Egyptian Journal of Archaeological and Restoration Studies (EJARS)
An international peer-reviewed journal published bi-annually
www.ejars.sohag-univ.edu.eg

Original article

GEO-ENVIRONMENTAL FACTORS THREATENING THE OLD CAIRO ARCHAEOLOGICAL SITES: BABYLON ROMAN FORTRESS, CASE STUDY

Metwaly, D.[1,2], Elewa, H.[1] & Saleh, M. [2(*)]

[1]*Water Resourses dept., Engineering Application & Water Division, (NARSS), Cairo, Egypt*
[2]*Conservation dept., Faculty of Archaeology, Cairo Univ., Giza, Egypt*
**E-mail address: mohsensaleh_22@yahoo.com*

Article info.
EJARS – Vol. 16 (1) – June 2026: 15-21

Article history:
Received: 3-4-2025
Accepted: 9-1-2026
Doi: 10.21608/ejars.2026.511064

Keywords:
Historic Cairo
Al-Fustat area
Cultural heritage
Groundwater
Babylon Fortress
XRD
SEM

Abstract:
The Fortress of Babylon (Hisn Babilyan) has a great strategic importance as archaeological site. Archaeological sites in the Old Cairo area (Misr el-Qadima) are at great risk due to many human and natural factors. The Babylon Fortress located in Al-Fustat area; therefore, the Roman tower is an ideal model to illustrate the geo-environmental problems affecting the Old Cairo area. There are various aspects of damage in the lower part of the Roman tower, including the rise in groundwater, extensive biological damage to the walls, followed by the crystallization of salts, in addition to the growth plant, with the stains of bats and pigeons on the walls of the tower. A number of different samples were collected for analysis to diagnose the actual condition of the Roman tower. The samples were examined using the X-Ray diffraction (XRD), scanning electron microscopy (SEM) provided with Energy-Dispersive X-ray spectroscopy (EDX). Total dissolved salts (TDS) were determined, and interpreted by Piper plot to determine the groundwater genesis. Piper diagram indicated the dominance of meteoric surface water leaching to sulfate and carbonate cement rocks with $MgSO_4$ water type. This examination helped identifying the stone and mortar components moreover the types of salts affecting the building materials. E. coli was present in very high numbers in the investigated groundwater sample, with a count of ≥ 2400 CFU/100 ml with a total microbial count of 410 CFU/ml., as well as heavy metals was analyzed which indicated founding pollutions due to different pollutes. The XRD pattern of the limestone samples showed that the samples are mainly composed of Calcite $CaCO_3$ (81%) as the main component. Albite $NaAlSi_3O_8$ (8.2%), Dolomite $CaMg(CO_3)_2$ (3.3%), Quartz SiO_2 (3.1%), and halite NaCl (4.4%). The mortar samples showed that the samples are mainly composed of quartz SiO_2 (96.1%) and Calcite $CaCO_3$ (3.1%). A small amount of Halite NaCl (0.4%) and Sylvite (KCl 0.5%) were found. Roman tower needs an urgent project to preserve it, prevent its deterioration and preserve it as an important world cultural heritage for generations.

1. Introduction

The Babylon Fortress was built in the Roman period in 300 AD. [1] on the foundation of an earlier Ptolemaic structure and an ancient aqueduct. The site connected to the Nile River, and thus to the Mediterranean and Red Seas [2,3]. The Roman Emperor Trajan moved the head of the Red Sea Canal to Babylon and built a massive stone harbor around the entrance to the canal. He secured this important strategic location by building the massive Babylonian Fortress. The site of Babylon Fortress is of great importance to Egyptian civilization [4], as it occupied a site of great strategic importance at the head of the Nile Valley [5]. The entrance to the canal remained intact, although it is now linked to the massive round towers that today represent the entrance of the Coptic museum [1,3, 5]. It surrounded by an irregular wall that includes several towers belonging to the fort, in addition to a group of ancient churches. Some of these churches are built on the fortress itself, while others are being built next to it, such as the Hanging church and the Greek church of Mary Girgis [1]. The fortress covers an area of approximately 500 m^2, fig. (1).

