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ANALYTICAL INVESTIGATION OF DETERIORATION ASPECTS IN THE MIHRAB OF MADRASA GAWHARIYYA OF AL-AZHAR MOSQUE, EGYPT

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Abstract:
The present research paper discusses the deterioration aspects of the Mihrab (Prayer Niche) of Madrasa Gawhariyya, attached to Al-Azhar Mosque. The mihrab consists of decorative units made of marble, ceramic, and wood. Different factors, especially the previous restoration, resulted in many deterioration phenomena that led to the damage and deterioration of the decorative units of the mihrab. This research paper aims to study these aspects using different methods of examination and analysis, such as visual and optical examinations, Scanning Electron Microscope attached to Energy Dispersive X-ray Spectrometer, and X-ray Diffraction (XRD). The results obtained gave important insights into the deterioration processes of the Mihrab, such as dirt, cracks, and crystallized salts on the surface, the deterioration of the ceramic units, in addition to the deformation and deterioration resulting from the previous restoration of the mihrab.

1. Introduction

Madrasa al-Gawhariyya is located at the northeastern end of Al-Azhar Mosque Cairo, Egypt, fig. (1), The patron was Amir Gawhar al-Qunquba'i who occupied the position of al-Khazandar (Supervisor of the Sultanate Treasuries) during the reign of the Mamluk Sultan Al-Ashraf Sayf al-Din Barsbay. It was built in 844 AH/ 1440 AD during the Mamluk era. The madrasa was designated for teaching one of the four Sunni schools. Despite the small space available, the building was designed using the same system that predominated for madrasa-design during the Circassian Mamluk period. The ground plan consists of a small central courtyard surrounded by four iwans overlooking it, the largest of which is the qibla iwan on the southeastern side. The courtyard of the madrasa is covered by a wooden ceiling with window openings [1]. In the middle of the qibla wall, there is a mihrab covered with marble with a pointed arch covered with Ablaq marble "white/black" ornamented with sepal's floral leaves with the name of Allah at the top of the arch in golden color. The arch leans on two engaged columns supported on a base with a bell-shaped top. Moreover, the mihrab itself is a hollow semi-circular niche with a pointed arch divided into two sections: The niche "body" and the top of the mihrab "cap". The body is divided into two levels. While the first one consists of marble slabs white and black with faint red in the middle, the second level consists of white and black slabs of white and black marble only. The two levels are separated by white marble lines. The cap of the mihrab begins at the end of the second level of the body, starting with a rectangular frame decorated with a deaf arcade crowned with a tri-lobed arch that leans on two engaged columns. The field of the columns is decorated with bell-shaped floral leaves, while the inside of the cap is decorated with refracted lines in white and black colors. The two sides of the arch are outlined by two rectangular frames. The outer one is decorated with floral ornament, whereas the inner one is decorated with a repeated rectangular geometrical form that consists of a trifoliate leaf in white and black colors. The field of the sides is decorated with a circular medallion. On the sides, there is an almond shape decorated with floral ornaments [2]. The most important reason for the damage of the mihrab was the secession of some marble units due to the presence of groundwater and soluble salts. These salts can penetrate buildings easily with moisture, which can further transport them. Therefore, understanding the moisture transport processes in porous building materials is essential to prevent salt-induced damage [3]. The cyclic stages of dissolution and crystallization of salts lead to the progressive rock disintegration of most of the ancient buildings in Cairo. This process is widespread, with the astonishing decay of the architectural heritage, as claimed in the UNESCO (1980). Today, the problem is still unsolved, and cycles of groundwater rising and evaporation are destroying the lower parts of many historical buildings [4], leading eventually to serious damage or even the destruction of the decorative cladding that forms the mihrab.

