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Original article

RESTORATION AND PRESERVATION OF THE WOODEN CEILING OF AL-ASHRAF QAYTBAY MADRESSA, CAIRO – EGYPT

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Abstract
The painted ceilings of Qaitbay's madrassa is one of the Egypt's great monuments and among the oldest in the Islamic civilization, dating back to the Garkssy Mamluk period (879 AH/1474 AD). It represents an exceptional example of the quality and extent of medieval woodworking in Egypt. The wooden ceiling of Qaitbay's madrassa had been affected by an extensive deterioration due to many factors, such as loss of colors*, cracking, soot deposition, and losses of materials/units, insects' holes, and fungi growth, in addition to formation of corrosion products of its metallic parts. The main aim of the present paper is the characterization and investigation of the different components employed in the decorated ceiling of Madrassa of Qaytbay as wood units, painting ground, pigments, gilding, binding media and products of deterioration. Scanning Electron Microscope coupled with EDX analysis, Optical Light Microscope, X-ray diffraction and Infrared analysis were applied for investigation. Biological study was done. We present the results of identifying the wood species and insects of the ceiling of the Qaitbay's madrassa, which the aim of the providing information not only of the benefit to restoration but also to the historical- artistic background of the artifacts. Also this paper includes the present of its state of conservation for preservation the study will include the documentation, investigation, and analysis before the intervention process. The treatment steps were documented before, during and after the restoration. Preservation of the wood ceiling was carried out including the following: cleaning (mechanical and chemical cleaning), treatment of fungi infection, consolidation and restoration.*

Keywords: *Wooden ceiling, Pigment, Ground layer, Gilding, deterioration, restoration*

1. Introduction
1.1. *Historical and architectural background*

The Madrassa and Mosque of Sultan Qaytbay is located in the northern part of Qarafa, City of the Dead, lies in Maydan El-Rahbah that can be reached through the muiz street on Qalaat El-Kabsh, Cairo, Egypt Date of the monument: Hegira 879/AD 1474 Period/Dynasty: Mamluk Patron [1]. Qaitbay's Madrassa is a fine example of architecture during a period when decorative arts had reached their zenith. It is famous for its architecture and intricate design work. It was erected by Sultan El-Ashraf Abu El-Nasr Qaytbay who is credited to building many other monumental places in Egypt. Sultan Al Ashraf Abu El Nasr Qaytbay Al-Garkassy was born in 820AH. He was brought by a merchant called Mahmud Ibn Rustom comes to Egypt in 839AH. When he was 13 years old, so he was entitled El-Mahmudy because of the merchant. He promoted in several positions till he reached the throne to become the sultan of Egypt, El Sham (Syria), and El-Hejaz in 872 AH. /1467 AD [2]. He ruled for 29 years and some month which is one of the longest periods characterized by the construction of great huge establishments such as the Madrassa, Wekala, Sabils. He was famous for being a great builder since he left behind seventy monuments inscribed with his name. His Madrassa is considered by the archaeologists and historians, the most graceful example of the 9th century A.H. / 15th century A.D. architecture. The Madrassa is considered a good example for the classic congregational courtyard plan that date back to the Mamluk period. The ground plan of the madrassa consists of a square courtyard with a polychrome marble floor and a ceiling with a central skylight [3]. The façade of the Madrassa is designed on the Mamluk style of decoration, while the portal has a different style. The portal is gracefully ornamented by carved chevron Ablaq hood and stalactites. The Madrassa has a cruciform plan with four arched aisles and the walls are beautifully ornamented with rows of white Ablaq bands. The western aisle is dedicated for women to pray in and it is supplied with a small loggia. The floor of the Madrassa is gracefully covered with black and white marble patterns that still exist, fig (1).


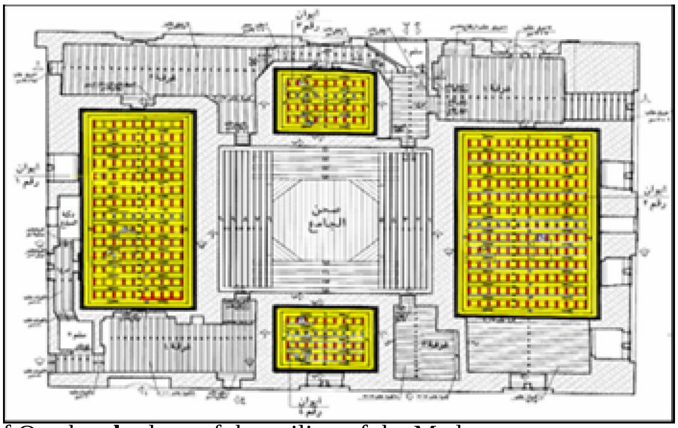

Figure (1) **a** Madrassa of Sultan al Ashraf Qaytbay **b** plane of the ceiling of the Madrassa

1.1.1.Ceiling Materials

Qaitbay's madrassa is full compliance with the surrounding geography. Wood, Gesso, pigments, and wood frame with brick filler (*hımış*) are used as the major materials in the construction of Qaitbay's madrassa. Wood is the most commonly used material in the ceiling construction. Ceiling with the various geometrical designs and construction techniques has been used in almost every part of Qaitbay's madrassa. Although, it contains some differences from the Mamluk buildings in the metal plates, plaster, glass, and traditional style used in the decoration of the ceiling.

1.1.2.Ceiling Construction Techniques

Ceiling as part of the decorations of Qaitbay's madrassa has some diversity in the context of the decoration and construction techniques. The construction and decoration techniques differ according to the wealth of the owner, talent of the craftsman and the function of the madrassa. These factors affected the ceiling type of the Qaitbay's madrassa. Wood is the intended coverage of the flat or slanted surfaces of the ceiling; different sectors of the veins with dimensions 10×10 cm to Baratim [a] sectors of 30×30 cm were used.

1.1.3.Decoration of the wooden ceiling

Wood Ceilings is one of the most important architectural elements in the Islamic architecture especially in Egypt. It was not only used for structural purposes but it was widely used to add aesthetics and creative in terms of the building and bring the soul aesthetic that has characterized Islamic art.The ceiling of Madrassa of Sultan al-Ashraf Qaytbay is a beautiful example of a composite decoration using the three primary ornamental forms of Islamic art, which include calligraphic, geometric and arabesque designs. Here, the star is prominent as it is elsewhere in Islamic art as a symbol of guidance often mentioned in the Quran. The richness of the decoration is amazing, and yet the total effect is well-proportioned and subdued [4]. The decorative motifs of wooden ceiling wear applied a (according to the Arab texts) as follows: the wood panels are covered with a layer of chalk ground, bound with animal glue [5]. The decoration are worked in a tempera technique in which the binding materials in the pigment are primarily made up animal glue to which oil has been added, the pigment are painted onto the primer after a meticulous drawing of the models has been undertaken, so that once had a clear impression of the flower and other elements, weight in the decoration as a whole after the first coat of paint had been applied. On top of this, further decorations were added, with small pieces of Gold foil for effects. The original polychromy is applied by traditional gold gilding techniques on a calcium carbonate (chalk) ground layer, following conventional techniques of the time. Several varnishes were employed, especially on the red pigments to give these a particularly intense pigment. Certain color may possible by further decorated with plant extracts. Furthermore, a final contouring is undertaken, so that blue and red lines frame, the entire decoration where it was possible decorated prior to its permanent installation [6].

