excavations site also affect the climate. The increase of urbanization or industrialization in an area increases the temperatures, while the values of winds, their speed, relative humidity, and the amount of precipitation decrease [9]. Tables (1, 2) indicate the monthly and annual average of climate elements in Cairo.

2. Research Methodology

The study involves monitoring the state of the Fustat excavations site and tracking the stages of its deterioration during a specific period (23 years). This will help in monitoring the rate of deterioration during this period and thus predict the condition of the site during a similar future period or more. To achieve this, the study relied on the following methodology: a. monitoring the current

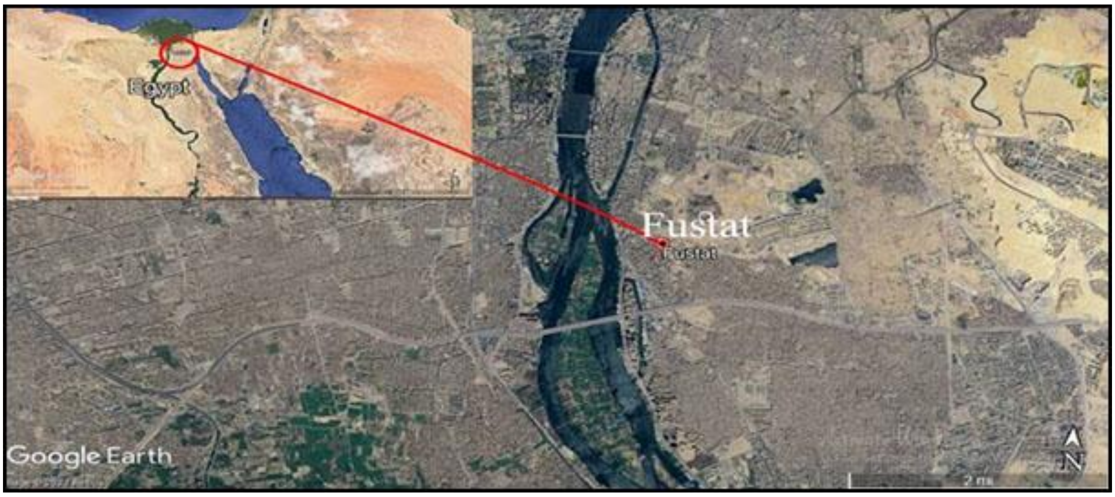


Fig. 1. Aerial photo shows the location of the Fustat archaeological site and the Fustat excavations site within its borders in Egypt (Google earth pro, 9- 1-2023)

Table 1. Monthly Average of climate elements in Cairo (temperature, humidity, winds, rain) [10]

Monthly Average	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Highest Recorded Temperature (^oC)	30	33	37	42	43	45	42	41	43	38	35	28
Average Relative Humidity (%)	65	60	55	50	50	50	60	65	60	65	65	65
Average Morning Relative Humidity (%)	74	71	72	68	71	76	83	85	83	81	77	75
Most Rain Reported in a Month (mm)	40	30	20	30	10	10	---	---	---	20	20	60
Average Wind Speed (km/h)	14	16	12	14	14	14	12	12	12	12	9	12

Table 2. Annual Average of climate elements in Cairo (temperature, humidity, rain, winds) [10]

Annual Average of climate elements	Annual (%)
Highest Recorded Temperature C	45
Average Relative Humidity %	59.2
Average Morning Relative Humidity %	76
Most Rain Reported in a Month mm	90
Average Wind Speed	12

deterioration phenomena of the site and studying its causes. The time-lapse feature available on the Google Earth application was used to provide aerial photos of the site from 2000 to 2023, that help in observing the various changes that occurred on the archaeological site and its surroundings, b. determining the state of preservation of the archaeological building materials by taking small representative samples to obtain the required information about its constituents and state. The scanning electron microscope was used for high magnification photographing with its elemental analysis unit EDAX to identify the state and elemental constituents of these samples, X-ray diffraction analysis was used to find out the constituent minerals of the sample, c. Standard samples of fired bricks and mortar were used for comparison with the results of the current samples to determine the state of preservation of the archaeological building materials at the site.

2.1. Current state of the Fustat excavations site

Through visual examination and an initial evaluation of the Fustat excavations site, it is clear that the site consists of ruins and archaeological remains of buildings bearing the features of authenticity [7], [11], [6] that distinguish it from other sites. These remains were exposed to various deterioration factors in their open environment, which led to their loss over time and thus the loss of a very important historical stage in the history of Egypt. Through successive visits to the site, it is noted that the site suffers from fluctuation between cycles of wetness and drought and various external deterioration factors, in addition to the deterioration of the archaeological remains and the weakness of their internal constituents.

Fustat area suffers from the rise of ground water level [12], due to different factors: a. ground water movement from underground reservoirs through rock fissures [13], b. the low level of the excavation site of +72 feet (+22 m) below the surrounding residential areas with high population density and a high level of ground water + 100 feet (+30.5 m) that causes sewage leakage (Fig. 2), c. garden irrigation water leak, especially after the establishment of the Fustat garden [12]. Underground water seepage has an important effect on the engineering mechanical properties of the soil and its water content which negatively affects the remains and foundations of buildings at the site [14], and also this seepage caused the formation of some lakes such as Ain El Sira Lake that later negatively affected the site [13]. Sewage and irrigation water leakage containing agricultural fertilizers caused ground water contamination with Nitrates, Aluminum and Manganese [15]. The current state of the site is not safe, besides the threat from the rise of ground water level, there are many encroachments from the residents and government agencies, and also there is an urgent need for restoration and intervention to control the loss of the remains of archaeological buildings [2] (Figs. 3, 4 and 5).