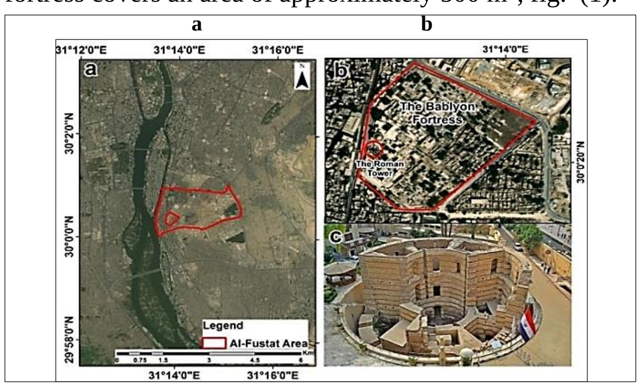


Figure (1) ETM+ Satellite image of **a.** the Babylon Fortress in Cairo, **b.** the Roman tower in relation to the Babylon fortress, **c.** the Roman tower (*After: Google Earth*).

The Roman tower is located at the entrance to the fort and consists of five-sections of limestone; each section consists of seven rows of limestone, while the sections made of mud bricks are seven sections consisting of three rows connected by lime mortar, which commonly used in the Roman era. This tower contains a group of windows topped by a semicircular arch with equal distances that are arranged around the entire tower [1], fig. (2).

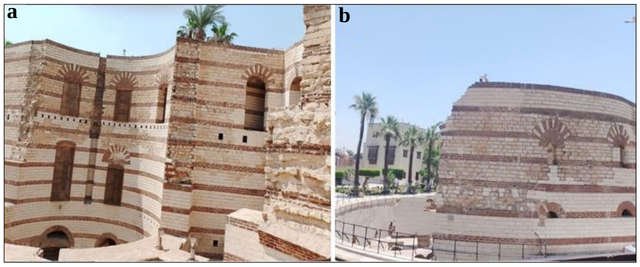


Figure (2) **a.** remains of the Roman tower guarding the Roman canal, **b.** exterior of the Roman tower that flanked the entrance to Trajan's canal.

At ground level, the central space of the Roman tower originally occupied by a circular portico of eight equally spaced columns, set against the inner wall of three concentric circular walls forming the base of the tower. During the works of the 102nd decade [5], number of stone architectural elements found in the tower, including some that clearly belong to this central portico, fig. (3).

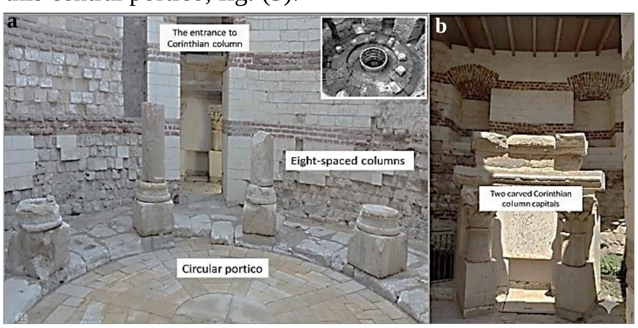


Figure (3) **a.** circular portico of columns space at eight intervals, **b.** installation of a column of the 2001 Water Land Project, **c.** two carved Corinthian column capitals

In recent years, the close relationship between threats to architectural heritage and environmental changes has emerged [7], and there has been a significant and noticeable deterioration in some of the major monuments in Old Cairo [8]. From the perspective of environmental changes, the groundwater problem in old Cairo is expected to worsen over time [9]. Groundwater poses a serious threat for all historical sites in Egypt, affecting the integrity of monuments and other valuable buildings [10], causing the deterioration of building materials [11] and foundations, threatening their stability. Moreover, increasing humidity encourages the growth of organisms, which deteriorates building envelopes and other organic building materials [10]. Preserving historic buildings and archaeological sites requires a thorough analysis of environmental, geological, hydro-logical, and human factors. This helps decision-makers create robust, long-term restoration plans. Because accuracy is critical, archaeological work is slow and must account for past changes and possible future impacts during restoration. Field survey and laboratory analysis combined to find and identify the causes of damage caused by dissolved salts and the type of stones used in reconstruction and preservation [12]. The current geo-environmental study aims to clarify the causes of deterioration and damage to the monuments and to suggest the appropriate solution for their preservation within a proposed a restoration plan. The aim of this work is assessment the current state of The Roman tower, the problem of rising groundwater remains a persistent issue at the Roman tower and the problem of bats although the excellent cleaning was processed on it, which is a particularly good example to represent the typical problems that historical structures in the religious area have suffered, including biological and human influences. The most important purpose of this work is to provide recommendations that may help planners and decision makers in responding appropriately to preserve this valuable human archaeological heritage.