2. Characterization of Deterioration and Decoration Condition

The historical building in Cairo area suffers serious deterioration aspects as a result of physico-chemical and biological effects of the deterioration factors. The decorative paintings on the ceiling of the madrassa were in a very bad condition. It is often made of a combination of organic and inorganic materials. A painting on wood is a complex structure, composed by wood support, preparation layer, painting layer and gilded, which can be described as a multilayer system fig (2). The painted ceiling had several different deterioration features:

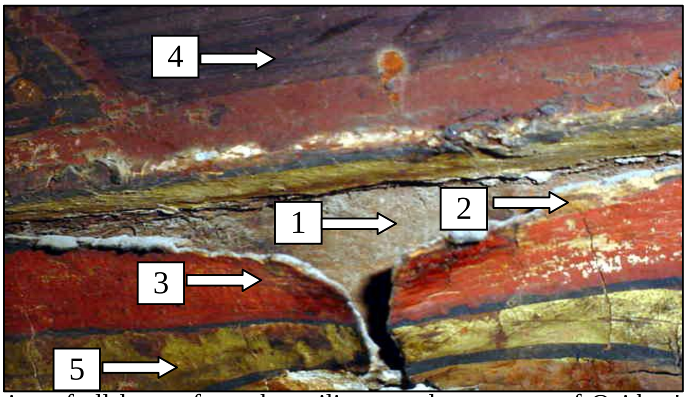

Figure (2) separation of all layers from the ceiling wooden support of Qaitbay's madrassa and shows multilayer system of the painting at the ceiling. **1** wooden support, **2** preparation layer, **3** red pigment, **4** yellow pigment, **5**blue pigment, **6**the gilded parts.

- Over time this composite deteriorates, mainly because of temperature and/or humidity changes, to which the wood is very sensitive. Different expansions and contractions experienced by different regions of the support lead to anisotropic deformations, amplified by natural aging, which can alter the mechanical properties of each layer and eventually lead to the formation of detachments and cracks, fig. (3). - Layer separation occurs at all levels in the paintings and colors falling thereby and rendering the ceiling to be too fragile. The most common alterations of the paint layers were is found in the paint layer as a result of moisture variations, it was, loss of cohesion (powdering), detachment of the paint layer (flaking), loss of paint layer, chromatic alterations (changes in appearance), natural deposits, Earth sediments and dust and Insect broods, fig. (4) - Extensive cracking of painting layer following the pattern of the damages of the support's surface were occurred, fig. (5). - The decoration were covered with numerous and different layers of dirties, stains and numerous cobweb nests, due to the accumulation of airborne deposits from different sources on the surface of the painted ceilings. This has caused the formation of dark film which obscure and deadens the original pigments, fig. (6). - Warps, twists and shape distortions were observed: These damages are caused by moisture. Wood is an organic material and moisture is its main degradation factor, leading to dimensional variations (shrinkage and swelling), fissures and warp development and changes in its mechanical [7] which led to fall the painting layer, fig. (7). Warping results from non-uniform moisture induced dimensional change. One reason for this might be because the amount of moisture getting to the piece of wood was different in different parts, for example because one side is painted or veneered and the other side is not. Another reason for non-uniform response might be that the reaction to a given amount of moisture was different in different parts [8]. - The ceiling of the madrassa of Al Al-ashraf Qaytbay had been damaged and loss of many architectural elements as a result of biological attack. Many birds lived in this building as, birds, kites, crows, pigeons. This had their nests and houses the largest impact damage in those places, as their droppings have led to damage elements, which fell out and there wastes make a good feeds for micro-organisms such as fungi and bacteria. In addition, there were animals such as mousses and rats, which have made many of the tunnels within the elements of the ceiling impact, causing damage and the collapse of many of these elements. This effect was also to serve injury and bats and their droppings, which led to damage to decorative items, and resulted in blood resulting from the process of menstruation, as well as urine to remove the layers of colors and distortion of architectural elements, fig.(8). - Crumbing in some parts of plaster were noticed. Gypsum mortar is less durable than lime mortar, as it is more soluble when exposed to water. However, at high temperatures, it dehydrates if the relative humidity is very low, that leads to crumble and decompose, fig. (9). In other cases the medium disintegrates, resulting in a loss of cohesion and powdering of the paint layer. - The microbiological infestation can be seen in varying concentrations causing discoloration often associated with detachment of the paint layer, fig. (10).Because wood is biological origin, wood is susceptible to deterioration by a variety of biotic agents. Physical, chemical and biological factors interact with wood including changes both in its compositional and structural characteristic. The intensity of bio-deterioration depends on the type of organic involved the wood species and environmental parameters (temperature and relative humidity). Warm and humid condition is extremely favorable to the growth of most organisms, thereby increasing wood's vulnerability [9]. Most deterioration problems in wood are caused by fungi, and are a direct result of excessive moisture. When wood is wetted, it is exposed to the attack of a succession of fungi. Fungal communities consist in part of pathogenic micro-organisms that cause plant diseases and wood degradation. If the wetting continues, decay will eventually begin, ultimately leading to the total destruction of the wood. Two major groups are known to be involved in wood decay, namely white rot and brown rot fungi [10]. Different chemical changes occur in wood depending on the action of the fungi. White rot fungi are effective degraders of cellulose, hemicelluloses and lignin components of wood [10]. Brown rot fungi are preferential degraders of the polysaccharide components of wood and are responsible for extensive depolymerization of cellulose early in the decay process [11]. Some fungi are called endolithic because they penetrate into the substrate causing pitting, a surface that appear to have many small holes [5]. - Insect attack and flight holes might appear also on the painting. Insect infestation of wood may result in damage to both structural components and decorative surfaces. Some insects cause damage even though their use of wood as a food source.

Figure (3) the formation of detachments and cracks of the wood ceiling due to temperature and humidity changes.

Figure (4) separation of painting layer of the ceiling.

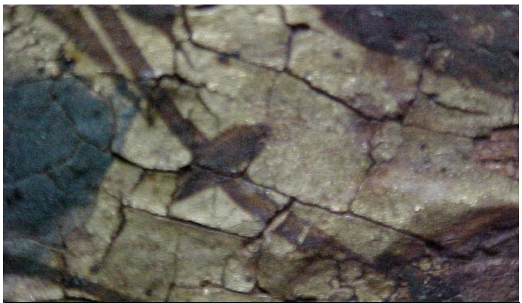

Figure (5) cracks and micro cracks at the preparation layer, paint layer, wooden support and falling of pigments.

Figure (6) the painting covered with numerous layers of dirties, stains, insects remains and numerous cobweb nests.

Figure (7) the warps, twists and shape distortions of the ceiling.