2.2. *Current state of archaeological building materials*

2.2.1. Materials and Methods

Sampling: The study was conducted on four representative samples of the used fired bricks and mortars in the ruins of the city of Fustat. Samples in table 3 were taken to evaluate their current state and determine their constituents through various examination and analytical methods.

Analytical methodology: It is necessary when studying the state of archaeological building materials to use a set of basic analyses that provide a clear picture of the constituents of the studied materials as well as the state of their preservation [16]. To achieve this, scanning electron microscope (SEM) was used to consider morphological features [17];

a) Surface images of nanoparticles were recorded by Quanta, FEG 250 scanning electron microscope. The samples were studied under different magnification range from 150 to 15000 x. Elemental analysis through the EDAX unit attached to the SEM microscope was conducted.
b) X-ray diffraction analysis (XRD) to reveal the constituent minerals [17] by using XRD PHILIPS 1730 diffractometer

Fig. 2. Aerial photos show the location of the Fustat excavations site in relation to the Nile River on the west and the state of the site during two decades, where 1. Site of the traditional crafts center, 2. the Fustat excavation area, 3. The Fustat Park, 4. Ain El-Sira Lake, a. aerial view in 2003, b. Aerial view in 2012, c. Aerial view in 2023 (Google earth pro, 9-1- 2023)

Fig. 3. Aerial photos show the exchange between wet and dry cycles at the site, a. The rise in the ground water level and total immersion of the excavation area, b. Dryness or partial immersion and the appearance of biological damage in some areas of low level, c. The lowest areas in the excavation site (70 - 80 feet), d. The highest areas in the residential surrounding areas (90 - 100 feet), (Google earth pro, 9- 1- 2023).

Fig. 4. Aerial photos show the disappearance of the Fustat ruins at a large rate within a short period (13 years), a. The visibility of building foundations, b. Deterioration and loss of building foundations

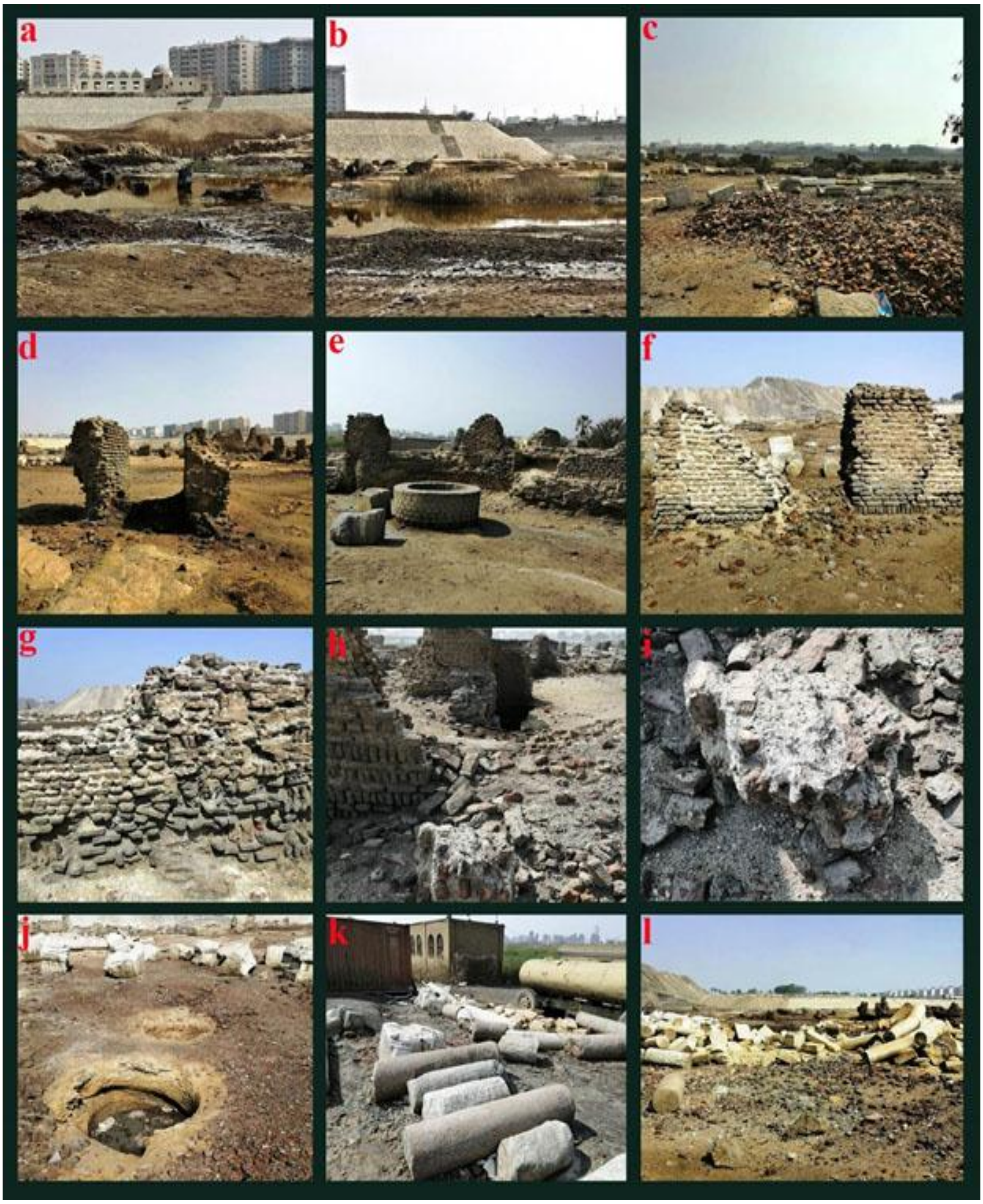


Fig. 5. The current state of the Fustat excavations site due to various damage factors, a, b. Ground water intrusion and the formation of ponds and swamps, c, d, e. General deterioration phenomena of the site, f, g. Collapsing of some parts of the archaeological remains, h, i. The fall of stone blocks and the decay of mortars, j, k. Not regulating the site boundaries and defining its protection zone to preserve archaeological remains and ruins, l. Water accumulation and frequency of rising in some areas.

