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Original article

DETERIORATION AND CONSERVATION OF ST. SRABAMOUN CHURCH BUILDING MATERIALS, AL-PTANON CITY – MENOUFIA - EGYPT

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Abstract
Church of St. Srabamoun is located in Al-Ptanon city, Menoufia Governorate, The building materials of the church were exposure to deterioration and degradation, so that many deterioration phenomena were appeared. Building materials which include , bricks, stones, mortars and the plaster layers in addition to salts and under ground water had been studied by polarizing microscope (PM), scanning electron microscope (SEM), X-ray diffraction (XRD), and chemical analysis to identify their components. On the other hand physical and mechanical properties were measured. As shown through examinations and analyses that brick consists mainly of clay minerals in addition to quartz. XRD analysis of stone showed that the stone is include mainly of calcite in addition to quartz and halite. The mortar used for building consists of gypsum, calcite and quartz in the form of sand, and plaster layers were contained calcite and quartz with the addition of gypsum. It found that stones affected by surrounding environmental factors and agricultural environment in the site of the Church, in addition to the lack of sanitation in the region which led to leakage of water irrigation and drainage in the soil in the site of church. In addition to the presence of salts dramatically in the soil, this led to crystallization of salts, loss and disintegration of mineral grains. The discussion dealt with the interpretation of deterioration phenomena of building materials. Finally, discussed the important recommendations for the restoration, treatment and conservation of building materials of St. Srabamoun Church.

Keywords: *St. Srabamoun Church, Stones, Brick, Plaster layers, deterioration, Conservation*

1. Introduction

St. Srabamoun Church is located in the north of Al-Ptanon, Shebin city - Menoufia Governorate. According to dictionary of geographical Al-Ptanon is one of ancient Egyptian villages. Semakka says in his book "guide the Coptic Museum" that Al-Ptanon contained number of churches, that had been disappeared, only two of them still preserved. [1] They are church of Srabamoun and church of the Virgin Mary. The church of Srabamoun have been built at the end of the nineteenth century on the ruins of the old church which was built on a high hill and opened in 567 AD, but it was collapsed and was rebuilt in 1897. [2] St. Srabamoun was born in Jerusalem, and his name was Simon, son of Ibrahim, son of Levi, and lived in Alexandria. He was martyred and his body was taken to the church that called by his name. The church is surrounded by a wall of brick with two entrances, and the doorways lead to the area of space surrounding the church. The interior of church is divided into three sections; the middle of them is the largest and the highest one. [3] The Church extends on the west side with a width of 14.5 meters and is composed of two floors. The church bell tower is based on four cylindrical pillars. The entrance of the church surmounted by stained glass painted with the cross in bright colors. The church is basilica style and its area is 184 m^2, fig. (1). [4] The aim of the current research is to study the building materials of St. Srabamoun church to identify its components, the causes of damage that affect these materials and led to several forms of deterioration. Moreover, suggestion the suitable procedures for restoring these materials.

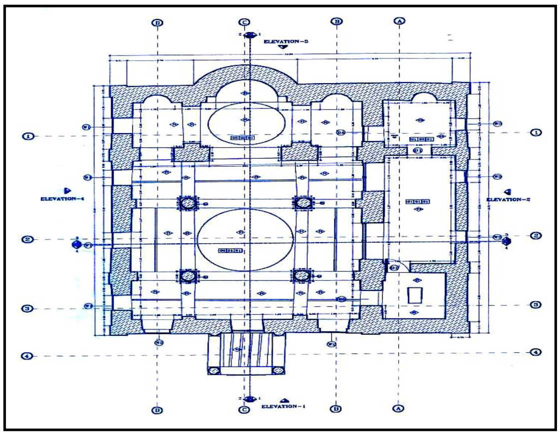

Figure (1) plan of St. Srabamoun Church

2. Field observations

Through field inspection of the site it was noticed that high level of ground water thus affecting the building walls and led to the salts crystallization [5], and the /shedding layers of plaster both in internal and in external walls of the church. Damage and erosion surfaces and the fragmentation of brick units were observed. In addition, the study indicate the presence of salt deposits on some parts of the stone columns inside the church, all of these features are shown in fig (2).

Figure.(2) **a** deterioration of walls, **b** the tower, **c** the church entrance, **d** damage of brick units, **e** decay of plaster layers, **f** rising damp in the walls, **g** crystallization of salts on stone surfaces, **h** missing parts from one of stone column.