Figure (8) loss of some architectural elements as a result of biological attack at the ceiling **a** bat droppings **b** extracts of birds **c** Bees nests

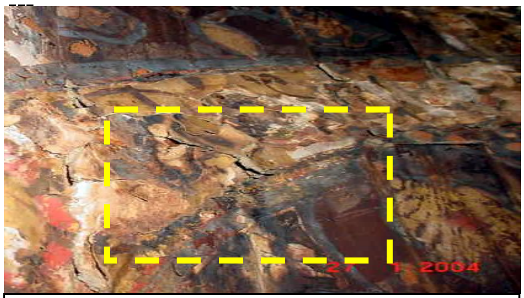

Figure (9) crumbing in some parts of plaster.

Figure (10) microbiological infestation causing discoloration often associated with detachment of the paint layer.

3. Materials and Methods

The scientific examination was intended to elucidate the nature of the original and added materials as well as to establish the state of conservation of the paintings. Due to the destructive nature of sampling, samples were carefully chosen during preservation work from areas that had no aesthetic or iconographic value for reconstruction and from areas which suffer from deterioration. Wood samples, pigment, plaster and gilding samples were taken from some fragments of painting that had previously fallen. Samples revealed their different levels of decay (state of conservation).The salts, plasters, gilding and pigments have been studied using different methods as follows.

3.1. *SEM examination*

The samples were examined as natural form in JEOL 6400 SEM attached with EDX unit combined system energy dispersive spectrometer. After the samples coated in a nanometer degree were attached in the holder of SEM, they were placed into the vacuum chamber to photograph and elemental analysis (EDXS). SEM micrographs were taken between magnifications 250_X up to 3000_X. EDXS microanalysis was conducted to obtain information on the elemental composition of the samples. The analysis was carried out under low vacuum conditions. In this way, it was possible to avoid coating the samples with a thin film (gold).

3.2. *X-Ray diffraction (XRD)*

The samples analyzed with X-ray diffractometry using X-ray diffraction analyses performed by PW1840 diffractometer, using Cu Kα radiation (40 kV, 40 mA), rotating sample holder and proportional detector. Measurements were carried out in the range 4.025: 69.957 with a step of 0.050. The ICDD data bank of standard X-ray powder spectra was used for phase identification.

3.3. *Fournier transforms Infrared spectroscopy (FTIR) analysis*

Binding medium has been studied by Fourier transform infrared spectroscopy (FTIR).The samples were analyzed as KBr pellets by JASCO FT\IR–460 plus. Powdered samples pressed into potassium bromide (KBr) pellets and the powder mixture was then crushed in a mechanical die press to form a translucent pellet. KBr pellets of powdered samples were examined between 4000 and 400 cm^{-1} at a resolution of 4 cm^{-1}. Spectra were acquired between 1000-4000 cm^{-1}.

3.4. *Micro-biological examination of the ceiling*

The changes in wood resulting from fungal decay were investigated. Samples of the predominant alterations were taken from the original paint layer and wooden decoration. These included; 1) Sample of the wood lining -far right- the qibla iwan [(b),] 2) Sample of wood Barthom No. 5 -Ewan kiss-right hand, 3) Sample of the wood lining -far right- the qibla iwan. A sterile scalpel was used to sample thicker alterations. Care was always taken to remove as little of the valuable wood substratum as possible. Swabs taken from pieces of painted wood by a piece of sterile absorbent wet cotton and a little sterile water and then scan the part to be selected and put a piece of cotton in the test tube containing about 20 mm of sterile water. After that, payment of the test tube with cotton and wrapped aluminum foil to ensure no contamination. During the sampling procedures the daytime and nighttime average temperature was 28/19ºC in April, these samples were placed in sterile bags and transported to the laboratory, where they underwent certain microbiological tests.

3.4.1. Media used:

Four agar media were used for the purpose of isolation and growth under aerobic condition. All of them were prepared according to manual of microbiological methods 1957 [12]. *Czapek's agar medium***,** sucrose 30g. Sodium nitrate $NaNO_3$, 2g. Potassium phosphate dibasic KH_2 PO_4 1g. Magnesium sulfate MgSO4. $7H_2O$, 0.5g. Potassium chloride KCL, 0.5g. Iron sulfate FeSO4. $7H_2O$, 0.01g. Agar 15g., Tap water 1000 million, PH 5.5–6. Cultural and Waxman *Waksman's medium* Glucose 10g. Peptone 5g. Magnesium sulphide 5g. Agar 15g. Distilled water, 1000 million, pH 5.5. *Culture Martin's medium*, which consists of 10g. Glucose, Peptone 5g. Potassium phosphate dibasic 1g. Magnesium sulfate 0.5g.. Astervtomaysan sulfate 3g. Agar 20g, PH 5.5–6. The most common microbial colonies were selected and transferred into agar slant; the colonies were purified and examined microscopically. The development and transformation of the wood in these decayed samples was followed by scanning electron microscopy (SEM–EDX).

3.5. *Wood identification*

Wood identification was carried out. Wood sample was embedded in poly ethylene glycol (PEG) and cut with rotative microtome. Thin section (15-20m) was obtained in the three principal anatomical directions (transverse, tangential and radial). The histological section was observed by optical microscope in transmitted light (Olympus BX40) with digital camera under 40-60X magnification.

4. Results and Discussion

4.1. *XRD study*

Wood samples: the wood sample contains some percentage of crystalline cellulose and show the presence of gypsum and calcite from preparation layer. In addition, halite was found as presence is due to salty water whish was absorbed. The result confirmed Graphite (Ca) from black pigment, tab. (1) & fig. (11-a).. ***Plaster Samples:*** XRD analysis in fig. (11-b) shows that the ground layers underneath the paint layers contain mainly gypsum mixed with calcite, in addition to quartz. Small proportion of the "gypsum" was found to be Anhydrite ($CaSO_4$); this may have been due to dehydration caused by the relatively low humidity and high temperatures in the madrassa. Therefore there is a possibility of the dehydration-hydration reaction playing a critical parts in the deterioration mechanism of the painting ground and the pigments itself of the decorated surfaces. Within the same context, the presence of Halite as trace minerals results from a chemical reaction between calcite and different contamination. ***Mortar samples*:** The results of XRD confirmed that, the mortar samples contain gypsum $CaSO_4.2H_2O$ (the main component of mortar) and calcite $CaCO_3$ which is mixed with gypsum and traces of quartz SiO_2 as fillers added to the mortar. Halite NaCl whose presence is due to materials used in the ground layer or salty water which leaked through the ceiling and the wall, fig. (11-c).