Table 3. Listing the types of samples, their codes, conducted analysis or examinations, their description and their location

No of Samples	Type	Code	Analysis and Examination Methods	Samples Description	Sample Location
1	Fired brick	F B X	X-Ray Diffraction	Fired brick fraction with a crumbled appearance and has dark red colour	
2	Mortar	Mo X	X-Ray Diffraction	A gray mortar sample with little cohesion	
3	Fired brick	F B S	Scanning Electron Microscope with E D X	An easily separated fired brick sample of dark red colour	
4	Mortar	Mo S	Scanning Electron Microscope with E D X	A grey, easily separated sample of mortar	

with Ni filter at a scan speed of 0.5/ min, Cu K alpha radiation.

2.2.2. Standard samples used for comparison with site's samples

Adobe bricks and fired bricks were used as the main building materials at the site, with the use of binder mortars. Fired brick was widely used in construction because of its low cost, durability and easiness to shape. Clay bricks are used as exterior and interior building materials for the structural and architectural elements and are made of clay that has some properties such as flexibility when mixed with water, clay granules clump together once exposed to high temperature[18], [19].

The fired brick contains some basic constituents, the most important of which are silica and aluminum which are the two main constituents of the clay before the burning process, and they are two constituents of aqueous aluminum silicate, in addition to some other materials such as lime, oxides of iron, potassium and magnesium. The presence of these constituents in their natural proportion makes the brick stronger and more durable and has good specifications for building and construction works [18], [19].

The main characteristics of the fired brick constituents are:

a) Silica (SiO_2) the addition of free form silica or sand as a main component to clay in appropriate quantities provides hardness and prevents deformation and contraction on drying, while adding Silica in greater quantity, makes brick fragile. Adding Silica in the form of (aluminum silicate) does not produce good bricks, as it will contract and cause cracking [18], [19].

b) Alumina (Al_2O_3) Loam soil (adhesive soil) produces good clay. In the absence of sand, pure clay will cause cracking due to contraction during drying and burning. Alumina absorbs water and makes the clay flexible. If alumina is more than the specified quantity, it produces cracks during drying. Both silica and alumina should be in the free form [20], [21].

c) Calcium Carbonate ($CaCO_3$): is usually found in less than 10 % of clay and should be finely grained. Calcium Carbonate decreases shrinkage during drying [22].

d) Iron oxide: It is responsible for the red color in fired bricks. A high percentage of iron oxide is responsible for its dark coloration, while lower percentages are responsible for light and yellow colors. Iron oxide provides hardness to the fired bricks [20].

e) Potassium and sodium: Alkalis are mainly salt of sodium (Na) and potassium (K). The presence of alkalis affects the bricks, as it causes the following: distortions and deformation of the shape of the brick, Alkali absorbs moisture from the air and when it evaporates, it leaves white or gray colors on the surfaces of the walls, so these white spots are the result of the presence of chlorides and nitrates of calcium, magnesium and potassium. They keep the masonry in damp and wet conditions [23], [24], [25], [26].

As for mortars: Air-lime mortars with or without pozzolanic constituents were generally used in archaeological buildings. Due to mortar dilapidation, it is often necessary to apply to repair mortars. Several historic records refer to mortars made of 1 part lime to 3 parts sand [27], [28].

Sand makes mortar workable, plastic (has constancy to hold and not flow on overloads), improves compressive strength and must show volume constancy (does not cause reductions or expansions). In the hardened status, it should be cohesive and have adequate porosity [29], [30].

Because lime particles are large in number and small in size, they can coat every sand particle, which provides a homogeneous mix and the ability to carry more sand without sacrificing workability, therefore reducing mortar costs, since sand is less expensive than masonry cement, or hydrated lime. Adding lime to masonry mortars produces several effects: increasing water retention, increasing sand-carrying capacity, self-healing, improving tensile bond, and flexibility [31].

3. Results and discussion

3.1. Site deterioration rate

By analyzing the aerial photographs taken of the Fustat excavations site from 2000 to 2023, it is clear that there are many variables affecting the site varying between environmental and urban.

Environmental variables: are represented by a. the variation of the ground water level and the variation between wet and dry cycles at the site. It is clear from the aerial photographs in 2000 and 2003 that the green area in the site expanded as a result of the biological damage caused by the growth of weeds and plants as a result of the high water level. There is also a noticeable relative decline in the green area in 2012 and its concentration in low-level areas. From recent aerial photographs and from field visits, it is clear that the area is dry, except for some ponds with a lower level, in which the water appears in the form of stagnant water accumulations. b. High temperatures during the day in summer up to 44◦ C in June and a sharp decrease at night during the winter months less than 10 ◦C in January, with an average monthly rainfall of up to 0.2″ in March, November and December. In addition to the high percentage of humidity that can reach up to 65% in August and northern wind with speed reaching up to 10.1 mph in June [32].