2. Problem Definition

Fieldwork observed biological damage and the growth of algae and lichen in the Roman tower, and the area of biological damage on the surface of the walls increased over time, in addition to an increase in the groundwater level. When creating a restoration plan for the local structures and archeological site, researchers and archaeologists need to take consequences into account. Some of the monuments' topographical degradation is addressed in this work. The study area's geological and hydro-logical damage indicators are linked to years of harm; a short-term restoration plan won't make them go away. It must take into consideration that the Roman tower remained submerged in water for many years, and despite the withdrawal of water from the site and the implementation of a project to lower the groundwater level in the area, the effects of this submergence still affect the monuments in the area. The salts contained in the groundwater also pose a serious threat to building materials, plaster and cladding of old buildings, in addition to biological damage and other negative effects. We will address this issue clearly in this work. Climatically, Egypt has a mainly hot desert climate with a significant increase in humidity, which has become evident in the last few decades. In addition to the scarcity of rainfall, extreme heat during the summer months is also a general climatic feature of Egypt. Although daytime temperatures are more moderate along the northern coast [13, 14]. Cairo experiences hot, muggy summers and mild winters with sporadic rains. [15]. Climatically, Greater Cairo belongs to the subtropical climate zone. Sandy winds prevail from March to May (spring) and from September to November (autumn). December to February is the winter months, when the weather is humid, and rainfall is low.

3. Materials and Methods

Documentation and fieldwork procedures were used to document the Roman Tower's current state and identify the most damaged portions. After that, reference data points collected using a global positioning system (GPS) were used to validate the information in the field. At the Desert Research Center (DRC) in Cairo, three water samples were taken from the groundwater of the Roman tower were examined for dissolved salts, microorganisms, and heavy metals. Three stone samples and three mortar samples were examined using X-ray diffraction ((BRUKER AXS D8 advance diffractometer, type of sample was powder, Copper (Cu) anode, Angle (2θ) from 15-60°, with a step of 0.2° min−1, 20 M A-35 KV) at the Desert Research Center (DRC) in Cairo, and Scanning Electron Microscope coupled with Energy dispersive X-ray unit (SEM- EDX) SEM Model QUANTA FEG 250, and type of sample a solid sample coated with gold was used to examine the limestone and mortar samples. at (DRC, Cairo). The authors are authorized to photograph the religious complex by the Permanent Committee for Islamic and Coptic Antiquities of the Ministry of Antiquities at the Supreme Council of Antiquities (SCA) in Cairo, according to the American standard testing methods; (-ASTM C97/ C97M - 2015 and ASTM C170/C170M -2015 and ASTM C20-00-2015).

4. Results

4.1. *Deterioration aspects*

Fieldwork revealed that the Roman tower's surface was harmed by biological and water contamination, and groundwater had pooled there. Furthermore, salt crystallization was discovered in the lion-head's chamber. The damage to the Roman tower throughout time is depicted in the following pictures, fig. (4). The Roman tower's interior is cold, dark, and shielded from the powerful winds that define the surrounding area due to its walls, and small windows. The Roman tower is a perfect home for bats because of these elements.

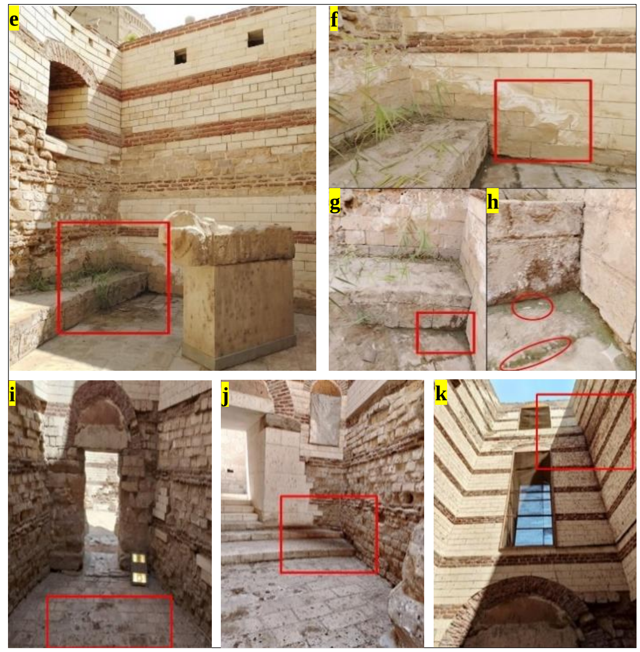


Figure (4) **a.** groundwater seepage channels showing that the ancient groundwater level 1 is older than 2, **b.** groundwater accumulations formed in the Roman tower, **c.** Surface deterioration due to rising groundwater level, **d.** signs of damage due to groundwater (groundwater accumulations, dense vegetation formed on the wall, crystallization of salts, presence of pigeon feather remains), **e.** different aspects of damage in the chambers containing the lion's Head dock, **f.** effect of the groundwater level rising and the resulting crystallization of salts on the walls, **g.** the sparse plants that grew due to groundwater, **h.** the presence of pigeon feather remains, **i.** & **j.** bats and pigeon droppings (the *red boxes*) on the floor of some chambers of the Roman tower, **k.** bats droppings (the *red boxes*) on the wall of the Roman tower hydro-chemical characteristics of ground-water