Table (1) Show X-ray diffraction (XRD) results of Qaitbay's madrassa ceiling

Kind of sample	***Compounds***
Wood sample.	Cellulose $C_6H_{10}O_5)n$, Gypsum $CaSO_4$ $.2H_2O$ Calcite $CaCo_3$ Halite NaCl and Graphite C
Plaster ceiling layer	Gypsum $CaSO_4$ $.2H_2O$, Calcite $CaCO_3$ and Quartz SiO_2
Plaster ceiling layer	Gypsum $CaSO_4$ $.2H_2O$, Calcite $CaCO_3$, Quartz SiO_2 and Halite NaCl
Layer mortar internal wooden beams	Gypsum $CaSO_4$ $.2H_2O$ and Calcite $CaCO_3$
Layer mortar internal wooden beams & ceiling	Gypsum $CaSO_4$ $.2H_2O$, Calcite $CaCO_3$ and Halite NaCl
Plaster ceiling layer with wooden ezar	Gypsum $CaSO_4$ $.2H_2O$, Calcite $CaCO_3$ and Halite NaCl
white pigment	Gypsum $CaSO_4$ $.2H_2O$ and Calcite $CaCO_3$
Red pigment	Gypsum $CaSO_4$ $.2H_2O$, Calcite $CaCO_3$ and Hematite Fe_2O_3
Red color with layer preparation	Gypsum $CaSO_4$ $.2H_2O$, Hematite Fe_2O_3 and Quartz SiO_2
Blue pigment	Gypsum $CaSO_4$ $.2H_2O$ and Ferric-Ferro cyanide Fe_4 $[Fe\ (Cn)_6]_3$
Brawn dark pigment	Gypsum $CaSO_4$ $.2H_2O$ and Hematite Fe_2O_3
Black color	Gypsum $CaSO_4$ $.2H_2O$ and Graphite C
Gilded layer	Gypsum $CaSO_4$ $.2H_2O$ and Hematite Fe_2O_3
Plaster ceiling layer with golden color	Gypsum $CaSO_4$ $.2H_2O$ and Hematite Fe_2O_3

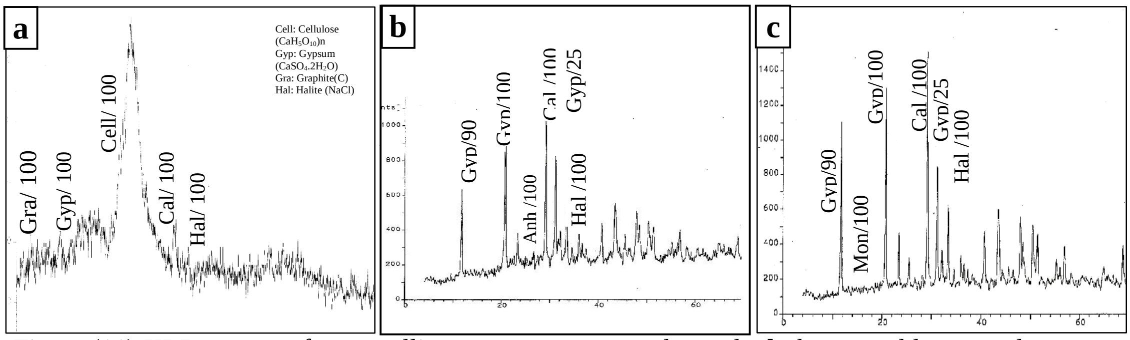

Figure (11) XRD pattern of **a** crystalline component at wood sample, **b** the ground layers and **c** mortar samples of Qaitbay's madrassa ceiling

The paint layers: *White pigment and deteriorated preparation layer:* is produced by mixing Gypsum and small amount of chalk $CaCO_3$, fig. (12-a). *Red pigment:* the result of XRD indicated that the red pigment consists of Gypsum as a main component, calcite and Hematite Fe_2O_3 and traces of quartz and halite, representing the accompanied), fig. (12-b). *Blue pigment:* XRD analysis proved that the main component is Gypsum, calcite and traces of ferric-ferro cyanide Fe_4 $[Fe\ (Cn)\ _6]_3$, that means the blue pigment is Prussian blue. According to Getten and Stout (1966) [13]. Prussian blue was used to obtain blue color, fig. (12-c). *Dark Brown pigment:* XRD analysis revealed traces of red lead Pb_3O_4, fig. (12-d). *Black pigment:* XRD analysis proved that the black sample consists of Graphite, fig. (12-e). ***The gilded layers:*** The examination of the gilded layer in the ceiling of Qaitbay's madrassa by XRD revealed a big quantity of Gypsum and Calcite as a main components of the preparation layer, traces of Hematite, fig. (12-f).

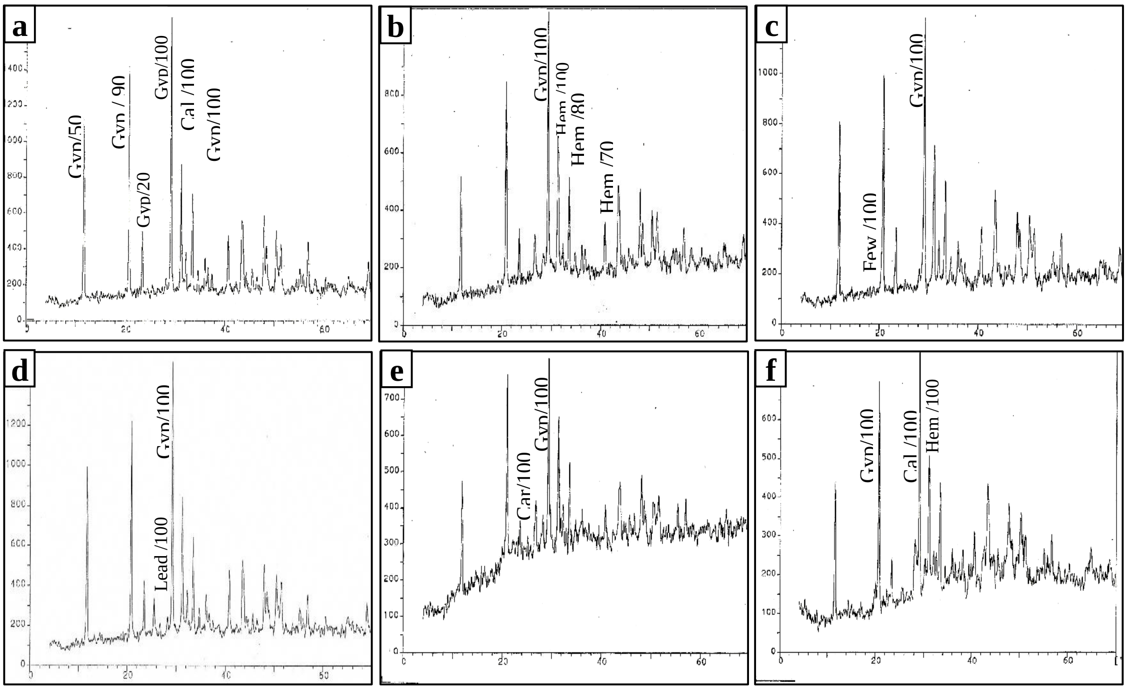

Figure (11) XRD pattern of the paint layers of Qaitbay's madrassa ceiling **a** white pigment **b** red pigment **c** blue pigment **d** brown pigment **e** black pigment **f** gilded layer.