All the previously mentioned weather changes led to the separation of the mortar bonding the brick blocks causing the collapse of many remains of the archaeological buildings and the scattering of their parts in the site and thus the loss of many parts of the archaeological site. c. Absence of any preventive measures such as the shading of the site, roofing it, reinforcing weak walls, or even covering it for preservation purposes. This caused the Fustat excavations site to be an open site affected by all the environmental factors in its surroundings. The danger of such open sites increases with the climate changes combined with a decrease and increase in temperature extremes, and an increase in the number of heavy precipitation [14]. d. The local environment or the soil on which the city of Fustat was built is a backfill soil with different characteristics that differ according to its various constituents. Backfill soil varies in its impact on the buildings built on it or their constituents, so it is treated as soil with problems that negatively affect the site.

Urban variables: The high density of buildings in the urban site is noted in addition to their great heights, with the presence of two sources affecting the rise in the water level in the site: a. Al-Fustat Park, which has been gradually neglected from 2012 to 2023, b. Ain Al-Sira Lake, which is cared for, determines its borders, and the development of its surrounding area, coinciding with the establishment of the Museum of Civilization and its opening in 2021.

As a result of environmental and urban variables, it is noted that many archaeological ruins have disappeared at the site in a short period from 2000 to 2023, in addition to the poor state of preservation of the rest of them, which threatens their loss.

3.2. Analysis results

3.2.1. X-ray Diffraction results

X-ray diffraction results for the main building material (Brick) (Fig. 6 a) showed the presence of Quartz SiO_2, Hematite Fe_2O_3, Albite $NaAlSi_3O_8$, Labradorite $NaAlSi_3O_8$, and Anorthite $CaAl_2Si_2O_8$. The used application for results interpretation clarified that the percentages of constituent elements of these minerals are: Silicon 29%, Iron 4.0%, Aluminum 10.6%, Sodium 4.1%, Calcium 3.7% and Potassium 1.2%.

X-ray diffraction results for the building mortar [33], [34] (Fig. 5 b) showed the presence of Quartz SiO_2, Calcite $CaCO_3$ and Gypsum $CaSO_4.2H_2O$, and the used application for results interpretation clarified that the percentages of constituent elements of these minerals are: Carbon 9.3%, Calcium 35.1%, Sulfur 3.2%, Hydrogen 0.2% and Oxygen 49.7%.

The results in both samples showed the presence of Gypsum mineral, which may have been used incorrectly in previous restorations or as a result of chemical deterioration of calcium carbonate due to the effect of sulfur oxides (as insoluble salt), taking into account what Gypsum does as a source of moisture in the internal structure of the bricks.

The results also showed the presence of both sulfur and sodium due to the deterioration of sewage lines and air pollution gases and the inclusion of those swamps by sulfur bacteria. It leads to weak internal bonds and fragmentation of brick constituents, as it encourages microbiological growth.

3.2.2. Scanning Electron Microscope results

The results of the samples that were taken from the Fustat excavations site for each of the bricks and mortar showed the following:

First: The results of the analysis of the fired brick sample using the EDAX unit (Figure 7a1-6a5), showed the availability of calcium, sodium, sulfur, potassium, iron and chlorine in varying proportions, which confirms the spread of calcium sulfate and halite salts. This is illustrated by the results of the examination with a scanning electron microscope of salt crystals.

Second: The results of the mortar sample analysis using EDAX unit (Fig. 7b1-7b5), also showed the availability of chlorine, sulfur and sodium elements, but more than brick constituents, due to the mortar’s ability to keep these constituents of salts more than the brick.

