

Natural Bed of Masonry Stones and Its Effect on the Stability of Wall Stucco Decoration in Historical Buildings

Mohamed Atyia Hawash^{1, *}, Hala Afifi Mahmoud¹, Mohamed Abd El Motelb Etman²

¹Conservation Department, Faculty of Archaeology, Cairo University, Giza, Egypt

²Al Ahram Higher Institute for Engineering & Technology, Giza, Egypt

Email address:

M_hawash@cu.edu.eg (M. A. Hawash), Hawash2009@hotmail.com (M. A. Hawash)

*Corresponding author

To cite this article:

Mohamed Atyia Hawash, Hala Afifi Mahmoud, Mohamed Abd El Motelb Etman. Natural Bed of Masonry Stones and Its Effect on the Stability of Wall Stucco Decoration in Historical Buildings. *International Journal of Materials Science and Applications*. Special Issue: New Strategies for Conservation of Historical Objects, Principles and Practical Applications. Vol. 5, No. 6-2, 2016, pp. 15-21.

doi: 10.11648/j.ijmsa.s.2016050602.13

Received: August 31, 2016; **Accepted:** October 21, 2016; **Published:** January 17, 2017

Abstract: The paper aims to achieve Proper knowledge of the properties of stone and understanding deterioration factors and deterioration mechanisms are necessary for successful maintenance, protection and suitable conservation interventions. avoiding technical errors that occur during building up the building. These technical errors cause stucco decoration falling. samples from the building (Mohamed Ali house) stone blocks and Crystalline salts are Analyzed by X-ray diffraction & X-ray fluorescence. To be able to interpret the wall damage accurately. Results showed that Halite salt efflorescence occur in vertically stone bedding plane. thermal expansion coefficient of a salt exceeds the surrounding rock stone weathering Exfoliation occur. So incorrect position for building stones, Not perpendicular to Bedding Plane of Sedimentary rocks, This problem must be avoided because its harmful effect to the Stability of Wall Stucco Decoration in Historical Buildings.

Keywords: Natural Bed of Stone, Bedding Plane, Efflorescence of Salts, Intrinsic Factors, Tensile Strengths, Crystal Lization Pressure, Exfoliation

1. Introduction

Mohamed Ali house was built at the period between 1882 and 1914, when crescent and Pentagonal star decorations prevailed, that represents the Egyptian flag in this period [1], and it's the main stucco decoration element in the house façade. limestone used for building up from nearby quarries (Mokattam quarries) at Cairo. In terms of mineralogy and structure, stone is an extremely complex material - a complexity is reflected in its weathering response to stone natural and the building environment. [2], The decay of materials is a function of intrinsic and extrinsic factors. The intrinsic factors are related to the material itself, and include the type of the material, its properties and its microstructure. The extrinsic factors refer to the effect that the environment has on the material and can be generally divided into factors related to the atmosphere and factors related to the usage of the material respectively. [3], Moisture and salt decay processes are amongst the most

recurrent causes of damage of plasters and substrates.

The mechanisms and factors that control the formation of salt crystals in porous media and the development of damage are poorly understood. A renewed interest in salt damage research has surfaced since the second half of the 20th century. The interest is probably due to the increase of large-scale salt damage hazards in the same period. The rise of the ground water, the increase in the salinity of ground, and the introduction of new sources of salts are the main causes of the enhanced risk of salt damage. [4], Salt crystallization causes damage in the form of scaling, spalling and flaking of the material [5],

The main problem is stucco decoration separation from the wall (substrate), this problem resulting from incorrect building stone position not being perpendicular to Bedding Plane of the stone blocks, it's kind of deterioration intrinsic factors The natural bed of stone indicates the plane or bed on which the sedimentary stone was originally deposited. Fig. 9. that made stones blocks very weak to bearing, Because of wall loads and

salt crystal growth in Bedding Plane (A distinct surface of contact between two sedimentary rock layers.) [6], Salts migrate in the form of solution through the complex capillary system of porous stones towards the surface. Crystallization of soluble salts may appear in the form of efflorescences or subefflorescences or within the pore of the stone itself Crypto efflorescence [7], salt crystal growth in Bedding Plane can be classified subefflorescences or Crypto efflorescence.

That led to Exfoliation it's the cause of Stucco decoration falling.

2. Material and Methods

2.1. Figures That Demonstrate the Problem



Figure 1. Show the general view of the building (Mohamed Ali house) Decorated with stucco ornaments.