4.2. *Fournier transforms inferred spectroscopy (FTIR)*

The aim of this study is to identify organic binders in used as an intermediary, such as fatty substances or protein or carbohydrate by FTIR reflectance spectroscopy. The identification of organic materials is important for the characterization of the painting technique and to provide evidence for dating or attribution of the work of art. Furthermore, the characterization of both original and added materials is essential for providing criteria for the development of preservation and maintenance interventions [14]. Samples from the red pigment and gilded layer were analyzed to identify the binders used with these pigments. The results were compared with standard samples of both animal glue and Arabic gum. Results showed that the tested samples have a high proportion of animal glue, fig. (13-a,b).

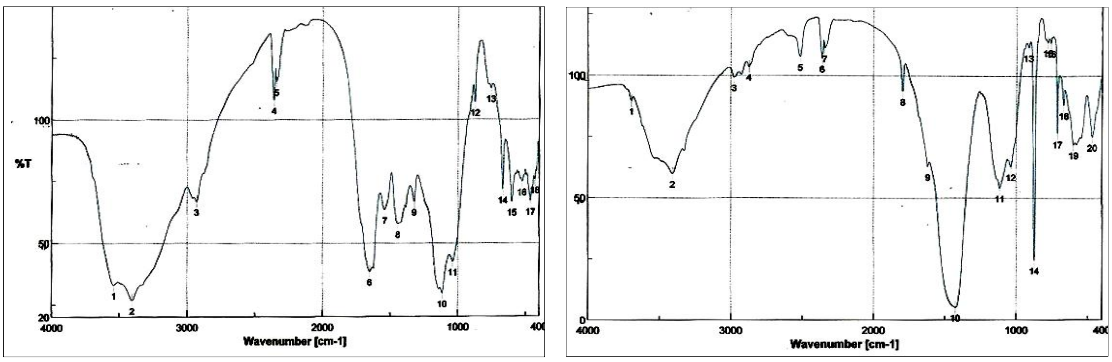

Figure (13) FTIR spectra showing, **a** FTIR sample of red pigment (animal glue) **b** FTIR sample of gilded layer (animal glue

4.3. *Chemical analysis for binding medium*

To determine the FTIR result, the Nitrogen test had been carried out. The paint sample was dissolved in mixture of calcium oxide (CaO) and manganese dioxide (MnO_2) with Concentration 10%. The mixture with sample was heated and the flame detector using paper, PH-Indicator paper was used, it was noted that the indicator paper turns to blue, that reveals to the presence of Nitrogen. To determine the organic matter in the sample, the glue test had been carried out; the sample was heated in test tube, a piece of cotton moistened with a solution of a substance with (Diethyl Amino Benz aldehyde) in Acetic acid (CH_3CO_2H), (as revealing yellow color) on the tube nozzle. It was observed turning a piece of cotton to brown, which confirms the presence of protein sample and thus of using glue as a binder.

4.4. *Biological and microbiological study of the Qaitbay's madrassa ceiling*

4.4.1. Insects' identification

The macroscopic analysis of the wooden samples was aimed at identifying adult insects. Close attention was paid to the wooden structures of the ceiling. Microscopic examination of the remnants and direct observation reveals six types of insects. Direct observation revealed numerous tunnels and boreholes due to insects *Anobiidae*. As regards the ceiling panels the biodeterioration by insect beetle furniture *Anobium Punctatum* they showed many *wooden worms* (*Anobiidae*) bore holes and piles of bore dust, brown dark has been detected and there remains of this insect in the cracks, gaps and wide open spaces and wood Baratim. The spider is an insect's pest spread to all the abandoned buildings and places. They secrete a fatty substance and lead to adhesion of dust at the architectural elements. Observation and sampling were carried out in the ceiling revealed *Lactidae* as well as insect beetle furniture. The insect *silver fish (family: Thermobia Aeguptiaca)* were found in the ceiling. It is an small insect or medium sized rectangular brown, gray or white color, live clearly in the wooden Isar of the ceilings, as well as the insects feed primarily on substances carbohydrate leading to damage represented in forms of erosion. In addition to the insect, Spider nests covered most of the stone walls and wooden ceilings. As a result of the existence of pools of water has been noted that there are many insects, *cockroaches*, *beetles* and *norepinephrine*. It leads to distorting the colored or patterned surfaces.

4.4.2. Identification of microorganisms:

Identification of fungi was carried out on the basis of the macroscopic features of colonies, the morphological and structural characteristics according to (Domsch, 1980, Pinar, G. and Lubitz, W., 2002) [10]. A light microscope with a magnification of 40× was used for preliminary identification of the moulds to generic level [5]. Several species of fungi have been isolated from weathered decorated wood by morphological methods and nutritional physiology and identified. They are *Aspergillus niger*, *Trichoderma album*, Penicillium *chermesimum*, Trichoderma *glucum*, Aspergillus *flavus*, alternaria *alternate*, Aspergillus *glaucus*, Trichoderma *koningi* and *Fusarium nivale*, fig. (14).

Figure (14) the identified fungi from Qaitbay's madrassa ceiling and inhabitation zone.

Most deterioration problems in painting and painted wood are caused by fungi, and are a direct result of excessive moisture. When wood is wetted, it is exposed to the attack of a succession of fungi. If the wetting continues, decay will eventually begin, ultimately leading to the total destruction of the wood [10]. These fungi are not only responsible for color change and deformation of colored spots and dark crusts on the surfaces (yellowish or blue- green patches, but also they are highly destructive to the wood and the painting [15]. Different chemical changes occur in wood depending on the action of the fungi, two major groups are known to be involved in wood decay, namely white rot and brown rot fungi. White rot fungi are effective degraders of cellulose, hemicelluloses and lignin components of wood [16]. Brown rot fungi are preferential degraders of the polysaccharide components of wood and are responsible for extensive depolymerization of cellulose early in the decay process [17] [18]. Fungal decay is also a problem with works of art and cultural and archaeological artifacts made of wood. It is a wide variety of examples of the deterioration found in archaeological wood from Qaitbay's madrassa ceiling. According to Jennings and Bravery [19], brown rot fungi commonly cause decay of timber in buildings and have been shown to have a serious impact on ancient and historic buildings. Knowledge of the type of deterioration and the chemical changes that occur in wood during degradation is critical to preserving our wooden cultural heritage. Microbial growth interacts with environmental factors in the degradation of wood. In terrestrial environments, temperature and relative humidity regulate microbial growth and deterioration. Sulfur dioxide in air pollution reacts on wood to form gypsum, which can accumulate on the wood surface as well as inside the wood. During formation, the gypsum traps hydrocarbons generated in the urban environment from burning fossil fuels, which then serve as a substrate for microbial growth [20].