3. Materials and methods

Samples were taken from various building materials of the church to determine, interpretation the causes of damage and to suggest the suitable recommendations and conservation methods. Minerals and petrographic description were carried out using a polarizing microscope Also, mineral composition of the samples was identified by a Philips X-ray diffractometer (PW 1010), using Cu K radiation. Ni-filtered copper radiation (λ = 1.5404 Å) at 30 kV and 10 mA. Scanning electron microscopy observations using a Philips XL-20 microscope were also carried out to describe the morphological features of the surface particles, voids and its weathering status. On the other hand physical and mechanical properties of bricks were measured, in addition to chemical analysis of ground water

4. Results

4.1. *Examination by polarizing microscope*

Petrographic study of bricks shows that it consists mainly of clay minerals which had been burned during the manufacture of bricks and quartz. In addition to a percentage of iron oxides. Furthermore some burning fibers were observed, which were added during brick making process, as argued previously by El-Gohary & Al Naddaf, 2010 [6]. Moreover, presences of some gaps as a result of high porosity, fig. (3). Within the same context the examination of stone samples shows that it consists mainly of calcite, dolomites and, iron oxides in addition to the presence of some types of fossils such as (Nummulites SP.,) fig. (4).

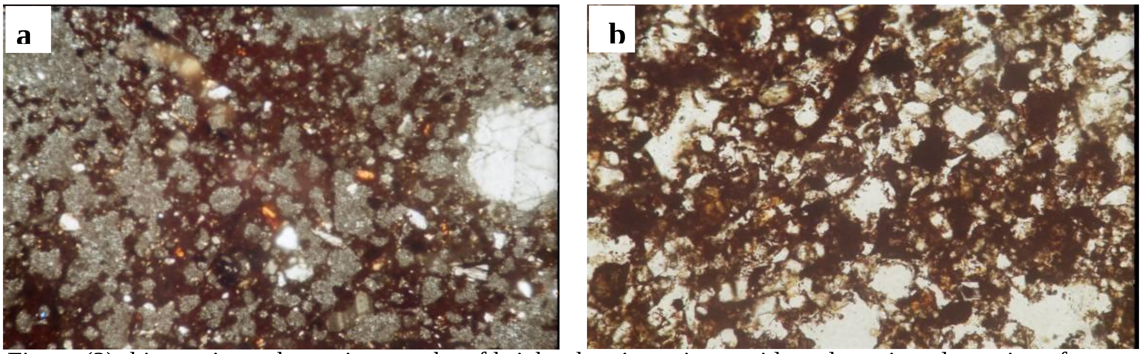

Figure (3) thin sections photomicrographs of bricks showing **a** iron oxides, clay minerals, grains of quartz and crystals of microcline and plagioclase under C.N as follow **a** 25 X, **b** 64 X

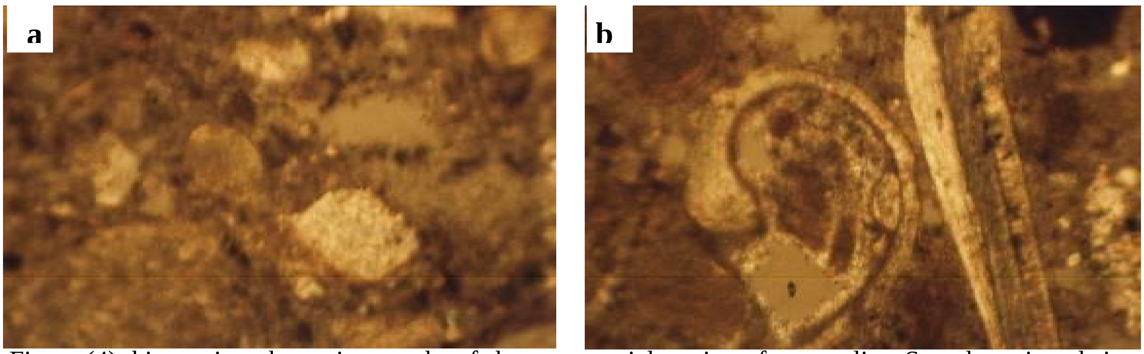

Figure (4) thin section photomicrographs of show equatorial section of nummulites Sp., clay minerals in a fine- grained matrix (biomicrite) under C.N as follow **a** 64 X, **b** 120 X

4.2. *Scanning electron microscope*

SEM observation, of bricks shows that there are some cracks, gaps and voids, which led to the disintegration, separation, thus erosion and weakness of the brick internal structure. Also, dissolving of some brick components and crystallizing some types of salts and thus influence the mechanical properties of bricks and stamina to the pressures and loads, fig. (5). On the other hand, SEM observations of limestone show loss of binding material between mineral grains due to severe impact of the salts crystallization affecting stone components .

