Treatment and Conservation of a Marble Plant Decorative Unit in the Form of Acanthus from the Ottoman Era and Preserved in Al-Fustat Museum store

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ABSTRACT

The multiplicity of use of plant decorative units in works of art since the ancient Egyptian civilization until the modern era, the most famous of which is the Acanthus plant, where the multiplicity of use of Acanthus leaves in decoration with some modifications, especially in the Coptic and Islamic eras. One of the decorative plant units for the study was selected from marble stone, which represents the Acanthus plant and dates back to the Ottoman era, it is preserved in Al-Fustat museum store; this unit suffers from heavy dust, dirt in addition to being a weak marble and loss in the lower part. Samples of marble were taken for the study, it was examined by a Stereomicroscope and a Scanning Electron Microscope (SEM), and it was found that there are many gaps and cracks spread across the surface of the sample, also analyzed by X-Ray Diffraction (XRD) and the EDAX unit (elemental analysis) attached to the scanning electron microscope to study the mineral components , elements and evaluate the current situation, it was found that calcium carbonate (Calcite) is the main component in addition to the presence of impurities such as: Muscovite and Fraipontite, which are the cause of grey color of marble, based on the results of the examination and analysis, it was found that the marble suffers from damage and weakness , hence the need for treatment and conservation . A treatment plan was put and implemented to preserve the selected plant decorative unit as an important cultural heritage expressing the period of time dating back to the Ottoman era, represented by mechanical cleaning with soft brushes and scalpels, chemical cleaning by a solution consisting of ethyl alcohol and water in a ratio of 3:1 in addition to consolidation processes with Wacker (OH) 100 at 3%.

KEYWORDS

Treatment, Conservation, Marble, plant decorative unit, Acanthus, Museum store, examination, analysis

الملخص

تعدد إستخدام الوحدات الزخرفية النباتية في الأعمال الفنية منذ الحضارة المصرية القديمة وحتى العصر الحديث ، ومن أشهر هذه الوحدات نبات الأكانتس ، حيث أستخدمت أوراق الأكانتس في الزخرفة مع بعض التحويرات وبخاصة في العصور القبطية والإسلامية ، تم إختيار أحد الوحدات الزخرفية النباتية للدراسة من الرخام والتي تمثل نبات الأكانتس وتعود للعصر العثماني ومحفوظة بالمخزن المتحفي بالفسطاط ، تعاني هذه الوحدة من العديد من مظاهر التلف المختلفة مثل : وجود الأتربة الكثيفة ، الإتساخات بالإضافة إلى ضعف الرخام ووجود فقد في الجزء السفلي من هذه الوحدة نتيجة تعرضها للكسر ، تم أخذ عينات من الرخام للدراسة (من مكان غير ظاهر في أحد جوانب الوحدة الزخرفية) ، حيث فحصت بواسطة

الميكروسكوب المجسم Stereomicroscopeوالميكروسكوب الإلكتروني الماسح Scanning Electron Microscope(SEM) وقد تبين وجود العديد من الفجوات والشروخ المنتشرة بسطح العينة ، أيضا تم تحليلها بواسطة حيود الأشعة السينية X-Ray Diffraction (XRD) ووحدة الإدكس EDAX (التحليل العناصري) الملحقة بالميكروسكوب الإلكتروني الماسح لدراسة المكونات والعناصر المعدنية وتقييم الوضع الراهن ، وقد وجد أن كربونات الكالسيوم (الكالسيت) هي المكون الأساسي بالإضافة إلى وجود شوائب مثل : معدني المسكوفيت والفرايبونتيت وهما سببا اللون الرمادي للرخام ، وبناءا على نتائج الفحص والتحليل تبين ضعف وتدهور الرخام وبالتالي إحتياجه إلى عمليات العلاج والصيانة. تم وضع خطة للعلاج وتطبيقها للحفاظ على الوحدة الزخرفية النباتية المختارة كتراث ثقافي هام معبر عن الفترة الزمنية التي تعود لها وهو العصر العثماني ، حيث تم التنظيف الميكانيكي بواسطة الفرش الناعمة والمشارط والتنظيف الكيميائي للإتساخات والأتربة بواسطة محلول مكون من الكحول الإيثيلي والماء بنسبة ١:٣ ، بالإضافة إلى عمليات التقوية بواسطة مادة الفاكر (OH) ١٠٠ بنسبة ٣%.

الكلمات المفتاحية

علاج ، صيانة ، رخام ، وحدة زخرفية نباتية ، أكانتس ، مخزن متحفي، فحص ، تحليل.