4.5. *Scanning electron microscope study (SEM-EDEX)*

SEM–EDEX analysis was undertaken in order to make preliminary observations of the decay and the fungal patterns of attack. Examination of the wood surface by SEM shows that there are deterioration forms affected the wood (weakness in the bonding materials between the fibers), and fungi infection, fig. (15-a). Cellulose fibrils originating from mechanical disruption of the wood cells surface by the fungal attack were observed in the inner part of a timber that was apparently barely damaged. Due to the fungal attack, degraded pit membranes were observed in the inner part and network of fungal hyphae channels inside a wood sample covered with calcium crystallization was observed in fig. (15-b, c). In addition, crystallized dehydrate calcium sulfate was found inside. Moreover, bored vessels and fibers surrounded by crystals were also found, fig. (15-d). SEM–EDEX microanalysis revealed the presence of environmental particles such as spherical particles emitted by wind action. The EDX spectrum, tab. (2) fig. (16). shows the presence of aluminum silicates and potassium oxide (K_2O) from dust and the presences of SO_3 and CaO essentially owed to calcium carbonate with traces of gypsum as a plaster, the presence of Fe_2O_3 are essentially owed to painted layer. In addition, the occurrence of NaCl indicative of the existence of Halite was found. Finally presence of $TiO_2$is sign of the organic rest. The results obtained by X-ray diffraction (XRD) declared that.

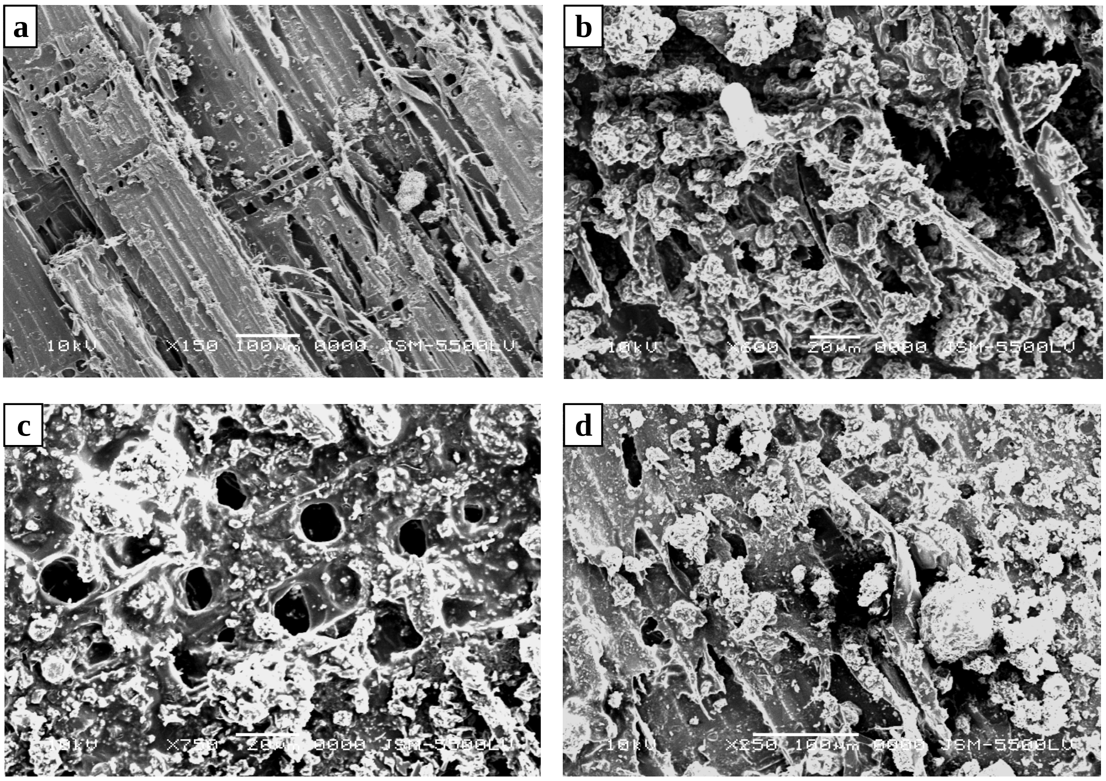

Figure (15) SEM images of the wood samples tested, shows **a** weakness and growing of microorganism on the wood surface. **b** Cellulose fibrils originating from mechanical disruption of the wood cells surface by the fungal attack, **c** degraded pit membranes were observed in the inner part, **d** crystallized dehydrate calcium sulfate was found inside

Table 2 EDX analysis of the wood sample.

Results	*Elements*								
	Na_2O	Al_2O_3	SiO_2	SO_3	Cl^-	K_2O	CaO	TiO_2	Fe_2O_3
Wt %	2.8418	1.0365	2.7424	46.428	0.6307	0.8469	43.392	0.4659	1.6155
Mol %	3.0607	0.6786	3.0467	38.711	1.1876	0.6001	---------	0.3892	0.6753

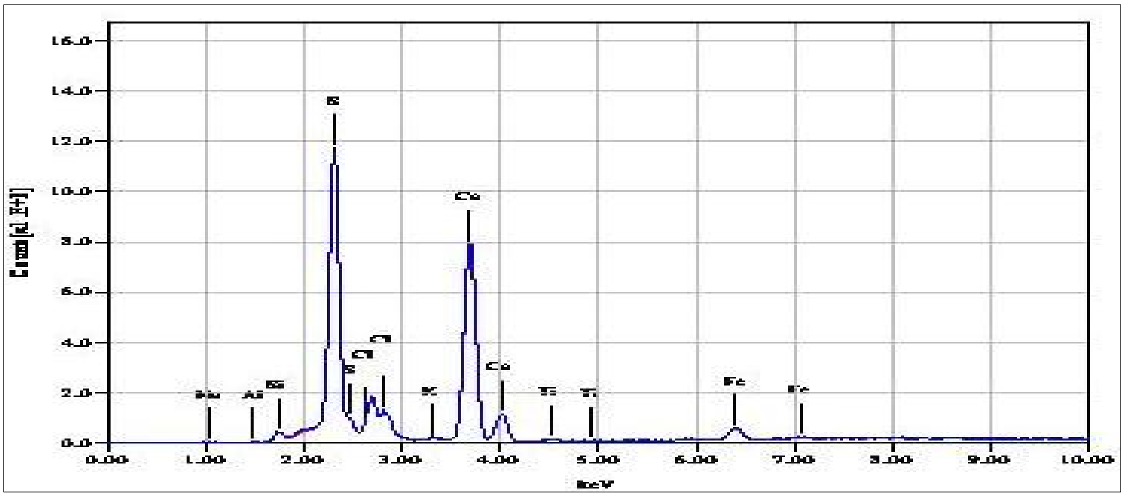

Figure (16) EDX patterns of analysis of the wood sample.

4.6. *Wood identification*

Anatomical analysis of the wood sample identified the wood as pine wood (*Pinus halepensis*). It was defined that from resinaceous aperture which characteristic the halepensis pine, fig (17).