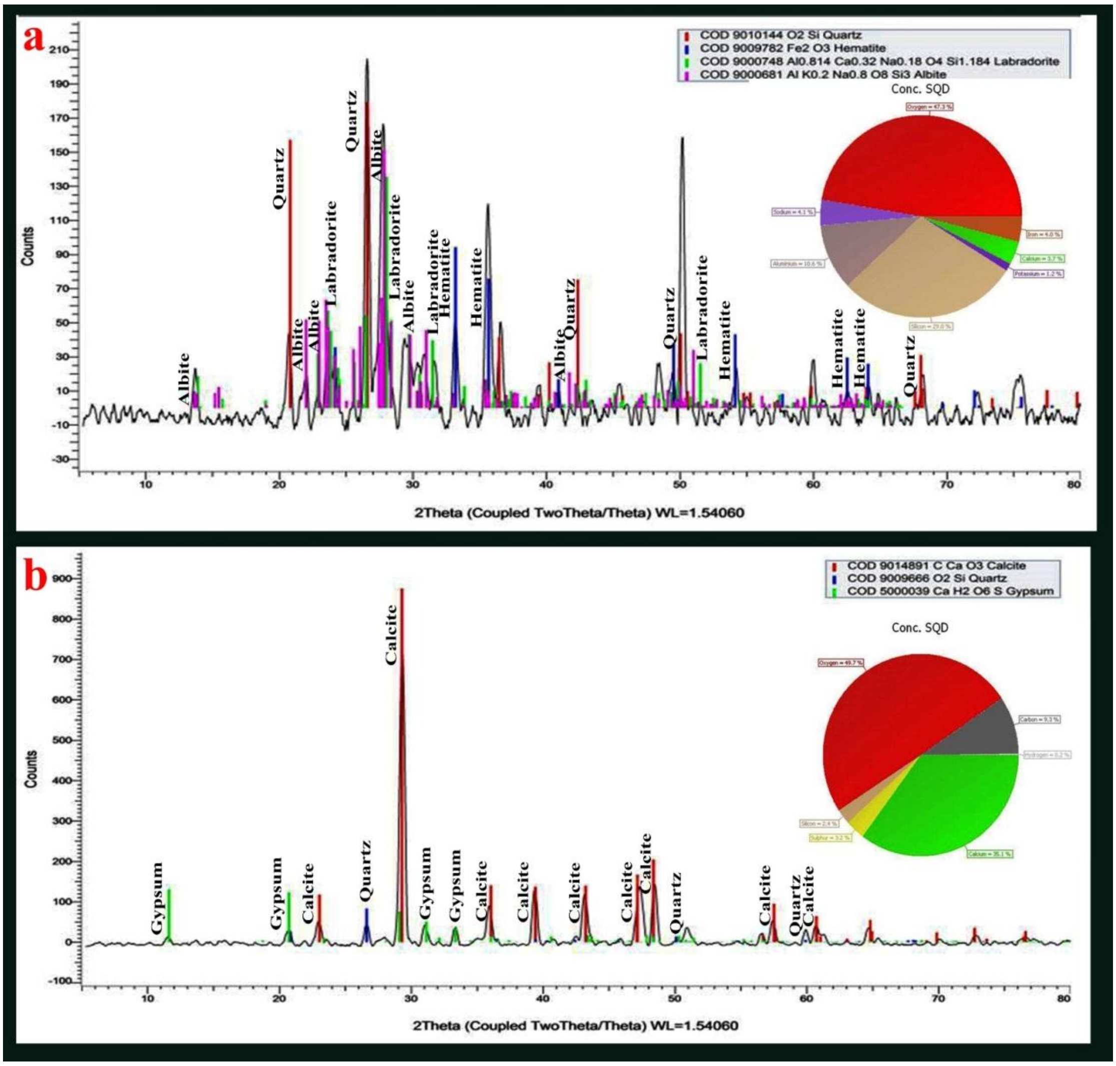


Fig. 6. a. X-ray diffraction results of the main building material (brick) with the percentages of the elements in it, b. X-ray diffraction results of the building mortar with the percentages of the elements in it.

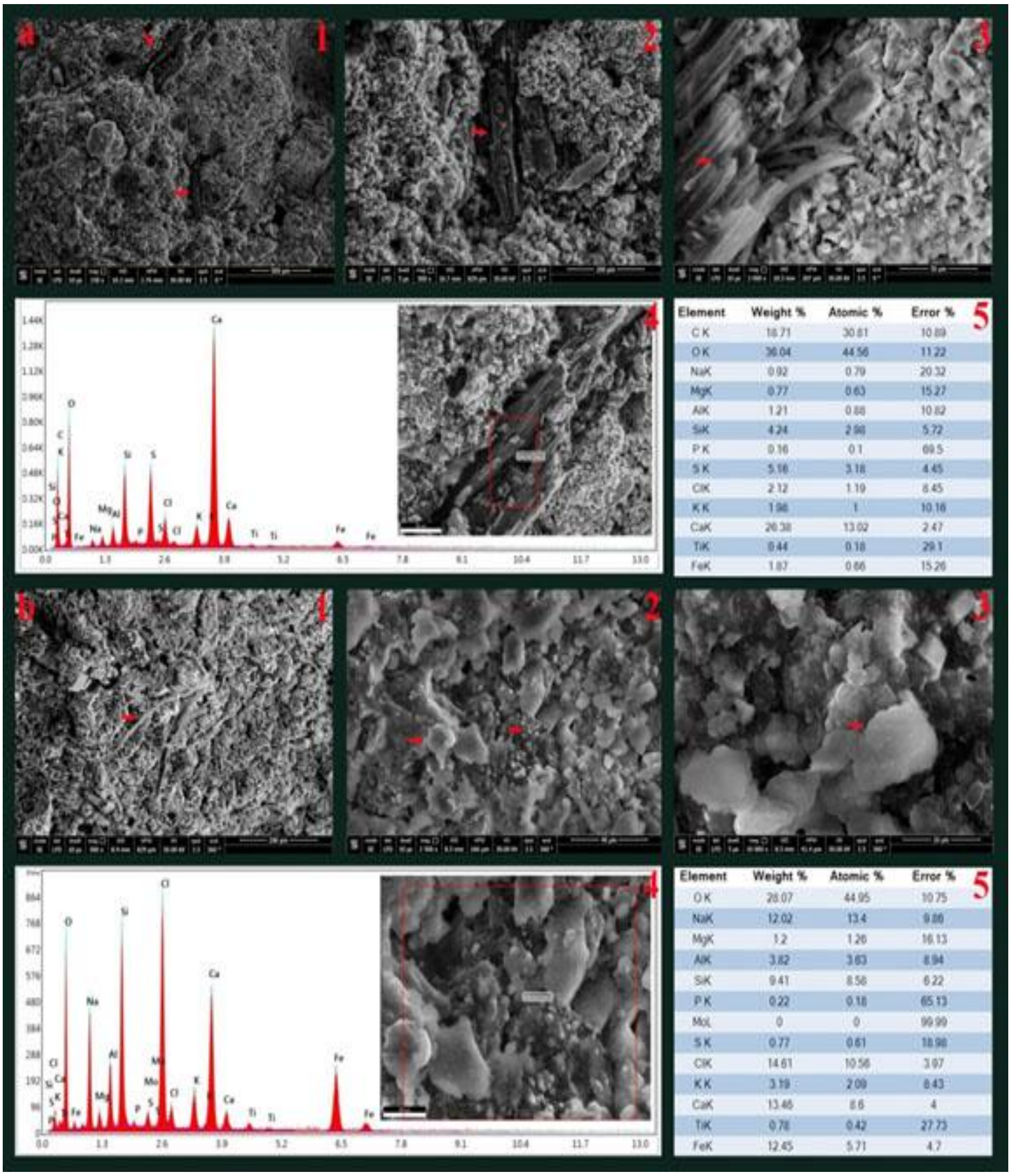
This appears remarkably in the results of the SEM examination, where salts and cracks are widely spread which create internal mechanical pressure leading to a weakening of the bonds of the mortar constituents.