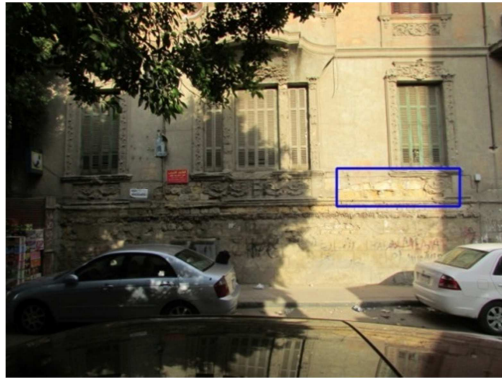


Figure 2. Show Inside the blue rectangle stucco decorations Separated from the wall.



Figure 3. Details of the previous fig shows the stones course that were built on incorrect Natural Bed.

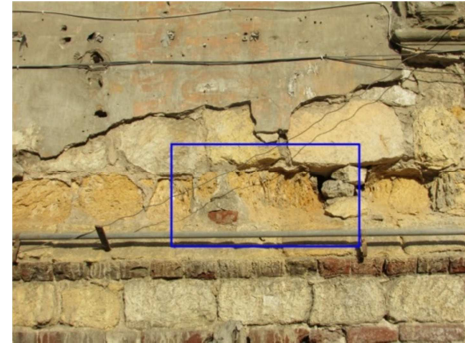


Figure 4. Details of the previous fig shows one of the building stone that have Exfoliation.



Figure 5. Show Exfoliation, efflorescence of salts.

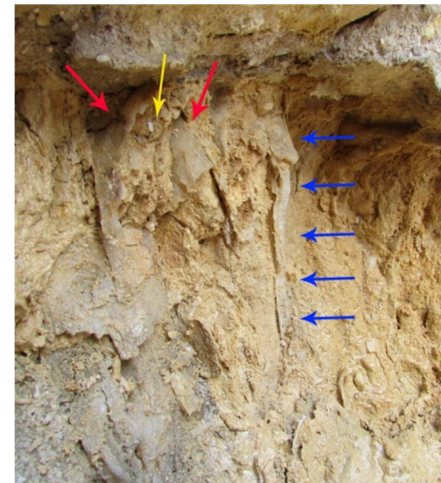


Figure 6. Shows Blue arrows represent efflorescence of salts Longitudinally, Red and yellow arrows illustrate the Sequence of sediment layers of stone and Longitudinally salt efflorescence.



Figure 7. Shows the longitudinally separation of sedimentation layers According to Bedding Plane.

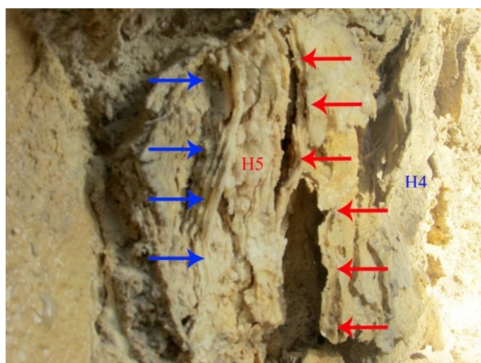


Figure 8. Blue and red arrows shows The longitudinally separation of sedimentation layers According to Bedding Plane As a result of the pressure force caused by salt crystallization longitudinally, H4: Place of fallen stone sample, H5: a sample from efflorescence of salts Longitudinally According to Bedding Plane.



Figure 9. Show Horizontal bedding of sedimentary rocks. [8].

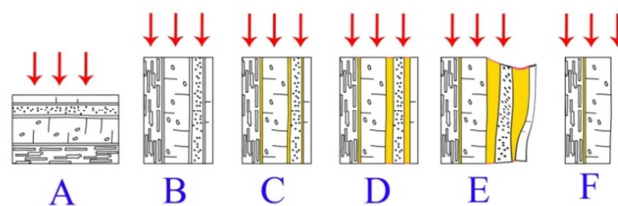


Figure 10. Show red arrows indicate loads located on the Stones, A: Correct position for building stone Loads perpendicular to the Horizontal bedding of stone, B: incorrect position for building stone, C: salt crystal growth in Bedding Plane with yellow color, D: Overgrowth of salt crystal, E: The collapse of the outer layers, F: Exfoliation happen.