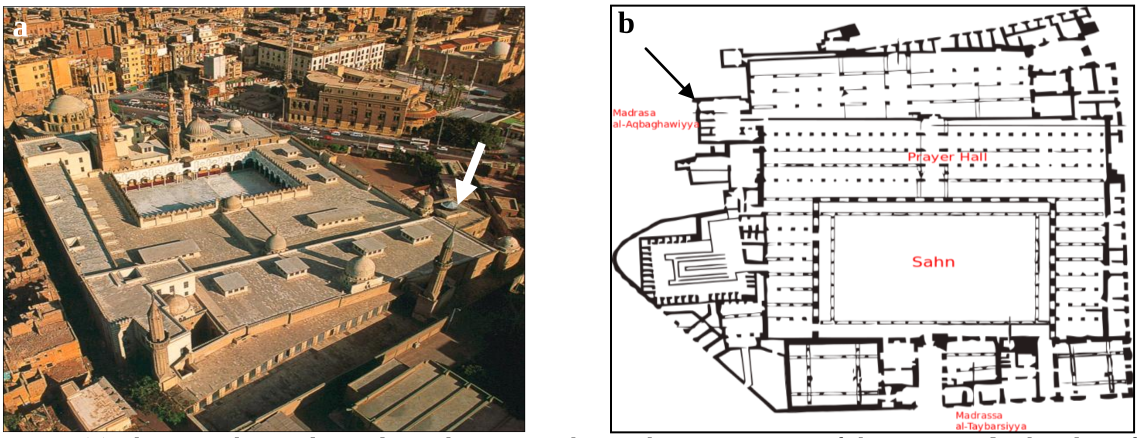


Figure (1) Shows **a.** the Madrasa al-Gawhariyya in the northeastern corner of the mosque, **b.** the plan of the Madrasa al-Gawhariyya in Al-Azhar Mosque

2. Mihrab Deterioration Aspects

The study of the deterioration aspects of the mihrab is the first step of restoration and conservation because understanding the nature of these aspects significantly determines the steps of restoration and conservation [5]. The mihrab consists mainly of decorative units made of white and black marble. It has widely been used since antiquity. An important part of our cultural heritage is built of or carved from marble. Marble is rather a hard rock that is characterized by good physical and mechanical properties, which make it suitable for construction and sculpturing. Nonetheless, it is subject to deterioration under the action of several agents in the surrounding environment [6,7]. In addition to some ceramic units, there is a wooden frame around these units. However, most of these units were degraded and deteriorated due to some factors, mainly previous restoration, high humidity, and salt weathering. On the other hand, it was found that different contaminants behave differently on bricks, stones, mortars, and wood, which react differently to the damaging action of salts and pollutants [8]. Therefore, it is important to understand the problem thoroughly regarding all the porous building materials and salt contaminants. The most important deterioration phenomena resulting from the previous restoration done wrongly for this mihrab, using materials and methods that increased damage, such as complete missing parts of marble by Portland cement, gypsum. Moreover, the ceramic units were replaced by other wooden ones. The surface of the ceramic units was painted with blue oxide colors. Concerning the mihrab wooden frame, there are missing parts and others painted by Duco, using wax to complement some marble decorations? Moreover, the surface of the marble units was consolidated using Paraloid B72 but in a very high concentration, resulting in a dark thick layer on the surface, fig. (2). The groundwater and salt weathering, which have caused the loss of some parts of the marble surface, depositing thick layers of salt, and soluble salts are considered one of the most important causes of decay. Salts cause damage by the growth of salt crystals within the pores, which can generate enough stress to overcome the tensile strength of the material and turn it into powder [9]. For instance, when the mortar turned into powder (fixing the marble units), some marble units were separated. These soluble salts are very harmful to building materials as they can exist in different states of hydration. The crystallization of these salts within the pores takes place if the saline solution is between the state of saturation and supersaturation. Salts, such as sodium chloride and calcium sulfates ($CaSO_4$ and $CaSO_4 \cdot 2H_2O$) cause serious damage to building material because the change from one hydrated phase to another is commonly associated with a volume change, which, in turn, gives rise to forces on the walls of the individual pores [10]. Salt damage, in literature also known as salt attack, salt crystallization, or salt decay, can exhibit itself by efflorescence, contour scaling, and granular disintegration (powdering or sanding). During salt crystal growth, high stress can arise even in large pores. The crystallization stress is higher in materials with small pores [11]. This weathering process, besides providing a loss of aesthetical effects, due to the surface alteration of the blocks, shows a more fundamental threat to the stability of the structure. The stone is exposed to weathering simultaneously at the surface and in its interior, with a progressive severe loss of physical coherence and mechanical properties [12]. Accordingly, we envisage the most serious risk to the conservation of the Islamic buildings in Cairo, especially their marble decorative cladding, i.e., the rising of the groundwater and salts. These factors were the main for the major deterioration of the components of the mihrab, especially the faulty previous restoration works as attested before by El-Gohary [13] in similar case.