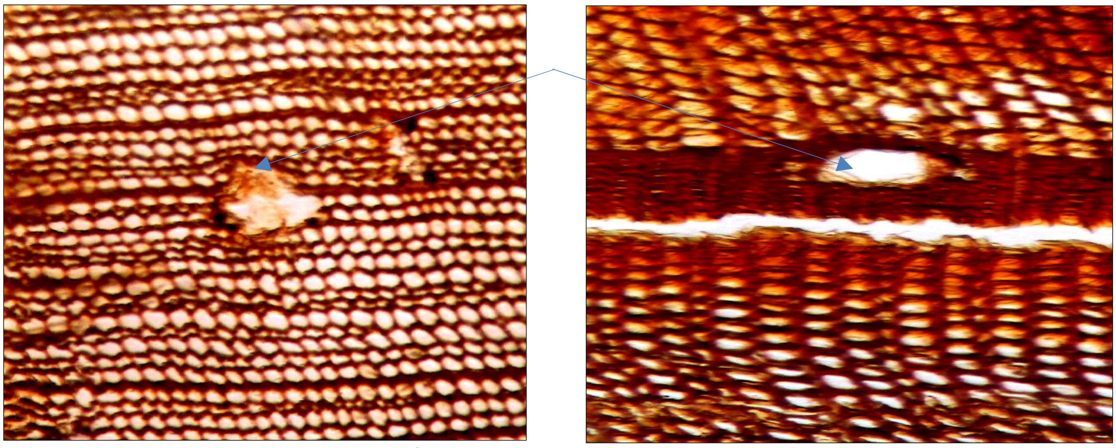

Figure 17 (a, b) transversal section of wood sample, shows resinaceous aperture which characteristic the halepensis pine.

4.7. *Measuring of the moisture content in wood*

Wood is a hygroscopic material. Its moisture content (MC) at equilibrium (EMC – Equilibrium Moisture Content) is a function of the relative humidity (RH) and temperature (T) of surrounding air. Whenever the hygrothermal conditions of the environment change, the wood tends to reach a new EMC, adsorbing or desorbing water. Shrinkage and swelling always accompany the variation of MC and they are probably the main source of problems for the preservation of wooden artifacts because they can cause deformations, internal stresses, cracks of the wooden support and degenerative phenomena of the painted layers such as delamination [21].Wood moisture content is expressed in terms of the weight of water as a percentage of the oven dried weight of the wood. According to Archimedes principle the samples were then oven dried at 105^{o}C for 2 hours and allowed to cool in desiccators to avoid absorbing moisture, the results of these experiments are listed in tab. (4). From the previous results, we could discover that the continent of moisture of the wood of the ceiling is 15.22 %, where it is 11.55 % in the standard samples of the same kind of the new wood, which means that the loss of normal moisture of wood of the roof comparing to the moisture content of the same kind of new wood is:15.22 – 11.55 = 3.67 %, we could also realize that the content of moisture the wood of the ceiling is 16.8 %, where it is 11.55 % in the standard samples of the same kind of the new wood, which means that the loss of normal moisture of the ceiling comparing to the moisture content of the same kind of the new wood is:16.80 – 11.55 = 5.35 %. From the previous results, we could discover that the continent of moisture of the wood of the ceiling is 15.22 %, where it is 11.55 % in the standard samples of the same kind of the new wood, which means that the loss of normal moisture of wood of the roof comparing to the moisture content of the same kind of new wood is:15.22 – 11.55 = 3.67 %, we could also realize that the content of moisture the wood of the ceiling is 16.8 %, where it is 11.55 % in the standard samples of the same kind of the new wood, which means that the loss of normal moisture of the ceiling comparing to the moisture content of the same kind of the new wood is:16.80 – 11.55 = 5.35 %.

Table 3 show the results of the measuring of the moisture content in wooden samples

Tests	*Samples A (Stander)*	*Sample B*	*Sample C*
Weight before	124.69	119.60	124.3
Weight after	110.28	101.39	103.4
The diversity /gm	14.41	18.21	20.9
Percentage %	11.55	15.22	16.8

5. Applied Work (Treatment)

Preservation and restoration are necessary interventions to conserve and enhance the values of a cultural object and recover lapsed functions through the process. When defining a methodology for the intervention, one must "evaluate the alterations present" determining whether they consist of a simple patina or true disfigurations or destruction. This diagnosis must be based both on an objective knowledge of the evolution of the materials and upon an idea we form about their original appearance, which in turn rests upon experience of works of art in their material and aesthetic reality [27].The Qaitbay's madrassa ceiling were restored before in 1983.The treatments were programmed as follows:

5.1. *Photographic survey of the ceiling to treatment*

We started with documentation, architectural and photographic of the studied painted ceiling before any kind of intervention. The fine restoration hasn't started yet until the architectural restoration has completely done to the wall of the madrassa.

5.2. *Listing of samples taken for analyses*

The second phase of the project consisted of analysis and direct observation of the ceiling, to determine its outstanding features, current state of conservation and indications of alterations.

5.3. *Treatment, restoration and consolidation of the Qaitbay's madrassa ceiling*

5.3.1. Cleaning

The ceiling was very dirty, with an accumulation of dust, soil and soot, especially at Qibla iwan. All the painted wood had an average degree of dehydration, which has caused fissures at the joints. The polychrome and gilding are basically in a bad state of conservation. The polychrome was the most deteriorated, due to sudden changes in humidity, condensation and temperature. This caused a separation of the paint layers, gaps, flaking, blistering, cracking and abrasion. There were also gaps varying in size along the entire surface of the ceiling.

Mechanical cleaning: The accumulation of dust on the surfaces of the ceiling is inevitable. To decrease this as much as possible, we used vacuum cleaners in the areas next to the decorative elements, but not on them, from corners and cavernous spaces between the sides of the wooden frame and the surface of a ceiling. To remove particles of dust and insect eggs we used a broad soft brush. The drops of wax and solid accumulations were prominent on the surface of the ceiling. It was removed by scalpels and appropriate sizes of spatula layers after layer to another. In some cases we used a warm spatula and absorbent paper to remove the wax residue stuck to the surface. To remove the old restoration represented in layer of cement used at the bottom of the black pieces of wood using scalpels and engraving tools with extreme care. **Chemical cleaning:** This work also involved the removal of tarnished varnish, also deep cleaning of exposed wood, principally where fungus infestation and rotted wood could be detected with the application of solvents. Several chemical solvents were applied for cleaning. The trichloroethylene and Xzylene gave good results in removing the wax and deteriorated varnishes. Also a mixture of Acetone, methanol and Ammonia solution gave a good result on excretes of accumulation of residue of insects and birds. Di-methyl formamide was used also to remove the black color at the wood and painting which was produced from pervious fault restoration, fig. 18 (a, b) .

Figure (18) the chemical cleaning of the painted ceiling.

5.3.2. Sterilization

Sterilization of the archaeological ceiling was carried out using Cideal L- 50 concentration of 3%, which was effect with the old wood. In addition we use pesticide dissolved in kerosene and pentachlorophenol by 5% in Elimination of insect infestation.

