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Study of Building Techniques and Deterioration Phenomena of Salty Limestone in Archaeological Buildings Applied on Oracle Temple in Siwa Oasis

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Abstract: *Archaeological buildings are exposed to many factors of damage to the surrounding environment, especially in Siwa Oasis, where the Temple of Oracle of Alexander the Great or the so-called Temple of Amun. It was made of salty limestone, which was examined by a scanning electron microscope (SEM), the examination showed the extent of the weakness and deterioration of the condition of the stone. The analysis was also done by X-ray fluorescence. It was found that the proportions of chlorine, sodium and potassium elements were high, which means the presence of halite (NaCL) and potassium chloride (KCL) salts among the components of the stone beside calcium carbonates CaCO3 (calcite), also, monitoring and study of the most important deterioration aspects to the temple that threaten its security and safety were conducted, in preparation for the development of a controlled treatment plan on scientific bases.*
Keywords: *building; techniques; deterioration phenomena; salty; limestone; oracle temple; Siwa Oasis*

I. Introduction

Siwa oasis is in the northernmost of the five oasis of the western Egyptian desert. It is sited 120 km east of the Libyan border and 300 km south of the Mediterranean coast, the oasis extends in east–west direction along a depression 17 m below the sea level bordered north and west by the rocky hills of the El Diffa Plateau, south and east by the sandy dunes of the great sand sea. Inside the depression there are four great salty lakes and many natural springs used for irrigation (Rovero, L., etal.,2009), Siwa Oasis is located in a homogeneous depression in the Marmaric plateau, the Marmarica plateau consists of limestone from the Miocene era consisting of decomposing marine rocks with carbonates and interferences of marl, the evaporates in Siwa Oasis consist of halite salts and gypsum mainly and other salts, the soil is loam and sandy loam. According to geological maps, the carbonate rocks from the middle and upper Miocene period are found in the north of the Qattara Depression and the Siwa Oasis (El-Sayed, S.S.M., 2021), Siwa is characterized by surface saline deposits, where these deposits are formed in a heterogeneous unit of dolomite, black clay, anhydrite salts, halite and other salts, which are among the weakest rock components, and these salts are crystallized after being deposited in a very arid environment and in the presence of shallow lakes (Abdel - Motelib, A., Taher, A.G., 2014). The climate is extremely arid all the year, except from January to June where the precipitation reaches 2 mm and in July it reaches 9 mm. Siwa is dominated by high summer temperatures (maximum 37.7 ○C in July and August and the evaporation rate varies from July to December between 16.5 and 5.5 mm/day. It is characterized by constant climatic conditions throughout the year and has monthly average temperature of 35 ○C, humidity of 58% and 300 average sunshine hours per month (Abdel-Motelib, A., et al., 2015).

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- Building Techniques of salty limestone in Oracle temple (Amun):

The Temple of Oracle in Siwa is located in the Aghurmi region, four kilometers from the center of Siwa, and it is one of the two temples of Amun in the Aghurmi region (the other temple is located in Umm Ubaidah). The history of the temple goes back to the rule of King "Ahmose II" (Amazes) from the era of the twenty-sixth dynasty, although it was made after modifications in later times. The temple consists of two halls, followed by the Holy of Holies, whose entrance is located on the main axis, there is a narrow corridor on the right that is, on the eastern side of the Holy of Holies and continues behind the back wall, and there is another room on the western side (Mohab, D., 2010), (Figure.1,2). The town of Al-Aghurmi was built on top of a rock in the form of a fortified fortress overlooking all the neighboring sides, and that at the bottom of the rock there are a large number of explosive springs. This village is one of the first villages built in Siwa in the Middle Ages, following the end of the era of the Temple of Amun and the end of the Roman era. Aghurmi was built of mud and stones on one of the rocky hills next to the Oracle Temple (Al –Khadraoui, R.K., 2012).

Figure 1. *The Oracle Temple in Siwa Oasis*

Figure 2. *The Main Façade of Oracle Temple in Siwa Oasis*

II. Review of Literature

The height of the original façade of the temple is about eight meters and is of a simple style, while the entrance to the temple topped by the corniche is 2.22 m wide and has no writings in it, the Ptolemies wanted to make the temple somewhat similar in appearance to the Greek temple, as they erected in front of it a half-column of recessed Doric style on each side of the entrance.The length of the first courtyard of the temple is 7.47 meters, its width is 4.95 meters, and its entrance is completely in the middle of the walls, while the second courtyard is slightly higher than the first, although their dimensions are roughly the same, and based on recent studies, the temple was built in three stages. The Holy of Holies is the only part that carries inscriptions in the temple, and its dimensions are 3.3 meters in width and 6.1 meters in length, and like the rest of the temple rooms, the Holy of Holies was covered (El-Sayed, S.S.M., 2021).