Figure (2) Shows deterioration phenomena of the mihrab **a.** breakdown of some ceramic units as peeling of the glaze layer, **b.** replacing the ceramic units with other wooden units, **c.** flaking of the marble surface**, d**. the use of cement in fixing some marble units and surface deformation

3. Materials and Methods

AutoCAD program was used to document visible deterioration aspects. Furthermore, some samples taken from components of deterioration aspects of the mihrab were studied by a portable digital microscope Olympus USB Digital Microscope, with the following technical specification: image sensor 1.3 Megapixels, magnification factor 10~1000 times, photo capture resolution 640×480, 320×240 and LED illumination light re-source adjustable by the control wheel. It is an ideal non-destructive tool for onsite analysis. To study the deterioration aspects and surface changes in these decorations of the mihrab, X-ray diffraction analysis was carried out using Philips Analytical X-Ray Diffractometer, with the following operating conditions: Diffractometer type: PW1840, Tube anode: Cu, Generator tension (KV): 40, Generator Current (mA): 25, Wavelength Alpha1 (Å): 1.54056, Wavelength Alpha2 (Å): 1.54439, Intensity ratio (Alpha2/Alpha1): 0.500, Receiving slit: 0.2, Monochromator used: NO. It was used to identify the compounds of the samples according to David, et al. [14]. Moreover, the morphological features and chemical analysis of the samples was performed using SEM-EDX according to Palanivel and Meyvel, 2010 [15] (Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., using 14-x up to 1000000 magnification and resolution for Gun.1n).

4. Results

4.1. *AutoCAD documentation*

The documentation results using AutoCAD program showed that there are some deterioration features affected the mihrab, fig. (3).