3.2.3. Comparison with standard samples results

A comparison was performed with standard samples of brick and mortar, to define their state (Table 4), (Fig. 8). As for the presence of Silica in brick, good quality brick should contain about 60% of silica [18], [19]. By comparing this percentage with its percentage in the studied samples, a clear decrease of 51% from the specifications of the good-fired bricks can be noticed, which caused the ruins to be fragile.

Good-fired bricks should contain about 20% of alumina [20], [21]. By comparing this percentage with its percentage in the studied samples, it became clear that there was a significant decrease in the percentage of alumina, as it decreased by 47% from the specifications of good quality bricks, which made it subject to shrinkage and cracking, and is susceptible to absorbing water.

Good-fired bricks should contain about 4% of lime [22]. After comparing the percentage of lime in each of the constituents of the new bricks and the constituents of the Fustat bricks, it became clear that the percentage



Element	Weight %	Atomic %	Error %
C K	16.71	30.81	10.89
O K	36.04	44.56	11.22
NaK	0.92	0.79	20.32
MgK	0.77	0.63	15.27
AlK	1.21	0.88	10.82
SiK	4.24	2.98	5.72
P K	0.16	0.1	69.5
S K	5.16	3.18	4.45
ClK	2.12	1.19	8.45
K K	1.98	1	10.16
CaK	20.38	13.02	2.47
TiK	0.44	0.18	29.1
FeK	1.87	0.86	15.26

Element	Weight %	Atomic %	Error %
O K	28.07	44.95	10.75
NaK	12.02	13.4	9.86
MgK	1.2	1.26	16.13
AlK	3.82	3.63	8.94
SiK	9.41	8.56	6.22
P K	0.22	0.18	65.13
MoL	0	0	99.99
S K	0.77	0.61	18.98
ClK	14.61	10.56	3.97
K K	3.19	2.09	8.43
CaK	13.46	8.6	4
TiK	0.78	0.42	27.73
FeK	12.45	5.71	4.7

Fig. 7. SEM and EDAX results of fired brick and bonding mortar samples that were taken from the Fustat excavations site.

7a. SEM and EDAX results of the main building material (fired brick) and bonding mortar, a1. Organic matters involved in the composition of the brick and formation of clay minerals, a2. Decomposition of organic matter, a3. Clay minerals formation, a4. and a5. EDAX results of the fired brick sample.

7b. Fossil remains within the composition of mortar, b2. and b3. Pores and degradation of crystals, b4. and b5. EDAX results of the bonding mortar sample.

of lime decreased by 7.5% from the specifications of good quality bricks, which subjected the granules of the bricks to disintegration and non interconnection.

A small quantity of Iron oxide (6-8%) is desirable [20]. By comparing the percentage of the iron oxides in the standard brick sample and the constituents of the Fustat bricks, the percentage of iron oxides is decreased by 50% of the specifications of good quality bricks. This decrease caused color change and made it softer and weaker.

A small quantity of Potassium (4%) is required for good quality bricks [19], but the percentage of Potassium in the studied samples decreased by 70% of these specifications. This decrease negatively affects the structure of the brick.

As for mortar (Fig. 8, Table 4), (Fig. 9, Table 5), the results of the X-ray diffraction analysis showed a decrease in the percentage of sand in the mortar in relation to lime which was significant and weakened the mortar and made it unable to withstand the acting forces.

Perhaps this is due to the weakness of the bonding strength of lime due to various deterioration factors which made it lost its most important mechanical properties; tensile and compressive properties. This led to the falling of the mortar layer after layer and it was followed by brick falling.

Table 4: Comparison between the average constituents of new fired bricks (standard samples) and Fustat fired bricks (studied samples) and the percentage difference between them.

Constituents	Silicon Oxide (SiO_2) %	Aluminum Oxide (Al_2O_3) %	Iron Oxide (Fe_2O_3) %	Calcium Oxide CaO %	Potassium Oxide K_2O %
Fustat fired brick	29.0%	10.6%	4.0%	3.7%	1.2%
Good fired brick	60.0%	20.0%	8.0%	4.0%	4.0%
Percentage difference	51.0%	47.0%	50.0%	7.5%	70.0%

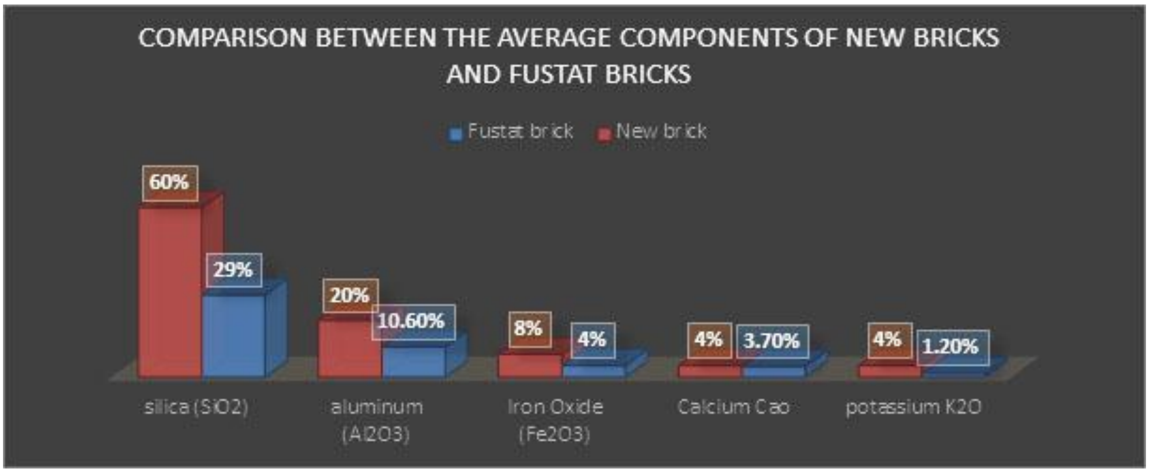


Fig. 8. Indicating the comparison between the average constituents of new brick and Fustat brick