To describe the chemical composition of groundwater in the study area, the following data were obtained: electrical conductivity (EC), total dissolved solids (TDS), major cations and anions, nutrients: NO_3^- and NH_4^-, tab. (1). Heavy metals of Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Si and Zn were determined and microbiological analysis was performed. Hydrochemical analysis of the groundwater sample was taken from the Roman tower showed that the TDS ranged from 6133 mg/l in 1984 [16] to 6251 mg/l in 2000 [12], but with a significant decrease in the sample collected by the authors in 2024 (764 mg/l). Interpretation of the groundwater sample from the Roman tower with the Piper diagram [17] determines the groundwater genesis. Piper diagram indicated the dominance of meteoric surface water leaching to sulfate and carbonate rocks with $MgSO_4$ water type. The ground-water contains dissolved salts of potassium chloride (KCl), potassium sulfate (K_2SO_4), sodium sulfate (Na_2SO_4), magnesium sulfate ($MgSO_4$), magnesium bicarbonate ($Mg(HCO_3)_2$) and calcium bicarbonate ($Ca(HCO_3)_2$) which may be harmful to the foundations and ancient building stones of the Roman tower. The concentration of nitrate (Nitrate (NO_3^{2-}) in ground and surface water is high (5.4 mg/l), very few terrestrial materials consist of nitrate minerals, and as a result, the presence of this anion in water usually indicates pollution [18]. Heavy metals are the major pollutants found in industrial and sewage waste-water and can negatively affect the biological wastewater treatment. The concentration of heavy metals in the groundwater sample was detected. Chromium (Cr) is a trace element essential for all living organisms [19]. The concentration of copper (Cu) in wastewater increases up to 0.01-0.47 mg/l, which is due to the effects of different pollution sources [18]. However, in this sample, the (Cu) is more than 0.7941 mg/l indicating a lot of pollution. Surface freshwater samples reach low levels of manganese (Mn) concentrations of 0.027-0.142 mg/l, with the concentration being 0.0157, which is within the standard range. Lead concentration is <0.009 mg/l, which according to [18] is not higher than the recom-mended level as it is not severe (0.005-0.017 mg/l) compared to the water samples from the Nile branches with an overall range of 0.006-0.163 mg/l in wastewater.

Table (1) major cations and anions of the groundwater sample at the Roman tower.

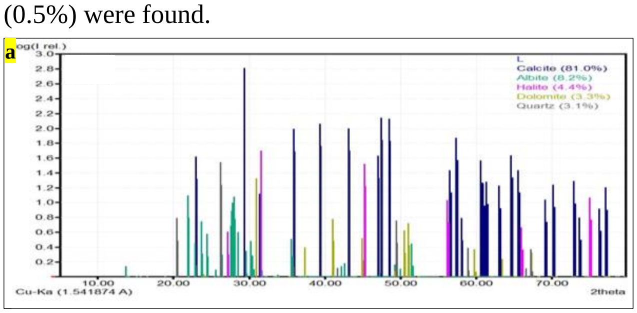
EC at 25° (ds/m)	1228			
TDS (mg/l)	764			
Cations (mg/l)	***K^+***	***Na^+***	***Mg^{++}***	***Ca^{++}***
	94.00	65.00	33.70	80.00
Anions (mg/l)	***NO_3^{--}***	***CL^-***	***SO_4^{--}***	***HCO_3^-***
	5.40	57.10	280.20	268.40

4.2. *Bacteriological analysis of groundwater*

The analysis results indicated that E. coli was present at very high levels in the investigated groundwater sample, with a count of ≥ 2400 CFU/100 ml with a total microbial count of 410 CFU/ml. A number of other types of bacteria were analyzed including pseudomonas, Alcaligenes, Aeruginosa, Citrobacter, Salmonella, Shigella, Klebsiella, Proteus, Enterobacter and these sorts didn't find in the sample. Degradation of historic monuments caused by number of biotic and abiotic factors is a common feature. These deterioration factors have affected not only the esthetic appearance of these structures, but also lead to deterioration of their strength and durability. The microorganisms are amongst the major players of bio-degradation of several stonework buildings [20].