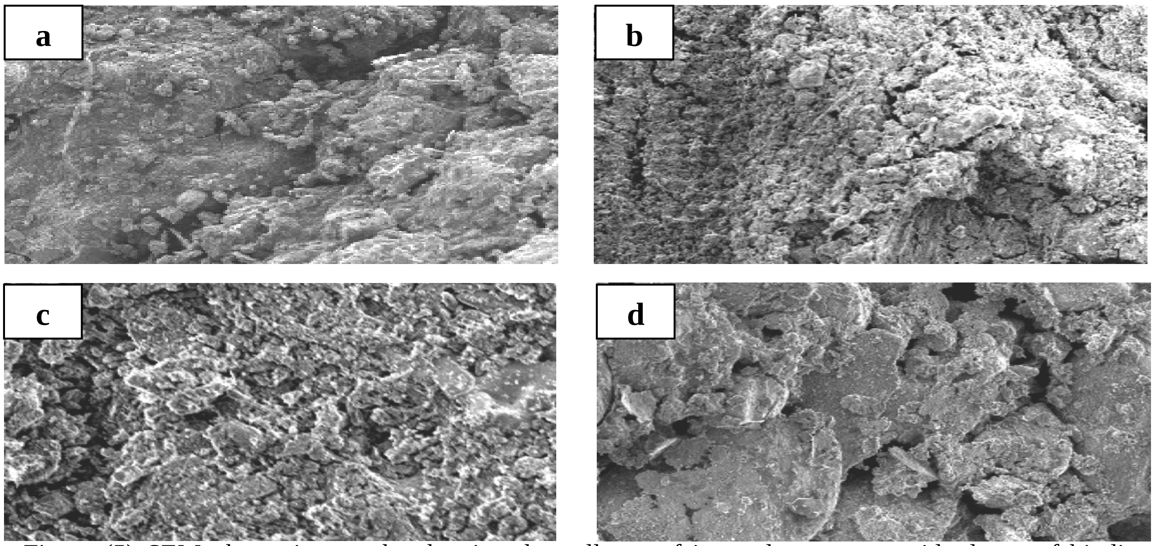

Figure (5) SEM photomicrographs showing the collapse of internal structure, voids, loose of binding material and salts crystallization between mineral grains **a** & **b** brick samples 400 X, **c** & **d** limestone samples 650 X.

4.3. *X-ray diffraction Analysis*

XRD analysis of brick samples proved that it consists of clay minerals, quartz, feldspar and calcite, in addition to halite (sodium chloride). The stone samples consist of calcite and halite. Furthermore, the analysis of mortar shows that the sample consists mainly of quartz, calcite, gypsum and halite. On other hand, analysis of plaster layers of the interior walls of the church shows that it consists of calcite, gypsum and quartz, and, the exterior layer of plaster on the surface of out side walls consists of calcite and quartz. Finally, the analysis of the also, shows that the main salts dominated is halite NaCl (sodium chloride), all of the XRD patterns are shown in fig. (6).