III. Research Methods

Samples were taken from the essential building material of the temple, which is salty limestone, which were examined by a scanning electron microscope (SEM) and analyzed by X-ray fluorescence.

3.1 Scanning Electron Microscope's examination (SEM)

The sample of salty limestone was examined by scanning electron microscope to identify the status of deterioration and the texture appearance of the surface – (Figure.3).

3.2 X-Ray Fluorescence Analysis

X-ray fluorescence analysis is used to determine the elements of the sample and their percentage – (Table.1).

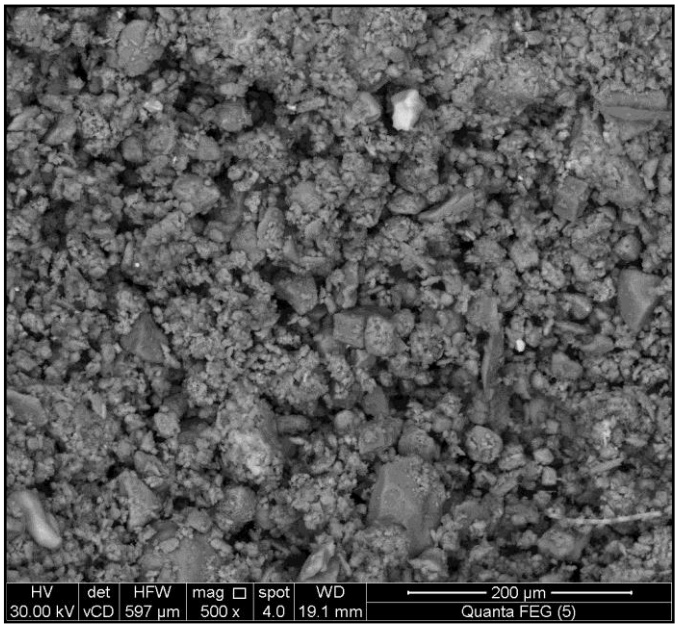

Figure 3. *The Scanning Electron Microscope's Examination of the Salty Limestone Sample (mag 500×)*

Table 1. The XRF Elemental Analysis Table of the Salty Limestone

Compound	Weight %
SiO2	6.50
TiO2	0.05
Al2O3	0.40
Fe2O3	0.25
MnO	0.01
MgO	0.87
CaO	5.40
Na2O	14.40
K2O	10.50
P2O5	0.01
CL	19.00
SO3	0.45
CO2	41.50

IV. Discussion

The scanning electron microscope's examination (SEM) of the sample (mag 500×) shows that the texture of the surface contains gaps and cracks due to the nature of salty limestone which influenced by deterioration factors in the surrounded environment. The xrf analysis of the sample clarify that the sample contains high percentage of sodium chloride salt (Halite) in the sample because of the existence of (Na 14.40%) and (CL 19.00 %) elements beside the calcium carbonates (Calcite) which is the main component of limestone (Ca 5.40 % and C 41.50%) , there is potassium element (K) in the sample (10.50%)and silicon (Si) (6.50%), the existence of potassium K in the sample beside CL refers to the existence of potassium chloride salt in addition to halite which are water-soluble salts.

4.1 The Deterioration Phenomena of Salty Limestone in Oracle Temple

The Oracle or Amun temple in Siwa oasis suffers from the weakness of the essential building material in the temple, which is a salty limestone, where halite salt is one of the main components in limestone, and it is a highly soluble salt in case of high relative humidity in the surrounding environment, which results in the following deterioration phenomena:

1. Erosion of stone layers as a result of salt dissolution in case of high relative humidity – (Figure.4,5).
2. The presence of salt efflorescence on the surface of limestone as a result of its dissolution- (Figure.6).
3. The erosion in the stones of one of the facades of the temple as a result of wind erosion- (Figure.7).
4. Loss in the stone as a result of the presence of one of the fossils within the formation of the stone – (Figure.8).
5. The presence of a fracture in the threshold stones on the main facade as a result of the large loads and the weakness of the salty limestone- (Figure.9).

6. There is a loss in the lower part of one of the walls and it has been completed with new limestones with higher mechanical properties – (Figure.10).