4.3. *XRD*

XRD analyses were performed to determine the chemical compositions and proportions of the limestone and mortar; along with Energy dispersive spectroscopy (EDS) to examine the microstructure and elemental analysis [1]. XRD patterns of the limestone samples, fig. (5-a) showed that the sample is mainly composed of calcite $CaSO_3$ (81%) as the main component. Albite Na Al Si_3O_8 (8.2%), dolomite CaMg $(CO_3)_2$ (3.3%) and quartz SiO_2 (3.1%) were also recorded, small amount of halite NaCl (4.4%). The XRD result of the mortar samples shown in fig. (8-b) showed that the samples are mainly composed of quartz SiO_2 (96.1%) and calcite $CaCO_3$ (3.1%). A small amount of Halite NaCl (0.4%) and sylvite KCl (0.5%) were found.



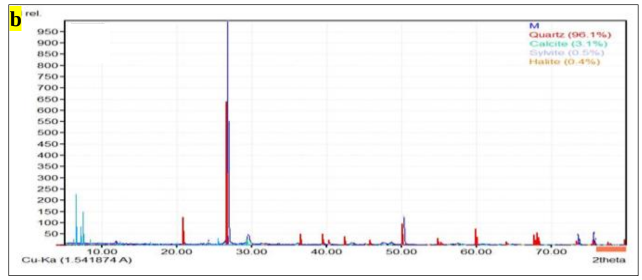


Figure (5) XRD patterns of investigated samples from the Roman tower; **a.** limestone, **b.** mortar.

Limestone samples can be inferred to have high calcium (Ca) content, fig. (6-a). The significantly high Ca value in the mortar reflects the higher amount of calcite ($CaCO_3$). The sulfur (S) content is small compared to the Ca content, reflecting less gypsum and most of the Ca is present in the form of carbonate (Calcite). The Na^+ and Cl^- contents are low; reflecting the presence of salts and can be attributed to the contribution of halite (NaCl). This is consistent with the XRD interpretation, fig. (5-a & b). The Si, Al and K contents are related to the composition of the sand used in the mortar preparation mainly (Qz), as listed in tab_s. (2) and fig. (6-b).

Table (2) Elements ratios of investigated samples

%	C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Fe
Elements ratios of limestone (Wt. %).											
Weight	2.0	36.3	0.7	1.6	1.5	4.2	3.1	1.2	1.1	48.5	-
Atom	4.0	55.3	0.7	1.6	1.3	3.7	2.3	0.8	0.7	29.5	-
Elements ratios of mortar (Wt. %).											
Weight	2.1	31.2	0.5	0.2	0.9	5.9	15.6	1.5	1.5	39.3	1.2
Atom	4.5	49.0	0.6	0.3	0.9	5.2	12.3	1.1	1.0	24.7	0.5

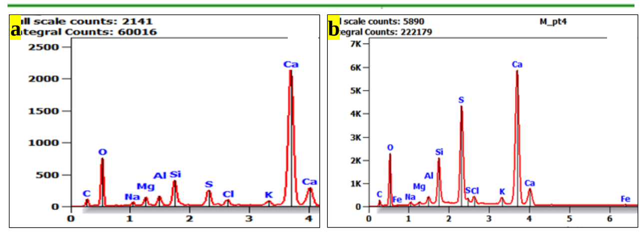
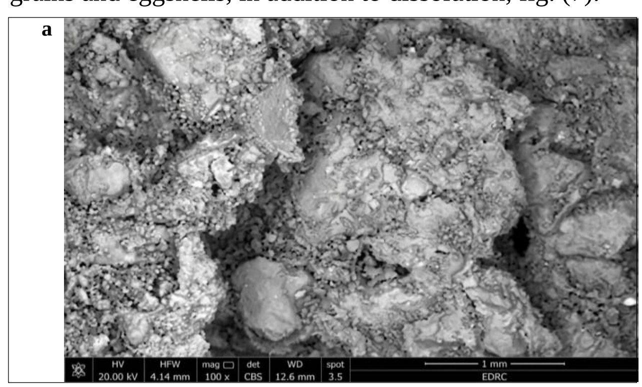


Figure (6) EDX patterns; investigated samples from the Roman tower; **a.** limestone showing high Ca ratio, **b.** mortar showing Si used in the mortar preparation.

4.4. *SEM results*

The samples taken from the surface of the limestone and mortar confirms that the walls were affected by the groundwater in the Roman tower, and the aspects of the damage include: cracks, powdering, notable spaces between mineral grains and eggshells, in addition to dissolution, fig. (7).



