The Thermal Weathering Of Limestone In Atfiyah's Sarabium Archaeological Site From The Late Period – An Investigative Study

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Abstract: Atfiyah Sarabium Archaeological site belongs to the 26th dynasty (Late period), it locates in Atfiyah center – Giza, this site exposed to many deterioration factors like: Air temperature, relative humidity, salts, ground water and Biodeterioration "mainly plants". The main deterioration factor is the air temperature which cooperates with all the previous factors to deteriorate the archaeological site in the end, there are two building materials in the site "limestone and mud bricks", limestone is the most impressed material from the thermal weathering in the site. We found two types of the limestone, the first one directly exposes to the sun, it's very fragile and turned to powder due to the high air temperature and the existence of salts inside it from the ground water, the second one is in the shadow " not directly exposes to the sun", it's stronger than the first one although there are salts also inside this limestone's type.
This research will include an investigative study of the limestone' types which suffered from high air temperature 'degrees, the difference between them to explain the thermal weathering of Atfiyah's Sarabium Archaeological site.

Keyword- Thermal weathering, Atfiyah's Sarabium Archaeological site, Air temperatures , limestone, ground water ,salts.

I. INTRODUCTION:

Sarabium archaeological site locates in Atfiyah center – Giza governorate, Apis bull buried in many tombs which Called "Sarabium "like Saqqara Sarabium site but Atfiyah's Sarabium is for the burial of Hathur cow which was the main goddess of Atfiyah's center in this time, the site contains of many tombs for Hathur cow from the 26th dynasty (The Late period in the Ancient Egyptian History) [1]. The site suffers from the existence of groundwater in the carved limestone's coffins because of the short distance between the site and the fields around it (100 meter approx.), the site is lower than the surrounded area and the groundwater aggregates inside the coffins [2].
The site has two building materials (Limestone and mud bricks), the site suffers from the deterioration factors like: Air temperature' variations, relative humidity, salts, winds, Biodeterioration and groundwater's existence, but the most impressive one is the air temperature because it is the leader of the last deterioration factors, the air temperature causes the thermal weathering for the building materials especially the limestone [3].
There are two types of limestone, the first one exposes to the sunlight daily and seasonally but the other type doesn't expose to the sunlight (the shadow area in the study site), the air temperatures as a deterioration factor don't work alone but in a tight cooperation with the other deterioration factors and the result is the loss of the building materials and this unique cultural heritage in the end - Figure (1-3).

II. MATERIALS AND METHODS

We took two samples from the essential building material (limestone) which affected by the thermal weathering in the site to explain this phenomenon.

2.1- The First sample from the sunlight exposure area:

A. X-Ray Diffraction Analysis (XRD):
   The first sample was taken from the limestone exposed daily to the sunlight; the sample was analyzed by x-ray diffraction (XRD) to identify its components. Figure (4).
B. Scanning Electron Microscope examination (SEM):

An Examination by scanning electron microscope was done to the surface of the first sample to study its state. Figure (5).

C. Physical properties ' measurement:
Physical properties were measured for the first sample (especially: porosity, density and uniaxial compressive strength). Table (1).

2.2- The second sample from the shadow area in the site :
The second sample was taken from the limestone from the shadow area in the site.

A. X-Ray Diffraction Analysis (XRD):
The sample was analyzed by x-ray diffraction (XRD) to identify its components and how was it different from the first sample. Figure (6).
B. Scanning Electron Microscope examination (SEM):
The sample was examined by scanning electron microscope to identify its state with various magnification powers. Figure (7).
C. Physical properties ' measurement:
Physical properties were measured for the second sample (also, porosity, density and uniaxial compressive strength). Table (2).

III. RESULTS AND DISCUSSION:

- The First sample ' components are (Calcite 54.5 % (the main component) , Feroxyhite 15.3% , Wuestite 11.66% , Zinc oxide 11.28% and Dolomite 7.19 %) , there are iron oxides with high percentage (Feroxyhite 15.3% +Wuestite 11.66% = 26.96 %).
- The Scanning Electron Microscope's examination for the first sample (350X) shows that the surface is very weak due to the thermal effect of the sunlight.
- The Measurement of the physical properties for the first sample (porosity = 10 %, density = 2.3 gm / cm^3 and uniaxial compressive strength= 5.033 KN /cm^2).
- The second sample ' components are Calcite (the main component with 70 %), hydrous calcium sulphates (8%), Quartz (Silicon dioxide 9%) and sodium chloride 13%).
- The Scanning Electron Microscope's examination for the second sample (500X) shows that the surface is better than the first sample, although it is weak.
- The Measurement of the physical properties for the second sample (porosity = 7 %, density = 2.58 gm / cm^3 and uniaxial compressive strength= 7.055 KN /cm^2).