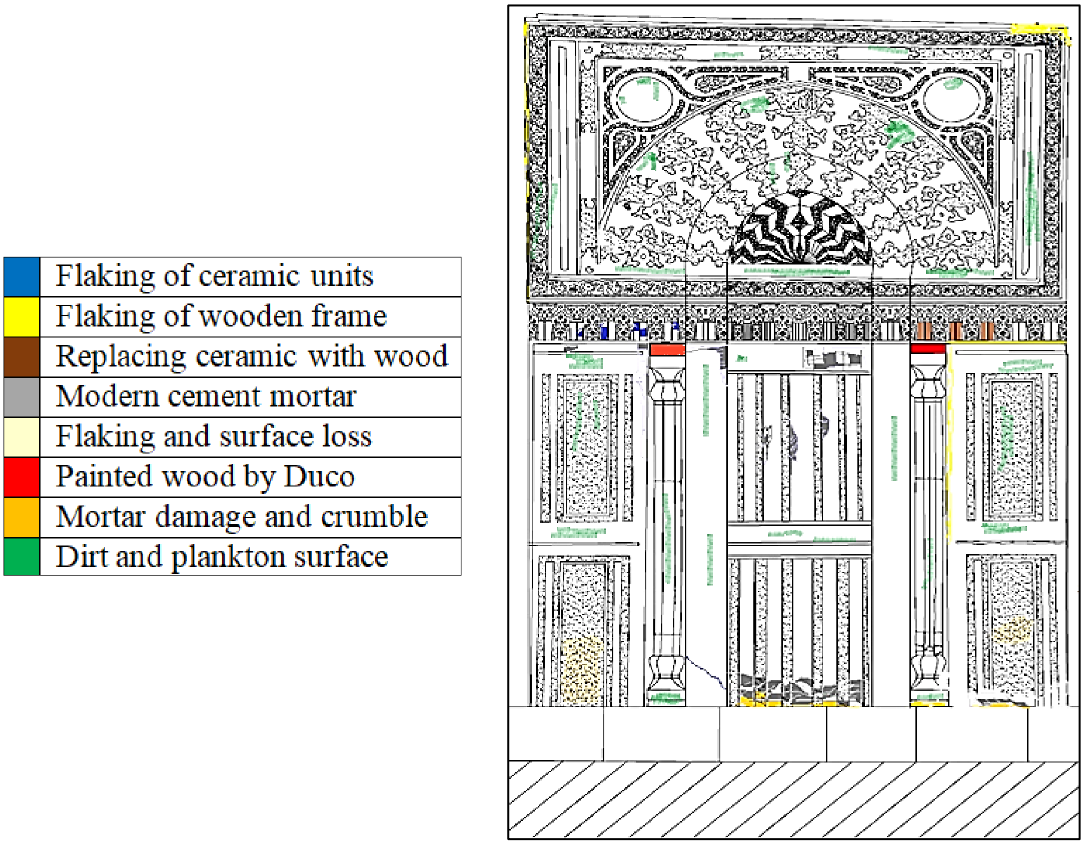


Figure (3) Shows geometric documentation of the deterioration aspects of the mihrab

4.2. *USB digital microscope results*

The microscopic examination of the deterioration aspects of the mihrab shows the following results:

4.2.1. The top parts of the mihrab

For the marble units, we found dirt and dust in the decorations of the white marble, fig. (4-a). There were also complete black and red marble units by wax, figs. (4-b), as well as micro-cracks in the marble surface, fig. (4-e). Micro-cracks, a flake of the glaze layer, fig. (4-c), and salt crystals were on the body of the ceramic, in addition to the presence of color stains, fig. (4-d).

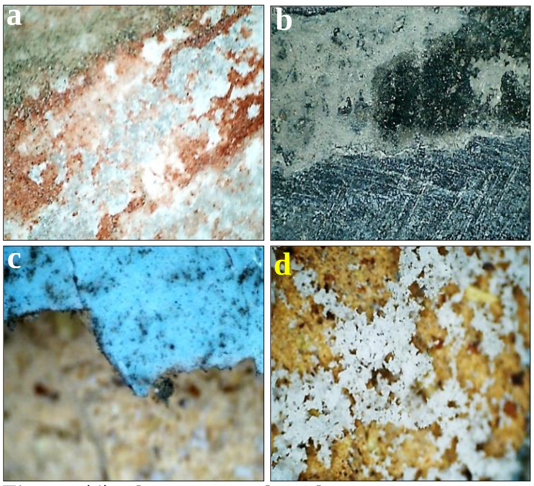


Figure (4) Shows USB digital microscope images of the top of the mihrab, **a.** dirt and dust in white and red marble units, **b**. complete the black marble by wax, **c.** micro-cracks and flake of the glaze layer of ceramic units, **d.** salts crystals and color stains on the ceramic body,

4.2.2. The lower part of the mihrab

In the lower part, the investigation reveals some deterioration forms due to previous restoration processes as; crusts at the marble surface, fig. (5-a). Dust and cracks in the white marble units, fig. (5-b). Salt layers were also found in many places both in the surface and under the surface, in addition to surface flaking, fig. (5-c). Wax stains attributed to completion of marble, fig. (5-d).