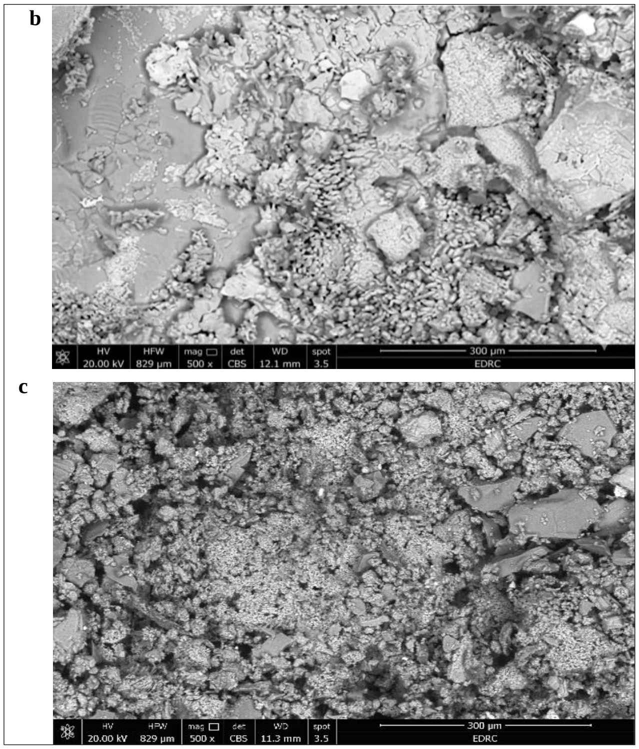


Figure (7) SEM photomicrographs of limestone showing different deterioration features; **a.** cracks, separated from the ground layer and reduced to powder, **b.** with spaces between mineral grains and eggshells, **c.** mortar sample showing dissolution, pores and spacing in mineral grains

5. Discussion

Based on the previous results and the fieldwork, we can conclude that the internal environment of the Roman tower is a suitable habitat for bats, which explains the presence of an environment that encourages the growth of microorganisms that feed on the bloodstains left by bats on the walls of the Roman fortress. By following TDS ranged from 6133 mg/l in 1984 to 6251 mg/l in 2000, to 764 mg/l in 2024 with a significant decrease in the sample collected by the authors it can be concluded the possible reason for the decrease in salinity may be due to the water drainage system installed in the study area to reduce the groundwater level. It was also noted that the concentration of nitrate in ground and surface water is high 5.4 mg/l, and it can reach high levels due to seepage from cultivated land or contamination with waste of human or animal origin. The highest concentrations were observed in areas with human activities, compared to normal soil solutions, those near human settlements and sites are rich in nitrates and chlorides; microorganisms from organic wastes produce nitrates, and chlorides are provided by the consumption of sodium chloride. XRD results showed small amount of halite NaCl (4.4%) in stone samples and 0.4% in mortar samples This can be explained by the fact that the continuously increasing humidity, combined with the cold environment inside the Roman fortress, did not allow the salts to fully crystallize. SEM scanning images of limestone and mortar show signs of deterioration. Specifically, signs of damage associated with the dissolution of water-soluble components, in addition to the spaces between mineral grains, demonstrate the role of high humidity caused by groundwater and its impact. The groundwater contains dissolved salts, which may be harmful to the foundations and ancient building stones of the Roman tower. One of the most significant effects of high relative humidity is the growth of biological harm, which can take various forms. Stone elements in archaeological buildings deteriorate due to a variety of processes, including chemical alteration, staining, discoloration, surface changes, biological erosion, and transformations into smaller crystals [20,21]. Microbial biofilm formation, organic and inorganic compound deposition, nitrification, sulfation, and residual hydrocarbons and other organic pollutants in dust have all contributed to changes in recent decades [22-24]. The mineral components of the stone and its surface deposits can support the growth of various biological organisms. Additionally, the surfaces are affected by pollutants and the byproducts of their reactions, which result in particle deposits, black scale, and a secondary reaction on the stone surfaces. The stone deteriorates and flakes as a result of these combined activities, decreasing the surface's overall structural strength and causing a loss of cohesiveness [25-27]. The growth of salt crystals within the pores of the stone can generate sufficient stresses to overcome the tensile strength of the stone and turn the stone into powder. The deterioration of world's greatest monuments can be attributed to salts [28]. The hot climate and high temperatures in Egypt accelerate microbial biochemical processes, influencing microbial reproduction type, morphology, and nutrient requirements. Temperature strongly governs microbial colonization, which in turn causes physical damage: grain dislodgement, exfoliation [29], chipping, and increased surface porosity and reactivity. Mechanical forces also create fractures of varying sizes [28]. The growth of organisms has been facilitated by the rise in groundwater levels brought on by sewage infiltration in the presence of humidity, which has had an impact on the stone structure [30]. When expanding the old Cairo archeological site, it is important to keep in mind that filling these ponds, or a portion of them, to make room for new housing developments will unavoidably elevate the groundwater level and flood the surrounding area. It is necessary to maintain a sufficient surface area to evaporate the pond with an amount of water equivalent to the recharge. This can be ensured by taking into account the geological and hydrogeological conditions of the project site within the feasibility study for new housing projects.