1. INTRODUCTION

The plant decoration is one of the most important decorations through different ages, from the ancient Egyptian civilization to the modern era, the artist has relied throughout the ages in his decorations on a group of plants that were found in his surrounding environment, as art is the product of the environment. The arts are a continuum, so every art appears influenced by the arts that preceded it and influenced the subsequent arts , the similarity between Islamic art and their predecessors in Persian or Sasanian and Byzantine arts were quite identical, even Muslims artists and architects , took a significant period of time to distinguish their art from ancestral influences, Plant motifs were the most important in these early productions, Islamic artist from early periods till the late ones seems to have had an endless and inventive urge for exploring the mass range of design possibilities offered by the natural variety in plant life (Elnawawy , A., & Belala, R., 2021). The Acanthus ornament is one of the most important plant motifs that have been used throughout the ages especially in the Greek and Roman times, whereas, Acanthus leaves were used in the decoration of column capitals and various stone works (Fig .1:3). The species which is used in decoration works is *Acanthus mollis* L., a Western Mediterranean species, although many Mediterranean countries Floras are in contradiction with respect to its native distribution in the Mediterranean coast, the maximum development of the use of Acanthus in the decoration took place in Roman times but always in connection with the Greek civilization as mentioned previously (Minissale, P., *etal*., 2019).

Figure 1. ***Acanthus mollis*** **L. leaf which is used in the decorations**

https://www.wikiwand.com/en/Acanthus_(ornament)#/google_vigne

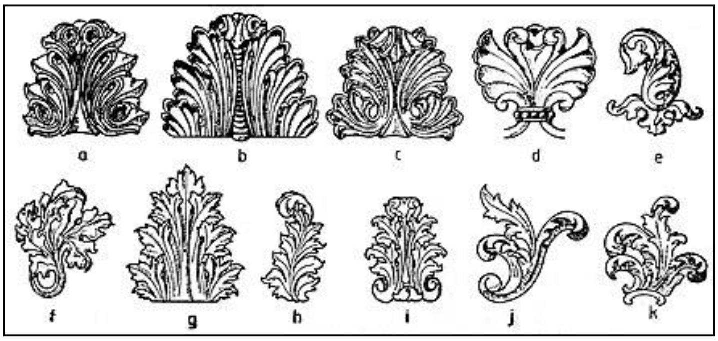

Figure 2. Acanthus styles: a) Greek; b) Roman; c) Byzantine; d) Romanesque; e & f) Gothic; g) Renaissance; h & i) Baroque; j & k) Rococo
https://www.wikiwand.com/en/Acanthus_(ornament)#/google_vignette

Figure 3. A Corinthian capital with Acanthus decorations
https://www.wikiwand.com/en/Acanthus_(ornament)#/google_vignette

As ornamentation, Acanthus inspired affluent imagination, first on the funerary stele, and later on the capitals of the columns and an architectural augmentation, Acanthus spread further to the Roman Empire. It also became a part of Buddhist art in India and China, and thereafter in the Islamic world as well, its finest ornamental role can be observed in Romanesque capitals. Acanthus was initially a symbol of death but later it became the symbol of life. Acanthus is a plant family having almost 30 species found in tropical and warm temperate regions in the Mediterranean countries and Asia, the word Acanthus, 'thorn'(akantha) drives from Greek probably due to ace (sharp point) and Anthos 'flower', which means thorn cover leaves as a thorny flower (GILANI, S. M., & SIDDIQUI, K.S.,).

The development of the use of Acanthus through the Islamic ages until the Ottoman era, in the Ottoman era till its end, plant ornaments were either designed by Persian artists or developed under their guidance. Ottoman artists not only introduced a new level of naturalism and precision to plant design in Islamic ornamental motifs, but they also enhanced it by introducing new types like as the Tulip and Hyacinth to pre-existing floral decorations including lotus, lily, peony, chrysanthemum, and carnation (El-Weshahy, M., & Ellabban, E.A.M.,2022). The principle of modulation was used in the decoration of the Acanthus plant in the Islamic ages; the Islamic formation took many forms.

The space was the controller of the sculptural formation, either by rotating the paper, elongating it, or even modifying part of it to match the surrounding other sculptural formations (El Far, M.A., 2018). The decoration with Acanthus leaves was used in the capitals of columns, tombstones and stonework in those periods.