2.2. Analytical Study

Stone sample were taken from the deteriorated stone at the middle of the house façade, salt efflorescence were sampled from stone bedding plane. samples list is shown in Table 1 and samples location in the wall in Figure 8. Stone and salt samples were studied with an X-ray diffraction Technique were used to study stone and salt mineralogy using a panalytical X-Ray Diffraction equipment model X, Pert PRO at 40 kV and 30 mA with a Cu source anode. and Micro-XRF were used to study stone and salt elements using C N S I (Micro-XRF) Orbis Micro X-ray Fluorescence (Micro-XRF) Analyzer.

Two samples stone H4, salt H5 whre taken from deteriorated parts.

Table 1. Describe Samples from Mohamed Ali house – Cairo.

Sample Coding	Required analysis	date	Color	Damage Type
H4	XRD- XRF	14/4/2014	yellowish White	Physical damage
H5	XRD- XRF	14/4/2014	White	Physical damage

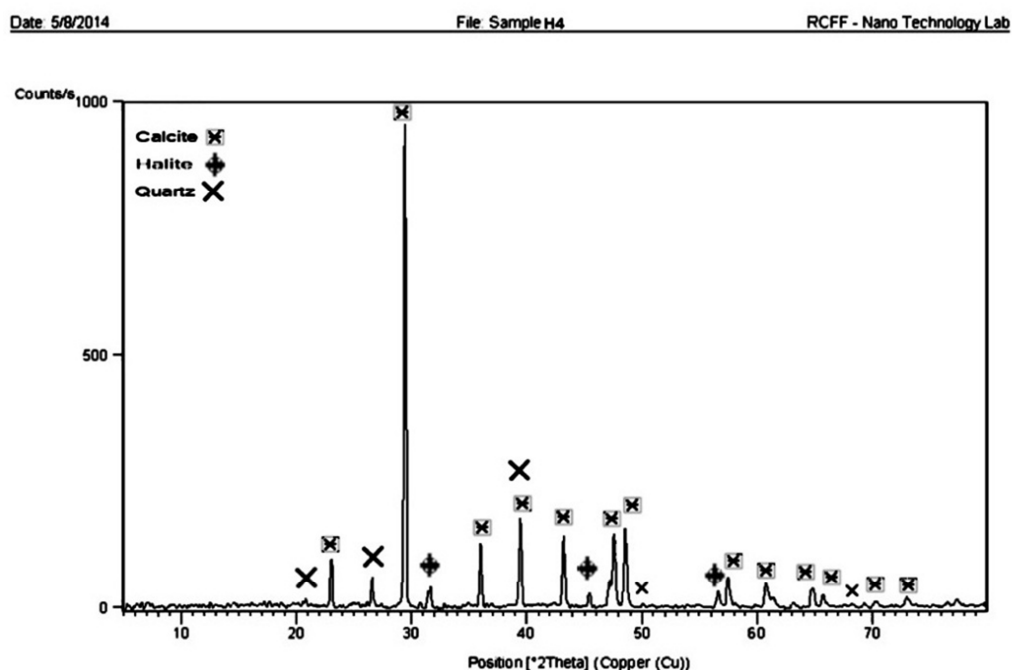


Figure 11. Shows X-ray diffraction pattern of the sample H4.

X-ray diffraction pattern of the sample H4 give the proportions of the stone component, Calcite the main component 89.14%, Halite 5.56% and Quartz 5.29%