6. Conclusion

The Roman tower (part of the fortress) illustrates how multiple factors combine to degrade historic structures. Rising Groundwater levels introduce harmful salts (sulfates, chlorides) that crystallize, cause mechanical stress, and weaken limestone and mortar. Pollution from sewage and urban sprawl adds nitrates and E. coli. Biological growth such as Algae, lichen, microorganisms, bats, and pigeons leave droppings and stains, accelerating decay. Salt crystallization cause Crystals forming on/in stone create flaking and loss of material. Human & environmental factors include Urban development, humidity, and temperature fluctuations together speed up deterioration. Restoration plans must address: ****)*** *Groundwater management to reduce salt and microbial damage.* ****)*** *Mitigation of biological growth and urban pollution.* ****)*** *Long-term strategies considering environmental and geological* *conditions. In this regard, two main recommendations should be adapted for maintaining sufficient surface area against the sever groundwater evaporation and preventing flooding effects.*

1) *Develop robust restoration plans that account for historical and environmental changes.*

2) *Monitor and control urban sprawl and sewage leakage near the Babylon Roman Fortress.*

3) *immediate and comprehensive conservation efforts should be achieved to preserve this valuable cultural heritage site it for future generations*

Acknowledgement

The authors would like to express their deep gratitude to the National Authority for Remote Sensing and Space Sciences (NARSS), the Supreme Council of Antiquities (SCA), and the Faculty of Archaeology, Cairo University (CU), for providing all the facilities and data necessary to complete the present work.

References

[1] Hemeda, S., Akarish, A., & Abu El-Nagga, A. (2018). Engineering investigations and durability problems of the construction materials of the Roman Babylon of Egypt. *Open J. of Geology*. 08 (04): 404-436.

[2] Dridi, A. (2015). Christians of Fustat in the first three centuries of Islam: The making of a new society. In: Vorderstrasse, T. & Treptow, T. (eds.) *A cosmopolition city Muslims, Christians, and Jews in old Cairo*. Oriental Institute Museum Pub. (OIMP), Illinois, USA, pp. 33-40.

[3] Penelis, G., Penelis, G., & Papanikolaou, V. (2014). Restoration of the historic church of St. George in Cairo and the Roman tower underneath. In: EAEE (ed.) *2nd European Conference on Earthquake Engineering and Seismology (2ECEES)*, Vol. 8, Curran Associates Inc., USA, pp. 7061-7070

[4] Salib, M. (2002). *The impact of groundwater on archaeological buildings in the Greater Cairo area*. MA., Institute of Environmental Studies and Research, Ain Shams Univ, Cairo (In Arabic).

[5] Sheehan, P. (2012). Accessing the archaeology of old Cairo. *ARCE Bulletin*. 200: 34-37.

[6] Esri Inc. world imagery: Base map, no. 0 (2020). *https://services.arcgisonline.com/ArcGIS/rest/services/WorldImagery/MapServer* (25/05/2025).

[7] Coppola, M., Benedetto, F., Garzonio, C., et al (2020). Groundwater damages on the historic buildings of Cairo: The case of the medieval walls of Mokattam limestone. *IOP Conf. Series: Materials Science and Engineering*, 949, doi:10.1088/1757-899X/949/1/012004.

[8] Hemeda, S. (2019). 3D finite element coupled analysis model for geotechnical and complex structural problems of historic masonry structures: Conservation of Abu Serga church, Cairo, Egypt. *Heritage Science*. 07 (01), doi: 10.1186/s40494-019-0248-z

[9] Tewfik, M., Fareed, A. & Fouad, R. (2001). Protection and strengthening of the Holy Family Crypt at Abu-Serga church. In: Roca, P., Lourenço, P. & Gaetani, A. (eds.) *Historical Constructions: Possibilities of Numerical and Experimental Techniques: Proceedings of the 3rd Int. Seminar*, Univ. of Minho, Guimães, pp. 1111-1120.