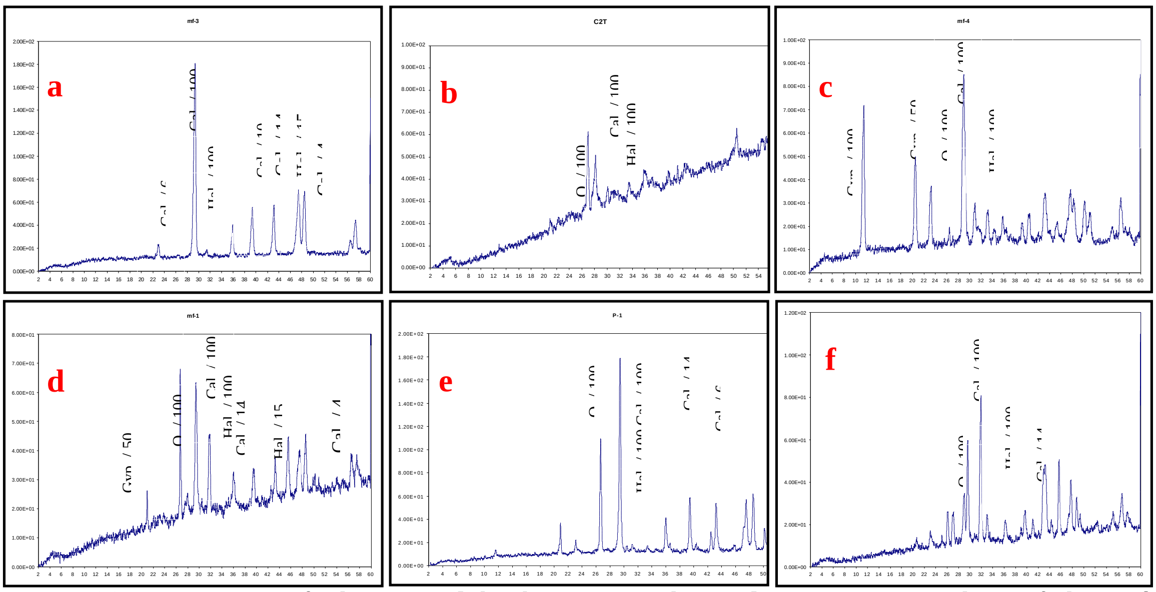

Figure (6) XRD patterns of **a** limestone, **b** brick, **c** interior plaster, **d** mortar. **e** exterior layer of plaster, **f** salts

4.4. *Chemical analysis of ground water church site*

Chemical analysis of groundwater in the our site indicates that there are high rates of sodium and chlorine ions, related to halite (NaCl), as well as a high proportion of sulfate ions, related to gypsum ($CaSo_4$. $2H_2O$), all of these results are listed in table (1)

Table (1) the results of chemical analysis of the sample.

Analytical Results	*(ppm)*
Total Dissolved Salts	4090
Chlorides as Na Cl	128
Sulfates	2744
Salinity	120

4.5. *Physical and mechanical properties of bricks*

Measuring of physical and mechanical properties of brick units include density, porosity, water absorption, compressive and tensile strength proved some difference in their records as listed in tables (2):

Table (2) Physical and Mechanical Properties of Bricks

Physical properties	*Sample Id*		
	Sample 1	*Sample 2*	*Sample 3*
Dimension cm.	5×5×5	5×5×5	5×5×5
Volume cm^3	125	125	125
Density g/ cm^3	1.42	1.57	1.49
Porosity %	43.22	41.58	42.77
Coefficient of Water adsorption %	28.58	27.47	28.34
Compressive Strength Kg/cm^2	46.12	47.58	46.81
Tensile Strength Kg/cm^2	6.94	7.25	7.19

5. Discussion

The examinations that were carried out to investigate the church building materials proved the following points. * **Examination by polarizing microscope** proved that the brick units shows the brick is composed mainly of clay minerals in addition to quartz and melting some of its components during the manufacturing process which helping in the damage and deterioration processes [7]. Furthermore, presence of some burned fibers, high porosity and voids inside the brick. In addition, PM examination of limestone proved that limestone consists mainly of calcite, as well as the presence of some crystals of dolomite in addition to iron oxides and fossils [8], which contributed to a certain extent significant damage to the blocks of stone by the effect of moisture [9]. * **Examination by SEM** of bricks and stones show that there are some salt crystals presence between the brick and stone components which led to the disintegration and loss of binding material between the grains, [10], in addition to the dissolving of some components, which led to the weakness, erosion and fragility surfaces of both bricks and stones. Moreover, weakness of the internal construction As a result of localized the effects of internal stresses and pressures through the crystallization pressures of salts [11]. * **XRD Examination** of the church building materials shows that stones consist mainly of calcite in addition to a percentage of halite. Mortar consists of calcite and quartz in addition to a percentage of gypsum that help to damage and deterioration due to the sensitivity of gypsum to be affected by high rates of relative humidity [12]. Also, this technique proved that there is more than one plaster layers found on the wall surfaces which is about three layers. 1st one: from the inside to outside (there is a layer on the surface of the bricks directly) consists of sand, lime and gypsum, and the 2nd layer is consists of sand with lime. The 3rd one consists mainly of lime with the percentage of sand and gypsum. Due to the presence of halite salt related to the high level of ground water in the study area. This salt plays an important role in the damage process affecting the study monument, either on rooftops or internal components because of its high hygroscopic index, [13], through the effects the alternative cycles of dissolution and crystallization. These cycles that leads to create some pressures and stresses and thus the disintegration of building materials [11]. All of these deterioration mechanisms lead to many aspects of damage of walls and other building materials. * **Physical and mechanical properties** of brick shows that it characterize by high value of porosity and the proportion of saline water absorption, in addition to effects resulted from moisture effects. All of these factors and their related mechanisms lead to many types of damage and degradation [14],[15]. Within the same context, the brick units characterize by low values of compressive and tensile strength which indicate that the brick mechanical properties have been affected by various deterioration factors [14]. Also, it could be confirmed brick building materials suffer from severe damage due to the nature of the soil that consists of unsuitable materials, high levels of relative humidity and high levels of ground water, [16],[17], [13]. Soil in church site consists of a surface fill layer to a depth ranging between 1.0 m: 1.5 m, followed by a layer of clay mixed with brick powder to a depth of between 3.2 m: 4.5 m, then layers of clay mixed with silt to a depth of about 9.00 m from the surface. Ground water has appeared at a depth of 0.70 m in the church site. Composition of soil in the site and ground water level has been played an important role in deterioration of building materials. Measurements of relative humidity in the church walls by digital hygrometer show that high rates of moisture inside the walls and to varying degrees, for example, the western façade of the church that contained the main entrance of the church, and in some places relative humidity reached to 95% at levels above ground level. Relative humidity in the three other external façades as well as in the interior walls of the church has reached to 98% in the lower level above the ground and reached between 70% and 30% in the upper parts of the walls. Human activity which carried out in agricultural land adjacent to the church and the requirements of these crops lead to water leakage and salts from the soil to the walls by capillarity.