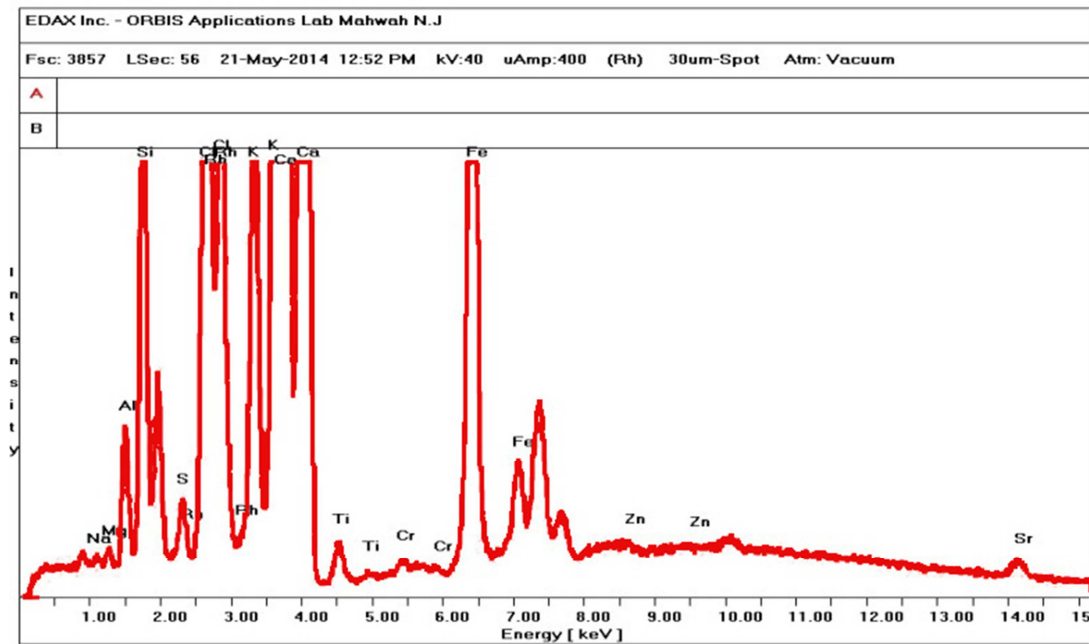


Figure 12. Shows (Micro-XRF) pattern of the sample H4.

Table 2. Shows (Micro-XRF) elements proportion in sample H4.

H4						
12:52 PM 21-May-2014						
Oxide:	Net	Wt%	At%	I-Error%	BG	Wt-Error
Na2O	10.86076	3.79	3.63	13.91	58.56121	0.53
MgO	20.01107	1.95	2.87	7.99	61.70065	0.16
Al2O3	182.9243	3.65	2.12	1.32	71.76112	0.05
SiO2	846.7383	8.78	8.68	0.5	77.54053	0.04
SO3	86.28099	0.43	0.32	2.5	87.69019	0.01
Cl2O	1369.952	3.49	2.38	0.39	105.7241	0.01
RhO	454.0411	X.XX	X.XX	0.76	108.8457	X.XX
K2O	874.4403	2.12	1.34	0.51	121.6354	0.01
CaO	28522	73.31	77.59	0.08	98.2858	0.09
TiO2	76.61298	0.28	0.21	2.14	37.20947	0.01
Cr2O3	35.53272	0.07	0.03	4.53	54.99367	0
Fe2O3	1438.54	1.94	0.72	0.37	91.82854	0.01
ZnO	27.38089	0.03	0.02	8.85	151.0854	0
SrO	53.99475	0.15	0.09	3.81	91.68584	0.01
Total		100	100			
kV	40		Live Tm	56.1		
uA	400		Reso	138.3		
Itera.	4		Method	FP-NoStds		