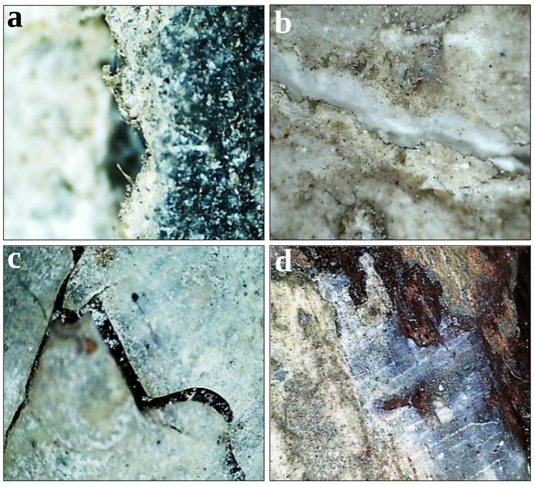
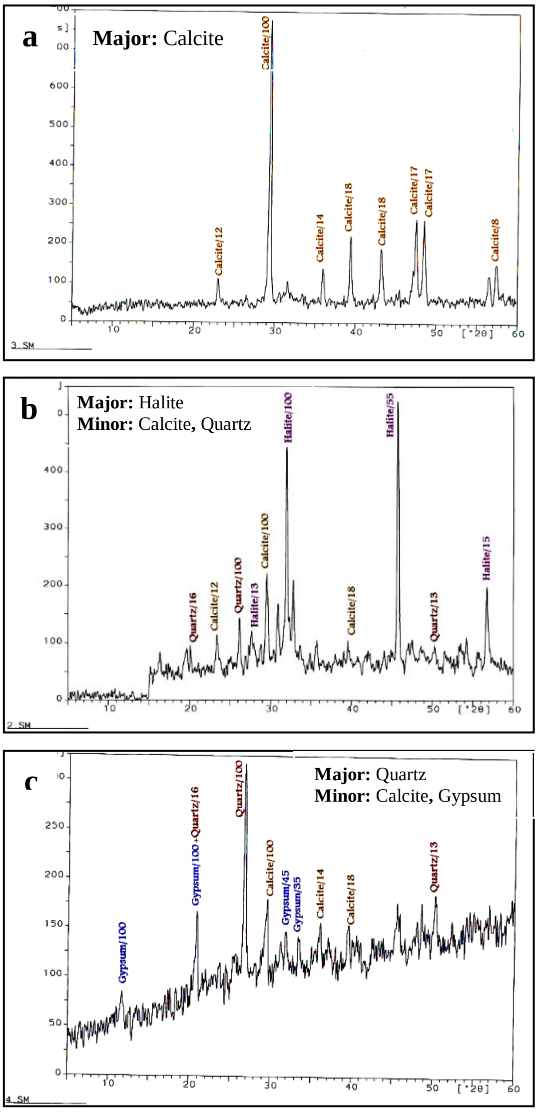


Figure (5) Shows USB digital microscope images deterioration aspects in the lower part of the mihrab, **a.** crusts at marble surface, **b.** dust and cracks in white marble units, **c.** salts under the surface layers of marble and flecking surface layer, **d**. wax used in the completion.

4.3. *X-Ray diffraction results*

XRD obtained results the samples show that the marble units consist of calcite ($CaCO_3$) only as a major component, fig. (6-a). The XRD results of the salt sample from the bottom of the right column of the mihrab show that it consists of halite (NaCl) as a major component and calcite ($CaCO_3$), quartz (SiO_2) as minor ones, fig. (6-b). Also, the XRD data of the completion mortar used in a previous restoration on the top of the left column of the mihrab shows that the sample consists of quartz (SiO_2) as a major component and calcite, gypsum ($CaSO_4.2H_2O$), fig. (6-c). The result XRD from the sample of the mortar used to complement marble reveals that the main minerals are gypsum, calcite, quartz. and halite, fig. (6-d).