- From the previous analytical and examination methods, we can explain the thermal weathering for the first sample , although the first sample doesn't contain any salty components in its structure like the second sample , it's very weak because it contains many components which have different expanding and contracting rates between the day and night which make big stress inside the lime stone, also , the first sample contains high percentage of iron oxides (Feroxyhite 15.3% +Wuestite 11.66% = 26.96 %) (The Cement material of the limestone) , they dissolve in the high humidity , the limestone turns into powder due to the thermal weathering and the dissolution of the iron oxides.
- Air temperature degrees in the site variety from 30 ^{0}C to 37 ^{0}C in the day and 24^{0}C to 26 ^{0}C in the night (Summer season) , 18 ^{0}C to 24 ^{0}C in the day and 10 ^{0}C to 14 ^{0}C in the night (Winter season).
- The thermal weathering is appearing clearly in surface's weakness of the first sample and the values of physical properties comparing to the second sample as shown in table (3).

IV. CONCLUSION

From the previous investigative study, we can conclude that the thermal weathering has a dangerous effect on the limestone' ruins which expose daily to the sunlight in the site, the first sample was taken from this area, analyzed and examined to identify its components and state but the second sample which was taken from the limestone' ruins in the shadow area was better than the first one , although it contains many salts components inside it , this means that the exposure to the sunlight continuously is more dangerous than the salts existence effect inside the stone .The Thermal weathering of limestone' ruins in the sunlight area causes the exfoliation and powdering of the stone.

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Figure 1. Shows Sarabium Archaeological site in Atfiyah (Study area)

Figure 2. Shows the exfoliation of limestone' ruins in the sunlight area

Figure 3.Shows the limestone's ruins in the shadow area

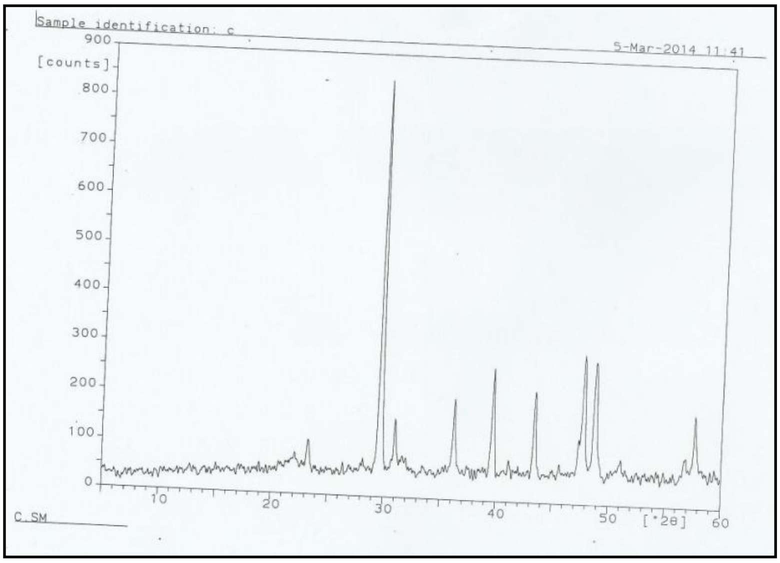
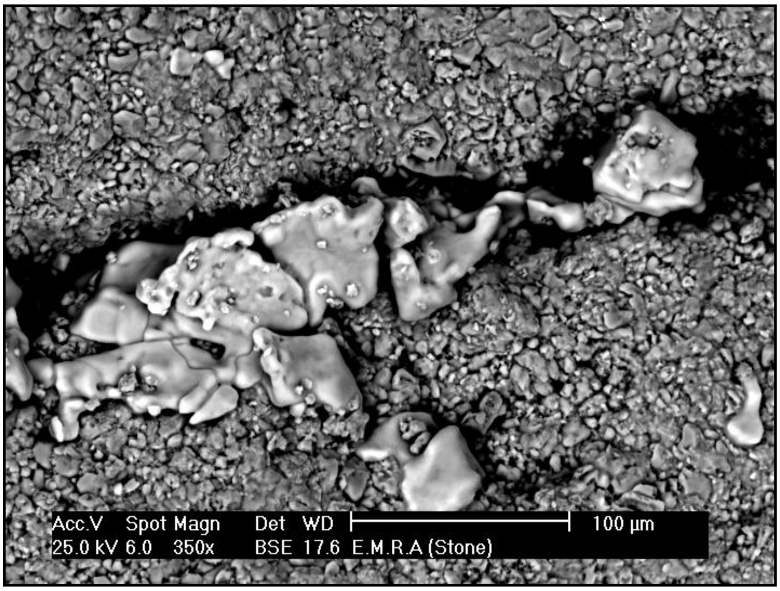