Date: 5/8/2014 File: SampleH5 RCFF - Nano Technology Lab

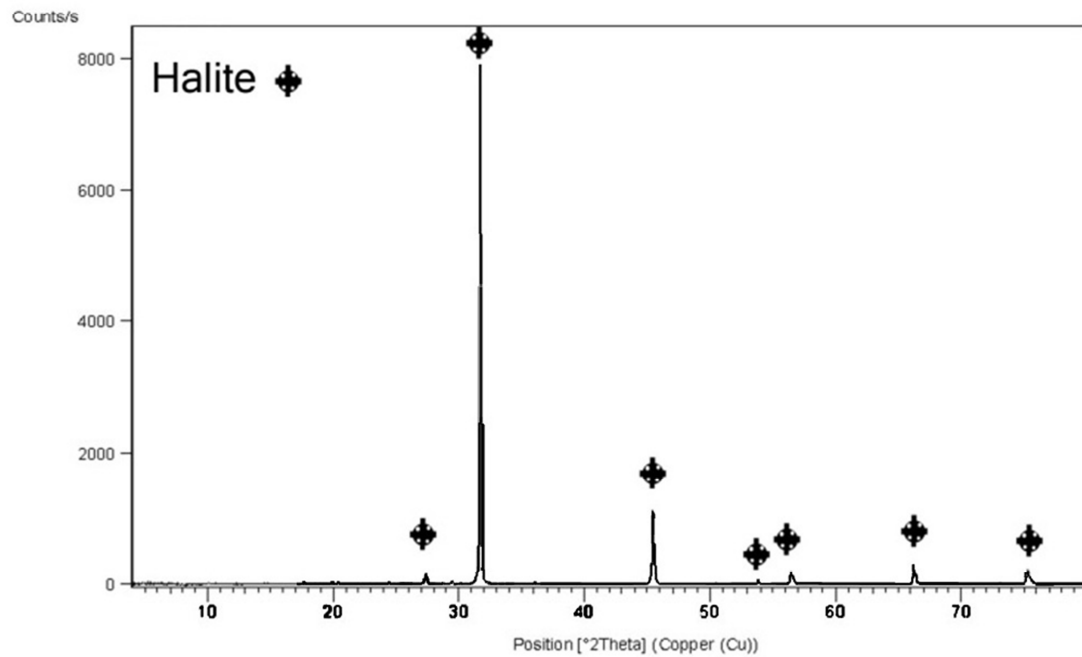


Figure 13. Shows X-ray diffraction pattern of the sample H5.

X-ray diffraction pattern of the sample H5 give a main component halite salt.

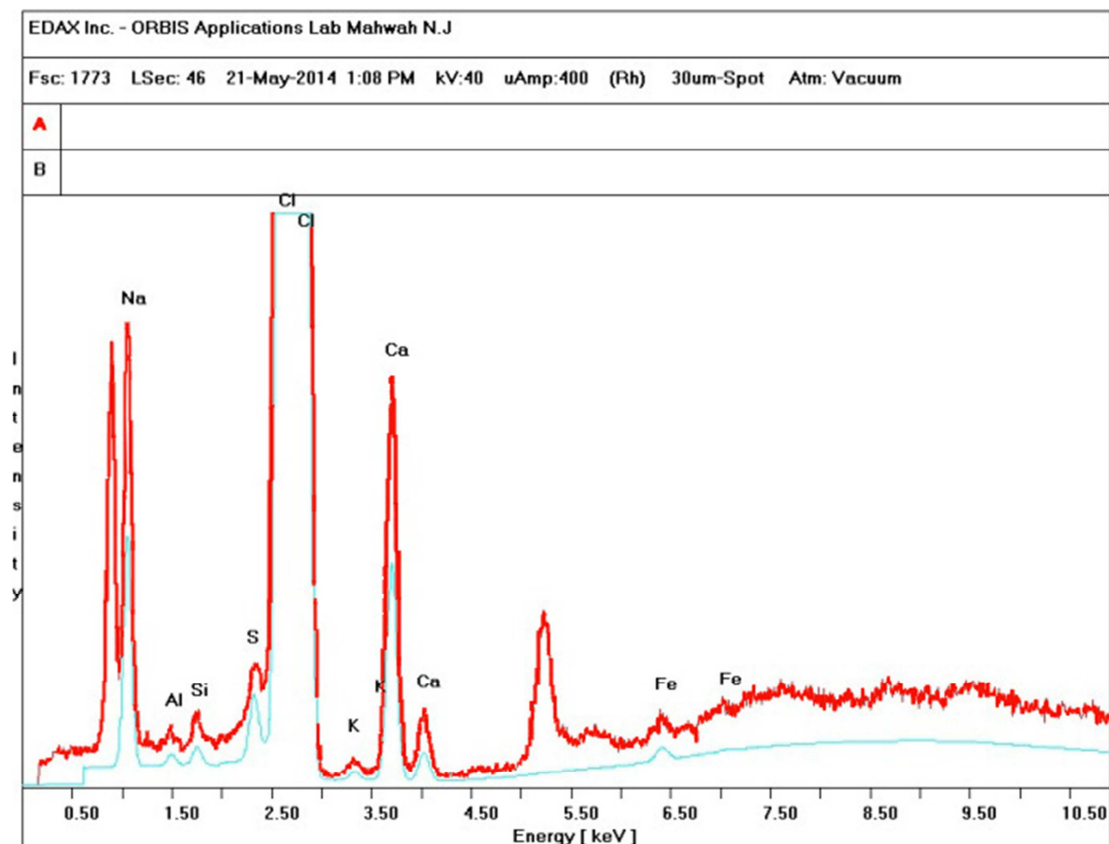


Figure 14. Shows (Micro-XRF) pattern of the sample H5.

Table 3. Shows (Micro-XRF) elements proportion in sample H5.