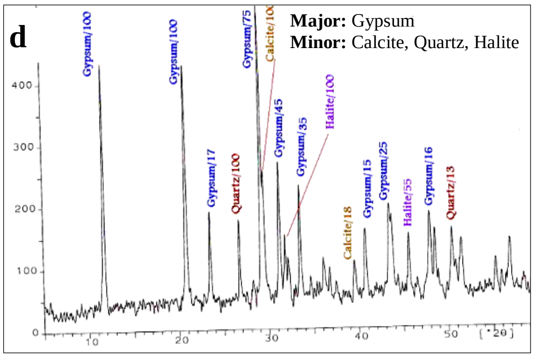
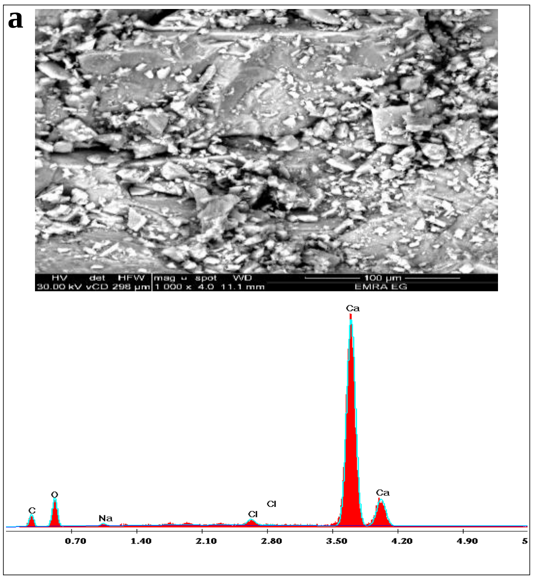
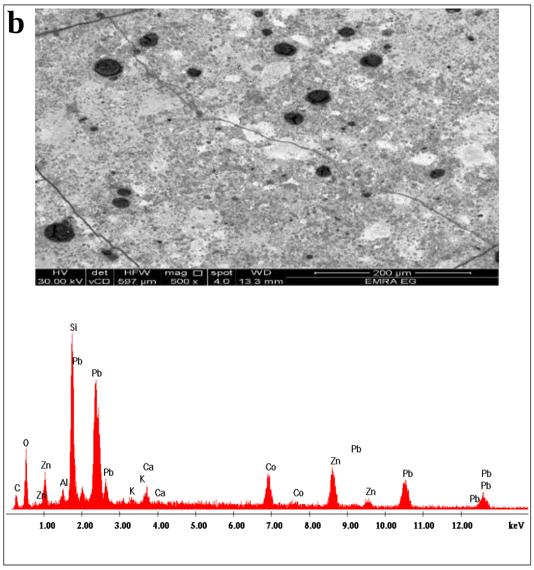


Figure (6) Shows XRD pattern, **a**. marble sample, **b**., salt sample from the bottom of the right column of the mihrab **c**. sample of the completion mortar used in a previous restoration on the top of the left column of the mihrab, **d**. sample of the mortar used to complement marble.

4.4. *SEM-EDX results*

The examination of the samples of marble and salts by SEM shows that salt crystals grew between calcite crystals. As for the result of analysis by EDX of a sample of the marble, fig. (7-a) exhibits (Ca) as the main element, while (Na, Cl) are presented in low percentages. The SEM of the glaze layer shows that micro-cracks and black points spread on the surface, indicating lead oxide. The EDX of the glaze layer, fig. (7-b) shows that (Si and pb) are the main elements, whereas (Al, K, Ca, Co, and Zn) exist but in different percentages. The SEM of the salt sample shows halite crystals. The EDX analysis of the same sample, fig. (7-c) shows (Na, Cl) as a good indication of the salt of sodium chloride.





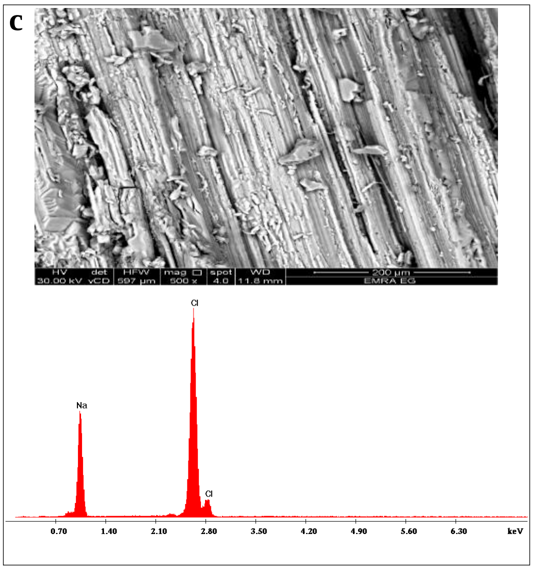


Figure (7) Shows investigated samples by (SEM-EDX), **a**. micrograph of calcite crystals and salt crystals (1000×), and EDX spectrum of marble, **b**. SEM micrograph of micro-cracks in the glaze layer, with the appearance of lead element (500×), and EDX spectrum of the same layer, **c**. SEM micrograph of sodium chloride (halite) (500×), and EDX spectrum of the sample of the salt from the mihrab