The selected object (Acanthus plant decoration unit) bears the number 131/1 in the museum store's record and stored in Al-Fustat museum store – Ministry of Tourism and Antiquities – Egypt, it's from marble and dates back to Ottoman era , the description of the selected object in the museum store's record is a part of a vase-shaped marble overlay, containing floral motifs in high – relief (Acanthus plant decoration), its dimensions is 55 cm (height) and 37cm (width), the current status of the Acanthus unit shows that it has heavy dust, dirt; and part missing from the bottom- (Fig 4:7).

This research aims to restore and conserve one of the marble plant decorative units (in the form of acanthus leaves) that is stored in a museum store, by studying the stone carved with it, which is the marble, its components and the most important deterioration phenomena present, as well as the treatment and conservation processes for this selected decorative unit.

Figure 4. The Photographic documentation of the acanthus plant decoration

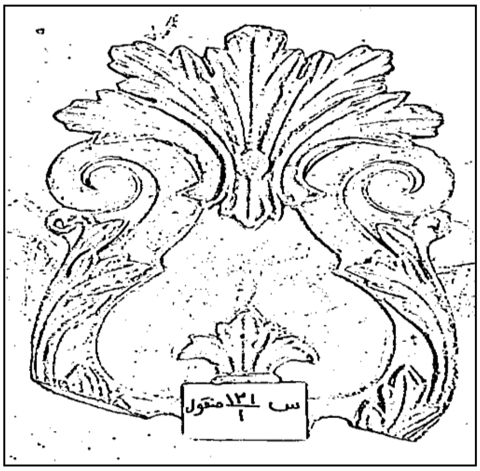

Figure 5. The Drawing documentation of the acanthus plant decoration

Figure 6. The heavy dust and dirt on the decorative unit

Figure 7. The part missing on the bottom (As arrow refers)

.2. Marble's origin and quarries in Egypt:

Marble is a metamorphic rock; they are derived from pre-existing sedimentary, igneous, or other metamorphic rocks through the application of high pressures, high temperatures, or chemically active hydrothermal fluids deep below the Earth’s surface. The metamorphosis operation occurs in the solid state (without melting) through secondary mineralization and recrystallization of the rocks, the resulting rocks are foliated and non- foliated metamorphic rocks, marble is a non – foliated rock (Harrell, J.A., 2014), marble was used from quarries scattered in the Eastern Desert (Red Sea Hills) (Harrell, J.A., & Storemyr, P., 2009), for example: Gebel Rokham near Wadi Miya, Eastern Desert (Harrell, J.A.,2013).Marble transformed from limestone (pure crystallized calcium carbonate (Calcite), or dolomite transformed under the influence of heat and pressure, some of other compounds such as magnesium carbonate, iron, and aluminium oxides, etc. are included in the composition, all these compounds differ from one place to another hence they affect the colour and other properties of marble in the world (GAMIL, H.M., *etal* ., 2022). It is very important to know the composition of the stone, its origin, and the degree of damage to it, so that the conservation plan can be developed on scientific foundations.

2. MATERIALS AND METHODS

Samples of marble were taken from invisible parts where they were examined and analyzed in order to identify their components and determine the state of damage in order to develop a treatment plan on scientific foundations, stereomicroscope and scanning electron microscope (SEM) were used in the examination process, while the analysis were done by X-ray diffraction (XRD) and elemental analysis by the EDAX unit attached to the scanning electron microscope.

2.1. Stereomicroscope examination:

The stereomicroscope (S9i) with camera (Leica S9I Stereozoom) (Format: 720p (1280 x 720) 16:9, Exposure: 151.0 ms, Gain: 5.0 x, Gamma: 0.45) at Centre of Research and Conservation of Antiquities (CRCA) – Faculty of Archaeology – Fayoum University was used to examine the surface of the marble sample with a high resolution.

2.2. Scanning Electron Microscope (SEM):

Scanning Electron Microscope (SEM) (ZEISS – Gemini, Sigma 500 VP) Faculty of Science – Fayoum University - Egypt was used to examine the surface's texture of the sample with a high magnification power to identify its status and deterioration degree.

2.3.X-Ray Diffraction Analysis (XRD):

The sample of marble was well- crushed and analyzed with x-ray diffraction device (PW1710) Central laboratories of the Egyptian General Authority for Mineral Resources – Dokki- Giza- Egypt, to identify the mineralogical compositions of the stone sample and their proportions.

2.4. EDAX (ENERGY-DISPERSIVE X-RAY SPECTROSCOPY):

The elemental analysis of the marble sample was carried out to identify the most important constituent elements and their percentages by EDAX unit attached to scanning electron microscope (SEM) (ZEISS – Gemini, Sigma 500 VP) Faculty of Science – Fayoum University – Egypt.