V. Conclusion

Archaeological buildings are exposed to many deterioration factors in different environments, and the nature of building materials may be the cause of their damage. Salt limestone is the essential building material in the Temple of Oracle in Siwa Oasis. It is a limestone that contains a high percentage of salt, especially halite salt and potassium chloride salt, which are water-soluble salts. Therefore, the high rate of moisture in the surrounding environment leads to the dissolution of these salts at a constant rate of dissolution for each salt, which is called the dissolution point of the salt; these salts migrate and grow on the surface of the stone. The salty limestone suffers from severe weakness as a result, as the surface layers of the stone erode, and this causes many structural problems and threatens the security and safety of the temple.

The wind also causes stone erosion as a result of the temple's presence in a desert environment, in addition to the effect of temperature rates fluctuation in the surrounding environment. Therefore, the research recommends the need to intervene and carry out restoration and conservation processes of the temple in order to preserve it for future generations.

References

Abdel-Motelib, A., Taher, A., El Manawi, A., (2015), Composition and diagenesis of ancient Shali city buildings of evaporate stones (kerchief), Siwa Oasis, Egypt, Quaternary International, 369, 78.

Al –Khadraoui, R.K., (2012), Preserving the urban heritage to achieve sustainable tourism development through civil society institutions - Siwa case study, un published Master's thesis, Department of Urban Planning and Design, Faculty of Engineering, Ain Shams University, 137.

El-Sayed, S.S.M., (2021), The Effect of the Geological Nature of Siwa Oasis on the Deterioration of Archaeological and Historical Buildings (The Temple of Oracle and Shali Castle), Scientific Culture, Vol. 7, No. 3, 94.

Mohab, D., (2010), The monuments of Alexander the Great in Egypt, Bibliotheca Alexandrina Publications, Egypt, 19.

Rovero, L., Tonietti, U., Fratini, F., Rescic, S., (2009), The salt architecture in Siwa oasis – Egypt (XII–XX centuries), Construction and Building Materials, El-Sevier, 23, 2492.

Shehab, S.A., (2006), The surviving traditional architecture patterns in the Western Desert of Egypt (a comparative analytical study), unpublished PhD, Islamic Archaeology department, Faculty of Archaeology, Sohag University.

Taher, A.G., Abdel-Motelib, A., (2013), Microbial stabilization of sediments in a recent Salina, Lake Aghormi, Siwa Oasis, Egypt, Facies, Springer-Verlag Berlin Heidelberg,2.

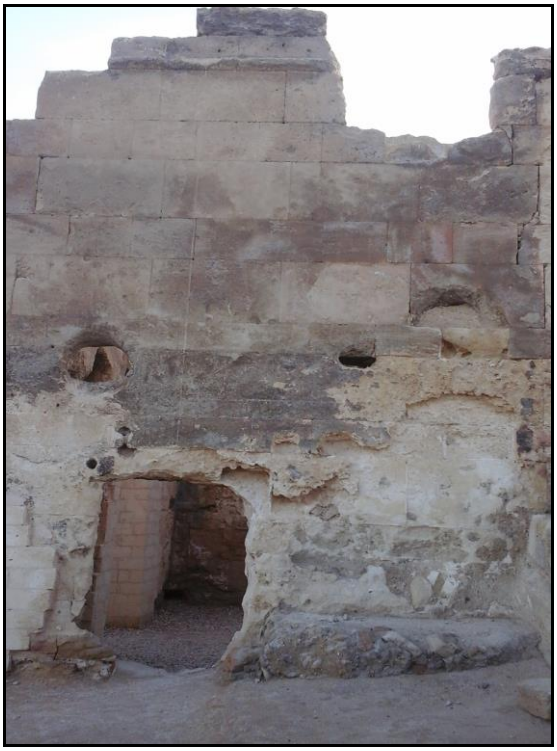

Figure 4. *The Erosion of Stone Layers as a Result of Salt Dissolution*

Figure 5. *The Erosion of Stone Layers in One of the Temple Walls*

Figure 6. *Presence of Salt Efflorescence on the Surface of Limestone*

Figure 7. *Erosion in the Stones of One of the Facades of the Temple as a Result of Wind Erosion*

Figure 8. *Loss in the Stone as a Result of the Presence of One of the Fossils within the Formation of the Stone*

Figure 9. *A Fracture in the Threshold Stones on the Main Facade as a Result of the Large Loads and the Weakness of the Salty Limestone (As Arrows Refer)*

Figure 10. *A Loss in the Lower Part of One of the Walls and It has been Completed with New Limestones with Higher Mechanical Properties*