Fig. 9. Indicating the comparison between the constituents of good quality lime mortar (standard sample) and Fustat lime mortar (studied samples).

Table 5. Comparison between the constituents of good quality lime mortar (standard sample) and Fustat lime mortar (studied samples).

Sand and lime ratio	sand	lime	lime to sand
Good quality mortar	75.0	25.0	1: 3
Fustat mortar	2.4	35.0	1: 0.07

4. Conclusions

It is clear from the study that the Fustat excavation site suffers from many problems in terms of its local environment and the building materials used in its buildings and ruins.

By tracking the site in the proposed period (23 years), it became clear that the site underwent many changes in terms of the fluctuation between wet and dry cycles, the subsequent growth of plants, the disappearance of some ruins, as well as the population density in its surrounding environment and the density of buildings with their subsequent problems of sewage leakage. This resulted in the disappearance of approximately 50% of the total area of the site that was revealed during the excavation work. This percentage portends the disappearance of the remaining part during 23 years.

Similarly, the examinations and analyses that were conducted on the samples of building materials and mortar, compared to standard bricks and mortar of good properties, confirmed the weakness of the internal structure of the brick constituents, which causes its fragility and easy loss due to the action of chemical factors (rainwater, sewage, air pollution gases, living organisms), mechanical factors (wind, water movement, lack of follow-up and lack of periodic maintenance). Correspondingly, the used mortar was friable, in poor condition, dry and unable to withstand the acting forces due to the decrease in the percentage of sand to lime.

Accordingly, despite the development projects that are underway in the Fustat surroundings, the study confirmed that the site is not only vulnerable to extinction during the next several decades, but its ruins will disappear after losing many of them without the ability to return them to their original condition or restore them if desired.

Therefore, this study was conducted to find out the current state of the Fustat historic city excavations site which witnessed many periods of Islamic rule and to draw attention to the need for urgent intervention to protect its remaining buildings and ruins.

References

1. https://egymonuments.gov.eg/archaeological-sites/al-fustat-old-cairo/, [Accessed: Aug. 13, 2023].
2. S. M. Al-Masry, Z. T. Ahmed, "The Civilizational Dimension of the City of Fustat at the End of the Twentieth Century, Civilizational Communication between the Countries of the Arab World". Yearbook of the General Union of Arab Archaeologists, "Studies in the Antiquities of the Arab World", Land Scape of Fustat At the end of the 20th Cent, Article 24, Vol. 2, No. 2, 1999, pp. 461-482.
3. A. Ismail, A. S. Al-Mahdi, M. A. Muhammad, "The Impact of Political Intervention in the Emergence of Ancient and Modern Cities (The Case of Islamic Countries)". Vol. 1, No. 2,, Journal of Engineering, 2018, pp. 1-26.
4. G. A. I. Hassan, "The Legacy of Residential Architecture in the Arabian Peninsula and its Role in the Residential houses Building in Fustat, Egypt". Journal of the General Union of Arab Archaeologists, Vol. 9, No. 9, 2008, 1- 38.
5. D. Whitecomb, An Umayyad legacy for the early Islamic city: Fustat and the experience of Egypt, Umayyad legacies (Medival memories from Syria to Spain). Edited by Antoine Borrut and Paul M. Cobb, Brill, Leiden, Boston, 2010, pp. 403 – 416.
6. A. Ali, O. Elsoqayem, Sh. Rizq, H. Ali, H. Fawzy, M. Shabka, R. Helmy, A. Lashen, A. ElSheikha, "A Proposal to Rehabilitate Ouda Pasha Archaeological Agency in Historic Cairo Based on the Building's Data and the Needs of its Surrounding Urban". Advanced Research in Conservation Science. Vol. 3, No. 1, 2022, pp. 13-29.
7. A. Ali, O. Abd El Hameed, "Courtyards' Effect on the Sustainability of Archaeological Buildings in Historic Cairo, Egypt". Journal of Architecture, Arts and Humanities. Vol. 33, No. 7, 2022, pp. 862-874.
8. M. Mady, "Traditional Ways of Dealing with Climate in Egypt". The Seventh International Conference of Sustainable Architecture and Urban Development (SAUD 2010), the Center for the Study of Architecture in Arab Region, Jordan: Amman (CSAAR Press), 2010, pp. 247-266.
9. S. M. Robaa, "Some aspects of the urban climates of Greater Cairo Region, Egypt". International Journal of Climatology, Vol. 33, 2013, pp. 2206-2216.
10. https://www.weatherbase.com/weather/weatherall.php3?s=66326&cityname=Cairo%2C+Muhafazat+al+Qahirah%2C+Egypt&units, [Accessed: Aug. 8, 2023].
11. A. Ali, A. ElShiekha, E. ElBanna, M. P. Francisco, "An approach to conservation and management of Farasan Islands' Heritage sites, Saudi Arabia". International Journal of Conservation Science. Vol. 9, No. 2, 2018, pp. 245-256.
12. A. Ali, "Orientation and vision for the sustainability of heritage sites, a case study of Port Said city". International Journal of Conservation Science. Vol. 12, No. 4, 2021, pp. 1343-1354.
13. UNESCO - World Heritage Center, Management of World Heritage Sites in the Arab Republic of Egypt, Urban Revival Project for Historic Cairo. Business Report for the period from July 2010 to June 2012, 2012, pp. 81-83.
14. N. A. A. Hassan, A. Kotb, A. A. A. Hassan, M. A. Hagras, "Dewatering using ground water modelling in Al-Fustat area, Old Cairo, Egypt". Ain Shams Engineering Journal, Vol. 3, No. 4, 2012, pp. 349-358.
15. S. Hemeda, "Geotechnical modelling of the climate change impact on world heritage properties in Alexandria, Egypt". Heritage science, Vol. 9:73, 2021, pp. 1-32..
16. S. A. El-Sayed, "Study of Ground water in Northeast Cairo Area, Egypt". Journal of Geoscience and Environment Protection, Vol. 6, 2018, pp. 229-251. .
17. O. M. Abd El Hameed, A. Ali, D. Atta, "Utilizing Laser Spectroscopic Investigations to Determine the Current Conditions of Hetep Heres' Pyramid in Giza, Egypt". Egyptian Journal of Chemistry, Vol. 65, No. 13, 2022, pp. 981-993.