5. Discussion

After analyzing the deterioration aspects of the mihrab of Madrasa Gawhariyya- Al-Azhar Mosque using the USB portable digital microscope, the investigation revealed that the mihrab suffered from several deterioration manifestations. The photograph showed cracks, micro-cracks, and flaking in the marble units due to the salts crystallized and fluorescence on the surface. In addition, there were dirt and dust in the decorations of white marble. All the decorative units of the mihrab were deteriorated due to the previous restoration, where, incompatible methods improper materials and were used, such as Portland cement and gypsum mortar. Also, many decorations in the mihrab were deformed because of the using these mortars. In addition to many aspects of damage due to salt generated by using these materials. Regarding, XRD results obtained from the marble sample taken from the top parts of the mihrab illustrated that it is mainly composed of calcite. The mortar sample contained calcite, quartz, and a high percentage of sodium chloride salts (halite). It resulted in the degradation of the mortar. Furthermore, there was a dislocation of the marble units. Sodium chloride salt (water-soluble salt) is one of the most important causes of decay. Salts caused damage by the growth of salt crystals within the pores, which could generate stresses that are sufficient to overcome the tensile strength of the material and turn it into powder [16]. The SEM-EDX observations and analyses showed the sample contains chloride (Cl) and sodium (Na) that indicating the presence of halite (NaCl) as a salt both on surface and in depth as identified by XRD, in addition to severe surface disintegration. This might be related to the transportation of some mineralogical components by the effect of saline water [17], these components that have a chemical effect on the monuments. Their presence is significantly increasing the hygroscopicity of materials (the content of 1.02% NaCl in limestone increases hygroscopicity by 17.25%). Where, they hydrolyzed and consequently changed the pH of pure water, then, affected the rock-forming minerals leading to full decomposition. Where, the crystallized crystals formed as a result of the pressure cause the surface of the stones to break down and disintegrate [18]. In our case, the surface of the marble cladding flaked, especially in the lower parts of the mihrab. SEM micrographs of the glaze layer sample taken from surface ceramic units showed the degrading effect of the glaze, especially in outer ceramic surface. Moreover, micro-cracks appeared in the glaze layer with lead were [19]. The elemental analysis of the blue glaze layer by EDX showed that the glazing type was (lead glazing) [20] due to the lead pb percentage (36.20%), in addition to the silica Si (21.32%) as the basis for the glazing [21], and alumina Al (1.15%) as a part of the basic composition of the glazed layer. A percentage of calcium Ca (2.70%) appeared because it was used to obtain the glossiness of the glaze layer. It is considered one of the most important materials for flux at high temperatures [22]. Furthermore, the percentage of zinc Zn (3.30%) gave a bright to the glaze. As for the blue color, it is a result of the use of cobalt oxide due to the appearance of the cobalt element Co (8.01%) [23], which is one of the well-known colors used to obtain the blue color. It was used extensively in the Islamic period.

6. Conclusion

The present study focused on the main changes and deterioration of the components of the mihrab to define the best and optimum restoration ways for this project. Based on the examination and analysis results, the Mihrab mainly contains marble, ceramics, and wood. The main chemical components of the marble are calcite, while the mortar contains gypsum, calcite, sand, and salt. Moreover, the main deterioration and flaking of the marble surface were caused by the groundwater rich in sodium chloride salts, which was the main reason for crystal erosion. The previous faulty restoration using Portland cement, gypsum, and wax in completing marble units, and the replacement of ceramic units with wood also caused deterioration. The study recommends the elimination of the source of moisture and salts urgently, as well as cleaning and removing the faulty old restoration.

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