6. Recommendations of Treatment and conservation

The walls of St. Srabamoun church need to apply horizontal isolation by chemical injecting with water repellent material. Laboratory procedures using water repellent materials must be tested before to ensure their efficiency. According to previous studies the following for treatment and conservation recommend could be concluded. **Brick**, need to mechanical and chemical cleaning to remove dust and stains, and extraction of salts using manual methods and poultices [18], Consolidation of weak, corroded parts and separate mineral grains using silicon or siliceous based material [19], which increase the mechanical durability of the brick units [20] and Completing the missing units by using contrived units similar to the original bricks in components and dimensions [21] [22]. **Stones** need to carry out mechanical and chemical cleaning using appropriate materials and methods, for example, manual tools and organic solvents [23]. Also, extraction of salts, using different types of poultices, includes clay and paper poultices. After removing the salts the walls become ready to apply the plaster layers. In the case of surface weakness, plaster layers could not be applied directly and consolidation procedure could be carried out firstly. This may be done by using one of the silicon based material [24] such as ethyl silicate because of its ability to link between the grains of mineral constituents of the stones [25], On the other hand, filling the joints between the stones and completing the missing parts must be carry out. Isolation process of stone surfaces to protect them from the impact of ambient air and moisture is needed using one of the silane and siloxane based material as a water repellent to avoid re-deterioration processes [26]. **Mortars** a **s**iliceous based material can be used to improve the natural and mechanical properties of the restoration mortar [13]. This recommended mortar is consists of sand, lime, and kaolin by 3: 1: 0.5 sizes, respectively, the components of the original mortar and it will be prepared as follows: - Fermentation of pure Portland lime in water free of salt for 24 hours to avoid any salts. - Mortar is mixed with lime water to achieve more efficient [27]. – Using pure sand with 500 microns then put it on polyethylene sheets until completely drying – Mixing these components with pure kaolin for homogeny. Adding responsible amount of water until gives us a homogeneous mortar suitable for the construction process [13]. **Plaster layers,** according to the studies and humidity measurements, walls need to horizontal isolate to cut off the source of ground water from the walls and protect the walls and their components. New plaster layers will be used after removing the ancient one from the surfaces. The walls must leave to dry to get rid of the moisture content, which is approaching saturation [28] Application of plaster layers must base on lime plaster and sand to be used as filler. [29], [30]. A water repellent material is recommended to protect the plaster layers from the impact of rainfall, humidity and condensation.

7. Conclusion

The results of samples characterization show that the clay minerals and quartz are the main components of bricks; however, the calcite is the main component of limestone associated with traces of halite as a deterioration factor. On the other hand, mortars and plasters were lime based materials. Also, results show that the physical and mechanical properties were affected according to deterioration factors. The mechanisms of moisture transfer are complex, particularly regarding with rising damp in our case study. Deterioration, erosion and disintegration of stone ornaments occur by moisture and soluble salts migration. The presence of Halite (NaCl) in the groundwater leads to dramatic changes of the surface of building materials (stones, bricks, plaster and mortars). Growing of salt crystals such as, halite is known to exert high pressures of varying degree within small capillaries and cause disintegration of building materials. The investigations and analysis of samples showed that the crystalline chlorides exert a pressure on the pores which cause disintegration and cracking of stone changing it into a brittle mass. Furthermore, the results show that the high content of subsurface water in the site resulted from rising damp, where the water trapped within the masonry system because of the high porosity of brick walls. Within the same context, crystallization of soluble salts caused many deterioration phenomena of building materials such as erosion, cracking, failure and fragile.

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