3. RESULTS AND DISCUSSION

Through examination and analysis of marble samples which were taken from the Acanthus decorative unit, the following results can be observed:

3.1. Stereomicroscope examination:

It was found by examining the sample's surface with a stereomicroscope; the gaps and cracks clearly spread on the surface as a result of the object's exposure to damage and deterioration while it was in the archaeological site or while being stored in the museum store, (Fig.8:9).

3.2. Scanning Electron Microscope (SEM):

As for the examination by scanning electron microscope (SEM) of the marble sample (35X), it was found that there are many cracks inside the sample caused by the weakness of the marble, (Fig.10).

3.3. X-Ray Diffraction Analysis (XRD):

It was found from the X-ray diffraction (XRD) analysis that the main component in the sample is calcium carbonate $CaCO_3$ (Calcite) with a percentage of 92%, (Muscovite-2M1, vanadian barian) 5% and Fraipontite-2M1 3% , (Fig.11).

3.4. EDAX (ENERGY-DISPERSIVE X-RAY SPECTROSCOPY):

Several elements of the sample and their percentages were identified through elemental analysis by the EDAX unit attached to SEM, such as: Oxygen (O) 45.01%, Calcium (Ca) 24.80%, Carbon (C) 10.69% , Silicon (Si) 2.91% , Iron (Fe) 1.18% , Aluminium (Al) 1.02% and Magnesium (Mg) 0.71% .The grey color of the marble may be due to the presence of impurities which are Muscovite $KAl_2(AlSi_3O_{10})(F,OH)_2$ and Fraipontite $(Zn,Al)_3(Si,Al)_2O_5(OH)_4$, (Fig.12), (Table.1).

Through examination of marble samples by stereomicroscope and scanning electron microscope, it was found that the marble is very weak, as there are gaps and cracks on the surface. As for analysis by X-ray diffraction, it was found that the main component is calcium carbonate (Calcite) with the presence of some impurities like: Muscovite and Fraipontite, which gave the marble a grey color, the results of the elemental analysis by EDAX confirmed the results of the analysis by X-ray diffraction.

Figure 8. A stereomicroscope examination of the marble's sample surface

Figure 9. Cracks and gaps on the marble surface (stereomicroscope)

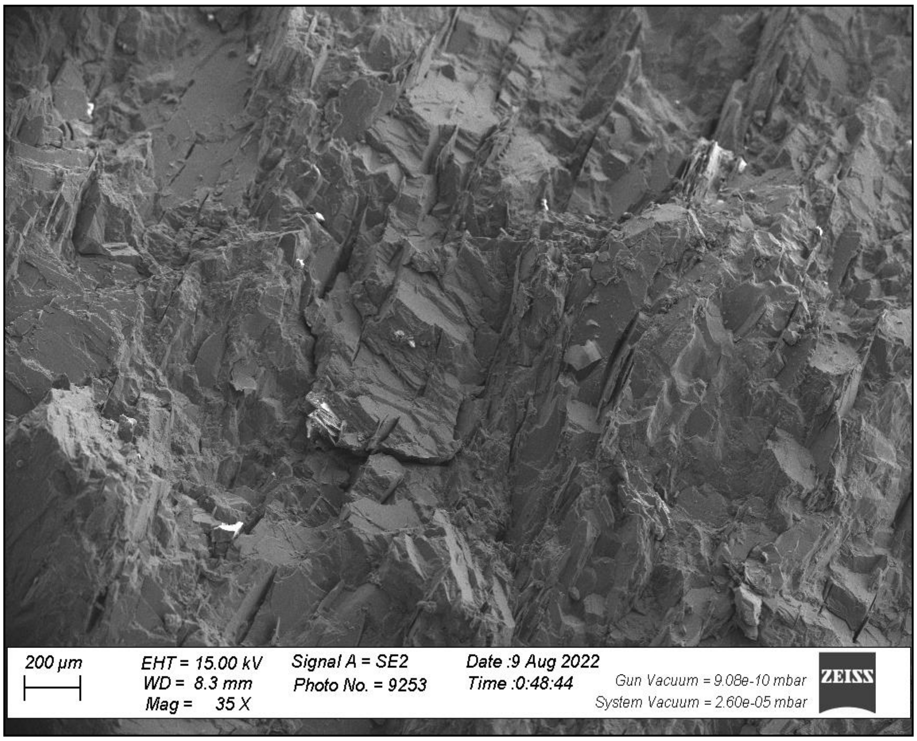

Figure 10. A scanning electron microscope (SEM) examination of the marble's sample (35X)