Figure 4. Shows the x-ray diffraction analysis's pattern for the first sample



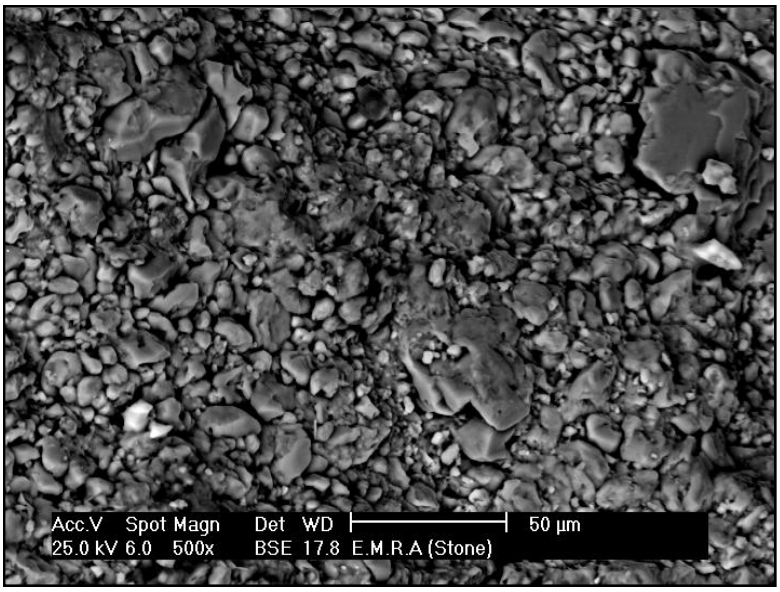


Figure 5. Shows the scanning electron microscope's examination for the first sample (350X)

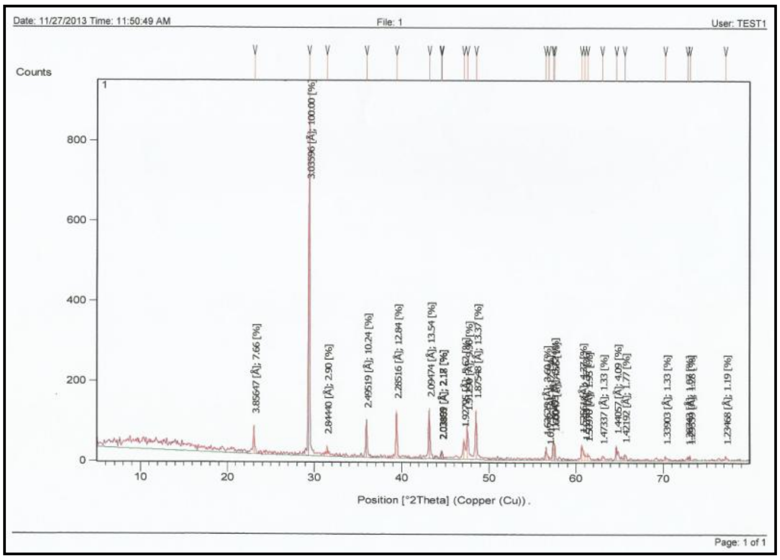


Figure 6. Shows the x-ray diffraction analysis's pattern for the second sample

Figure 7. Shows the scanning electron microscope's examination for the second sample (500X)

Table -1 Shows the physical properties ' measurement for the first sample

The First Sample	**Porosity %**	**Density gm/cm^3**	**Uniaxial compressive strength KN/cm^2**
	10%	2.3 gm/cm^3	5.033 KN/cm^2

Table -2 Shows the physical properties ' measurement for the second sample

The Second Sample	**Porosity %**	**Density gm/cm^3**	**Uniaxial compressive strength KN/cm^2**
	7%	2.58 gm/cm^3	7.055 KN/cm^2

Table -3 Shows the comparison of physical properties measurement ' values between the first and the second sample

Physical Properties	**First Sample (Sunlight area)**	**Second Sample (Shadow area)**
Porosity %	10%	7%
Density gm/cm^3	2.3	2.58
Compressive strength KN/cm^2	5.033	7.055