5.3.3. Fixation of the crust of paint layer;

The pigment and the painting layers lost its adhesion to the support in many places of the ceiling (micro cracks, flaking, crumbing were observed). Primary fixation of separated paint layer flakes was done by using emulsion of 10% Primal AC33, 1.5 Paraloid B.72 in trichloroethylene for the end fixation and it is installed by pressing peels gently with small piece of cotton. Warm spatula was used, fig. 19 (a, b). Thermal spatula was used in installation of paint layer crust that is difficult to address directly to the fragility of the cohesion and in case of the worst parts is plastic paper insulation and spatula are passed to the individual and the softening process and installation and without exposing skins and colored peels direct heat . For the installation and the strengthening of the pigment, which turned into a powder as a result of deterioration factors, Paraloid-B 72 concentration of 3% in acetone was used with aerosol spray-style plastic. This process was repeated several times until the paint surface was consolidated.

Figure (19) the fixation and consolidation of the paint layer.

5.3.4. Filling cracks and gaps:

The cracks and fissures in the painted ceiling were carefully filled with flax tape, after that it was filled with mixture of solution of Qalaphonia and wax with ratio 1: 1 dissolved in ethylene chloride. To fill the gaps, rabbit glue with sawdust of the same type of wood had been used.

5.3.5. Completion of the missing parts:

Complete understanding of a work of art is only possible when we understand all its tangible and intangible attributes [21]. In the areas were the missing part were bigger, it was filled with a small layer of Carboxymethylcellouse (CMC) and sawdust, suitable pieces of the same wood were then placed in the gap and covered with Qalaphonia and wax with ratio 1: 1 dissolved in ethylene chloride until the outer surface reached the expected level, fig. 20 (a, b,c, d).

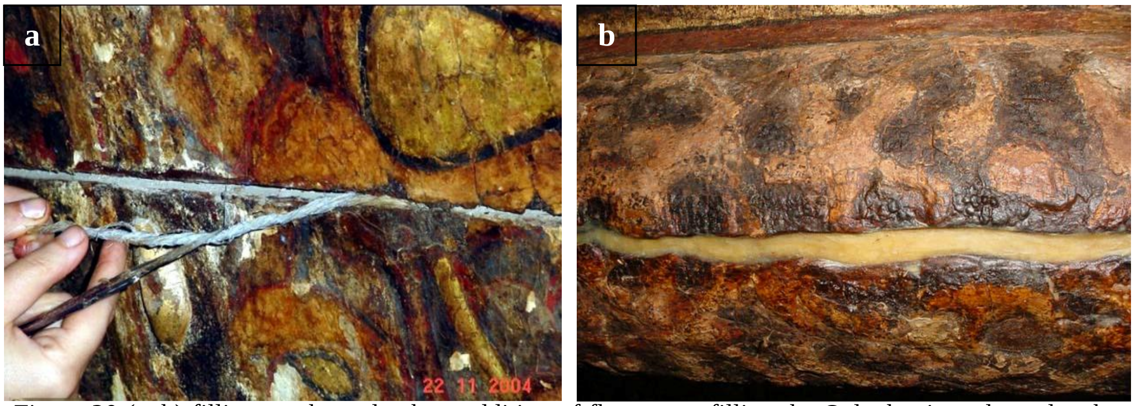

Figure 20 (a, b) filling cracks and gabs a addition of flax tape c filling the Qalaphonia and sawdust by wooden stick b the cracks after filling f the gaps and cracks after completion.

5.3.6. Color & the frills retouching

After the completion of filling cracks and voids, the surface were smoothed by using different sizes of soft sandpaper to remove all products from the surface and prepared for the work necessary frills color. At this stage used natural hair soft graduated sizes. In addition some oxides of color to give the mixture used the color of painting and wood, fig.. (21).

Figure (20) the painted ceiling of the Qaytbay madrassa after restoration.

6. Conclusion

The comprehensive study of the ceiling and its contents identified a number of significant problems affecting the Qaitbay's madrassa ceiling. Cracks and structural damage to the madrassa ceiling encompassed other problems and deteriorations that could be traced back to the filtration of rain water. This was reflected in marked water absorption by the wood of the ceiling in the Qaitbay's madrassa, also due to a significant alteration of the microclimate surrounding the madrassa.The anatomical features of the wood taken from different parts of the ceiling proved that the ceiling had been made from halepensis pine. The microbial examination confirmed that both brown and soft rot were encounted in the ceiling. SEM observation indicated that the decay was caused by fungi. Insects and salts as sodium chloride. Suitable materials and methods were used in preservation and restoration of the ceiling as cleaning (mechanical and chemical), Sterilization with Cedial 50, Fixation of *the crust of paint layer by Primal AC33 and warm spatula, Filling cracks and gaps with mixture of solution of Qalaphonia and wax with ratio 1: 1 dissolved in ethylene chloride. To fill the gaps, rabbit glue with sawdust of the same type of wood had been used, Paraloid B72 was used in consolidation of the paint layer and completion of the missing parts and color & the frills retouching were done.*

Endnotes

(a) **Wooden beams (Baratim)** Wooden blocks extending between the sides of the building have several labels such as squares and Almarbu'at, they are called "tide". The Baratim settle on the stone walls, while the rest of the walls are built above the Baratim. Thus appear as if buried in the walls for the installation , these are placed at equal distances due to the number and size of the area needed to be covered, by the course of time, the Bartom consists either of a hull of a squared sector (with perpendicular angles), and sometimes rinsed edges in the central region, or the body of a squared sector towards the wall, and a semi-circular sector from the bottom in the middle, and convert from the square to the semi -circular work by stalactites (to convert the square to the circular). the confined spaces between each other either cover the decorated panels and demonstrate the highest in the unseen parts, the carpenter fix in the space between each Brtom perpendicular opposite beams to comprise the shallow grooves divided into regions of Marbu'at and crocodiles, and fastens in the top of the Baratim and beams consisting of pallets and crocodiles by thin wooden boards bearing the decorative elements, and there on the square (right-angled) from both sides of it an installed wooden decoration which is known to the workmen as the sole, and extends by a tongue between the stalactites that helps in protecting the bottom of both sides of the Baratim from the effects of air on the decorations or it may be an installed one on the Baratim angles for a decorative purpose , on both sides of it there are wooden ornaments called "the swimmer", proving the hull sides of it In addition to the decorative form, it works to fill any holes between the Baratim and wooden pallets and crocodiles. Complementary elements of wooden ceilings: **- Hernaúa:** known to the workmen by that name, which is a rectangular piece of wood placed between each two Brtom when, and fixed with nails, it hides behind the walls and the rest of it which is uncoated, and maintains the distance confined between the Brtom and the others. **- Alqtronah**: which is fixed to the bottom of wooden planks with nails, and to be perpendicular to the wall to hide the Baratim overlap in the wall, and be a liaison between the Baratim, the izar and Hernaúaat.

(b) **Iwan** is a rectangular hall or space, the ground plan of the madrasa consists of a square courtyard. The courtyard is surrounded by four iwans, the biggest of which is the qibla iwan (house of prayer) which overlooks the courtyard by means of a horseshoe arch. This iwan includes a magnificent minbar made of wood and inlaid with ivory and mother-of-pearl, decorated with intricate geometric ornamentation

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