18. A. Ali, E. Al-Banna, "Study of the archaeological building materials on Farasan Islands, Kingdom of Saudi Arabia, and their relationship with the islands' local and climatic environment". the 3rd international Conference on Defence Sites: Heritage and Future (DSHF 2016), WIT Transactions on The Built Environment, Vol. 158, 2016. pp. 95 – 106.
19. H. H. M. Darweesh, H. M. Awad, A. Tawfik, "Red bricks from Dakhla formation clay -Tushka area- incorporated with some industrial waste by-products". Industrial Ceramics, Vol. 31, 2011, pp. 201-207.
20. M. Arsenovićc, S. Stankovićc, Z. Radojevićc, L. Pezo, "The effects of chemical composition and firing temperature in heavy clay brick production – Chemometric Approach". Interceram-International Ceramic Review, Vol. 01-02, 2014, pp. 26-29.
21. A. H. Abdulhadi, M. H. Mussa, Y. Kadhim, "The clay rocks properties for the production of the ceramic bricks". Magazine of Civil Engineering, Vol. 111, No. 3, 2022, pp. 1-12.
22. P. B. Lourenço, F. M. Fernandes, F. Castro, "Handmade clay bricks: Chemical, physical and mechanical properties". January 2010, International Journal of Architectural Heritage, Vol. 4, No. 1, 2010, pp. 38-58.
23. Brick Industry Association, Specifications for and Classification of Brick. Technical notes on Brick, 1850 Centennial Park Drive, Reston, Virginia 20191 A9, 2007, pp. 1-13. https://www.gobrick.com/media/file/9a-specifications-for-and-classification-of-brick.pdf
24. Y. Wang, J. Huang, T. Wu, J. Huang, Y. Liu, "Comprehensive utilization study of waste red brick in urban reconstruction". 4th International Symposium on Resource Exploration and Environmental Science, IOP Conference Series: Earth and Environmental Science, 514: 032066, 2020, pp. 1-6.
25. S. P. Purohit, S. Sharma, D. Soni, "Mechanical properties of red clay bricks under compression and shear: an experimental and numerical investigation". SEC18: Proceedings of the 11th Structural Engineering Convention, Jadavpur University, India: Kolkata, December 19 – 21, Paper No. 03781, 2018, pp. CT187, CT193.
26. I. Abdalla, S. B. Abdalla, K. El-Siddig, D. Möller, A. Buerkert, "Effects of red brick production on land use, household income, and greenhouse gas emissions in Khartoum, Sudan". Journal of Agriculture and Rural Development in the Tropics and Subtropics. Vol. 113, No. 1, 2012, pp.51–60.
27. G. Bumanis, D. Vaiˇciukynien, "Alkali Activation of Milled Red Brick Waste and Calcined Illite Clay with Silica Gel Addition". Materials, Vol. 15:3195, 2022, pp. 1-12.
28. P. Faria, A. Martins, "Influence of Curing Conditions on Lime and Lime-Metakaolin Mortars", International conference on durability of building material and constituents. XII DBMC, Portugal: Porto, 2011, pp. 1-8.
29. G. Lynch, The Myth in the Mix, The 1:3 ratio of lime to sand. Building conservation directory, Tisbury: Cathedral Communications, 2007.
30. M. Stefanidou, P. Koltsou, The Role of Sand in Mortar's Properties. Sand in Construction, IntechOpen, 2022, pp. 1-15 [E-book] Available: 10.5772/intechopen.102489.
31. G. Lynch, "Lime Mortars for Brickwork: Traditional Practice and Modern Misconceptions". Journal of Architectural Conservation, Vol. 4, No. 1, 1998. pp. 7-20.
32. J J. P. Speweik, Lime's Role in Mortar, The Aberdeen Group, after: The History of Masonry Mortar in America 1720-1995. Arlington: National Lime Association, 1995.
33. https://weatherspark.com/y/96939/Average-Weather-in-Cairo-Egypt-Year-Round, [Accessed: Nov. 26, 2022].
34. O. M. A. Abdel Hameed, "Nanotechnology applications to improve the mechanical properties of lime mortars in archaeological building". Journal of the

Faculty of Archaeology, Vol. 26, 2023,
pp. 423-438.