H5						
1:08 PM 21-May-2014						
Oxide:	Net	Wt%	At%	I-Error%	BG	Wt-Error
Na2O	237.853	48.63	56.7	1.07	31.17051	0.52
Al2O3	9.29076	0.21	0.15	14.1	35.15844	0.03
SiO2	19.53007	0.22	0.27	7.15	35.50334	0.02
SO3	71.07108	0.37	0.33	2.34	28.56219	0.01
Cl2O	15016.43	49.39	41.07	0.12	21.75038	0.08
K2O	11.76978	0.06	0.05	7.01	9.91593	0
CaO	288.0362	1.11	1.43	0.9	10.62729	0.01
Fe2O3	18.19358	0.01	0.01	9.61	61.84523	0
Total		100	100			
kV	40		Live Tm	46.4		
uA	400		Reso	138.3		
Itera.	4		Method	FP-NoStds		

3. Results and Discussion

limestone used in construction as a support for stucco decoration, calcite proportion nearly 90%, halite considered extraneous component due to the deterioration of the wall which means that the percentage of calcite exceed to 93%, quartz more than 5% in this case it consider the binder of calcite Crystals in limestone Fig. 11. the limestone has a small percentage of two salt halite and sylvite commonly found in Egyptian soil. stone yellowish color due to the presence of small proportion of iron and aluminum oxides. Table.2. Sodium chloride is most expected to be formed in the building materials due to its high solubility [9], halite salt is the main salt because chlorine and sodium ions which form the ratio exceed 98% There are some other ions such as potassium is an indicator for the presence of sylvite Salt Kcl. the two salts commonly merged in the Egyptian soil. there are some other ions such as iron, aluminum, silicon and calcium presence of such ions with the salts as a result of ions displaced between salt and stone. Fig. 14, Table. 3. so Stone deterioration caused by salt efflorescence. it is easy to observe and locate the natural bed as it lies along the plane of stratification. The natural bed can occur in case of only sedimentary type of rocks as our lime stone. In stone masonry, the direction of natural bed of all sedimentary stones should be perpendicular to the direction of pressure. Fig. 10. A Stone set in a building with its grain running horizontally, as it does in the quarry, is said to be set on its "natural bed" [10]. This arrangement ensures maximum strength of stone work. if it doesn't set on its "natural bed" The stone can easily split along this plane. [11], the split due to pressure from the wall loads and salt crystals growth in the Bedding Plane Fig. 10. B-F. Hydration, crystallization, and thermal expansion are additional types of expansionary force that are believed to cause rock failure. Such stress concentration effects contribute to crack growth from randomly oriented micro cracks inducing further damage and reducing the rock strength. [12], The assessment of the susceptibility of stone to salt decay can be accomplished

either through the calculation of crystallization pressure, rock tensile strengths fluctuate between 2 and 20 Mpa [13], Crystal growth gives rise to crystallization pressure. For instance, the crystallization pressure of halite, is about 65 Mpa [14], the big difference between rock tensile strengths and the crystallization pressure of halite led to stone deterioration. so Salt crystallization pressure is responsible for physical weathering of the stone. [15], when thermal expansion coefficient of a salt exceeds the surrounding rock, then the conditions are set for physical weathering to occur. The thermal expansion coefficient for halite is four times larger than for calcite. temperature changes can also produce stresses within the rocks. The fabric decay by salt loading is accompanied by micro cracking. which result in a permanent increase in volume. [16], Finally Exfoliation happen, Exfoliation used to describe natural stone deterioration it most often occurs along natural bedding planes, resulting in an unevenly layered surface. Incorrectly laid stones with their bedding plane laid up parallel or perpendicular to the surface of the building thus have a natural tendency to exfoliate faster, following the lines of the bedding planes. [17], Fig. 10. B-F so Exfoliation is one of the most important kinds of stone weathering.

4. Conclusions

- sedimentary limestone used in construction as a support(substrate) for stucco decoration.
- some stone blocks Incorrectly laid in the wall, their bedding plane laid up parallel to the surface of the building.
- halite is the main salt with crystallization pressure about 65 MPa, and rock tensile strengths fluctuate between 2 and 20 MPa.
- thermal expansion coefficient of a salt exceeds the surrounding rock.
- stone weathering Exfoliation occur and Stucco Decoration in this Historical Building fallen.
- the rock fabric plays a significant role in the degree of weathering and deterioration at all.

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