[10] AlGammal, M. (2007). *Economics & valorization of cultural heritage. Evaluation of cultural heritage benefits to urban-socio-economic development and sustainability*. MA., Scuola Superiore di Catania, Università degli Stuiḍi di Catania., Italy.

[11] Moncmanová, A. (2007). *Environmental deterioration of materials*, Int. series on advances in architecture, WIT Press, South Hampton.

[12] Ibrahim, H. (2002). Geo-archaeological studies and conservation of monuments at the yard of religions. *J. of Environmental Sciences*. 23: 71-94.

[13] Tork, H., (2012). Al-Fustat: Revitalizing the old capital, *https://www.behance.net/gallery/3670089/Al-Fustat-Revitalizing-the-Old-Capital*, (31/3/2025).

[14] Abd El Hameed, O. & Ali, A. (2023). Evaluation study of the Fustat excavations site between the past, present and expected future. *Advanced Research in Conservation Science*. 4 (2): 13-30.

[15] Rashed, M. (2015). *Architectural identity in contemporary Cairo*, MA., Facoltà di Architettura e Società, Politecnico di Milano, Italy..

[16] Saleh, M. (1996). *Study of the effect of soil on the damage of archaeological structures in Cairo and how to maintain these structures - applied to archaeological sites*. MA., Conservation dept., Faculty of Archaeology, Cairo Univ., Cairo (In Arabic).

[17] Piper, A. (1944) A graphic procedure in the geochemical interpretation of water-analyses. *Eos, Transactions American Geophysical Union.* 25: 914-928.

[18] Elewa, H. (2010). Potentialities of water resources pollution of the Nile river delta, Egypt. *The Open Hydrology J.* 4, doi: 10.2174/1874378101004010001

[19] Abskharon, R., Hassan, S., Gad El-Rab, S., et al. (2008) Heavy metal resistant of E. coli isolated from wastewater sites in Assiut city, Egypt. *J .of Basic Microbiology*. 48: 168-176

[20] Dakal, T. & Cameotra, S. (2011). Geomicrobiology of heritage monuments and artworks: Mechanisms of biodeterioration, bioconservation strategies and applied molecular approaches. In: Dakal, T. & Cameotra, S., et al (eds.) Bioremediation: biotechnology, engineering and environmental management, Nova Science Pub., NY., pp 233–266

[21] Dhami, N., Reddy, M. & Mukherjee, A. (2014). Application of calcifying bacteria for remediation of stones and cultural heritages. *Frontiers in Microbiology*. 5, doi: 10.3389/fmicb.2014.00304.

[22] Warscheid, T. & Braams, J. (2000). Biodeterioration of Stone: A review. *Int. Biodeter. & Biodegr*. 46: 343-368.

[23] Fernandes, P. (2006). Applied microbiology and biotechnology in the conservation of stone cultural heritage materials. *Applied Microbiol Biotechnol*. 73: 291-296.

[24] Pippo, F., Bohn, A., Congestri, R., et al. (2009). Capsular polysaccharides of cultured phototrophic biofilms. *Biofouling.* 25 (6): 495-504.

[25] Fitzner, B., Heinrichs, K. & Kownazky, R. (1997). Weathering forms at natural stone monuments: Classification, mapping and evaluation. *Restoration of Buildings & Monuments.* 3 (2):105-124.

[26] Caneva, G. a. (1988). Biodeterioration of stone. In: Lazzarini, L. & Pieper, R. (eds.) *Deterioration and Conservation of Stone, Studies & Documents on the Cultural Heritage*, UNESCO, Paris, pp. 182-234.

[27] La Russa, M., Ruffolo, S., Belfiore, C., et al. (2013). Study of the effects of salt crystallization on degradation of limestone rocks. *Periodico di Mineralogia*. 82 (1): 113-127.

[28] Bhatnagar, P., Khan, A., Jain, S., et al. (2010). Biodeterioration of archaeological monuments and approach for restoration. In: Jain, K., Khan, A. & Rai, K. (eds.) *Geo-microbiology*, CRC Press Taylor & Francis Group Science Pub., USA, pp. 255-302.

[29] El-Gohary, M. & Al-Shorman, A. (2010). The impact of the climatic conditions on the decaying of Jordanian basalt at Umm Qeis: Exfoliation as a major deterioration symptom. *MAA*. 10 (1): 143-158

[30] Arnold, A. & Zehnder, K. (1990). Salt weathering on monuments. In: Zezza, F. (eds.) 1st *Symposium on the Con-servation of Monuments in the Mediterranean Basin*, Grafo, Bari, pp. 31-58.