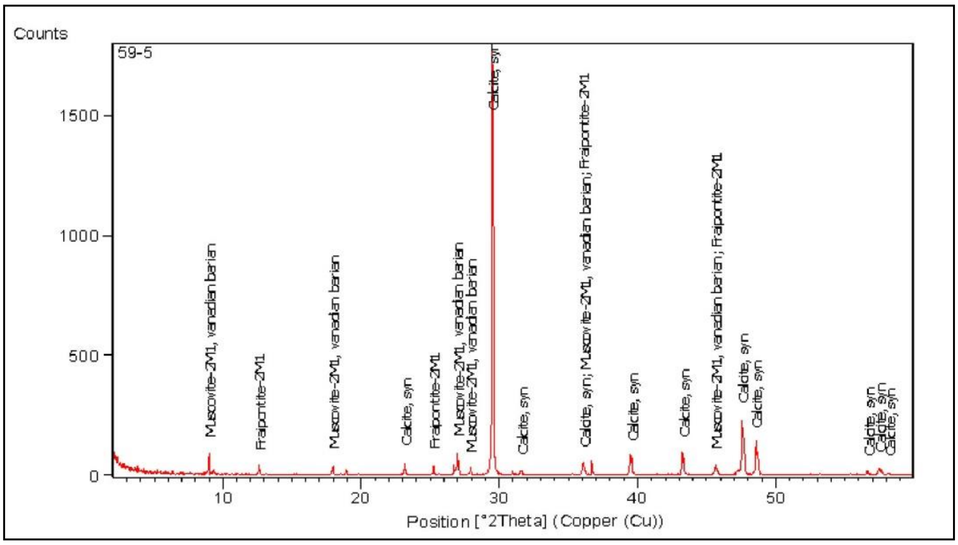

Figure 11. X-Ray Diffraction (XRD) pattern of the Marble's sample

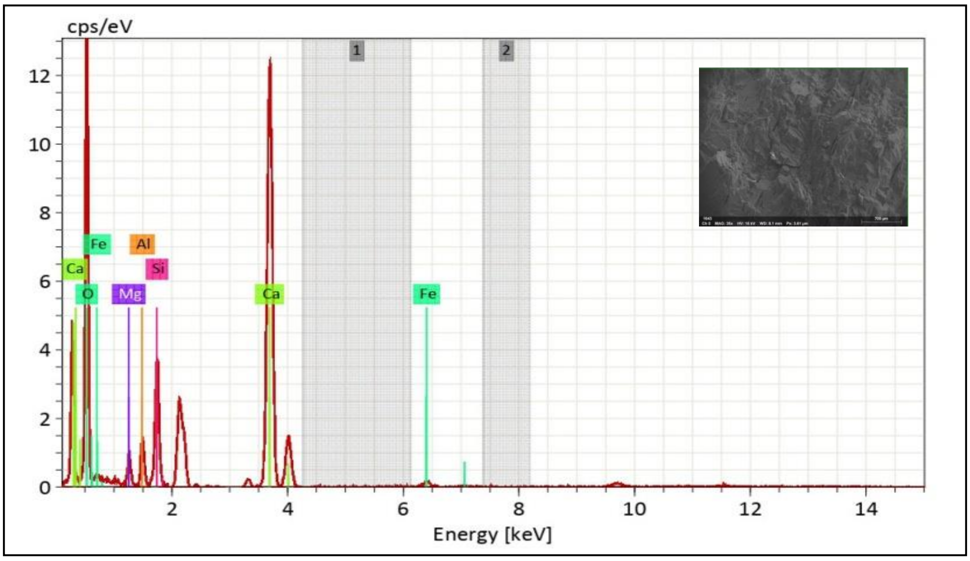

Figure 12. Elemental analysis spectrum by EDAX

Table 1. Elements of the marble's sample and their percentages (EDAX analysis)

Map

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]
Oxygen	8	39930	45.01	52.14	62.32
Magnesium	12	3042	0.71	0.82	0.65
Silicon	14	15893	2.91	3.37	2.29
Calcium	20	75645	24.80	28.73	13.71
Aluminium	13	5146	1.02	1.18	0.84
Iron	26	1379	1.18	1.36	0.47
Carbon	6	11304	10.69	12.39	19.72
		Sum	86.32	100.00	100.00

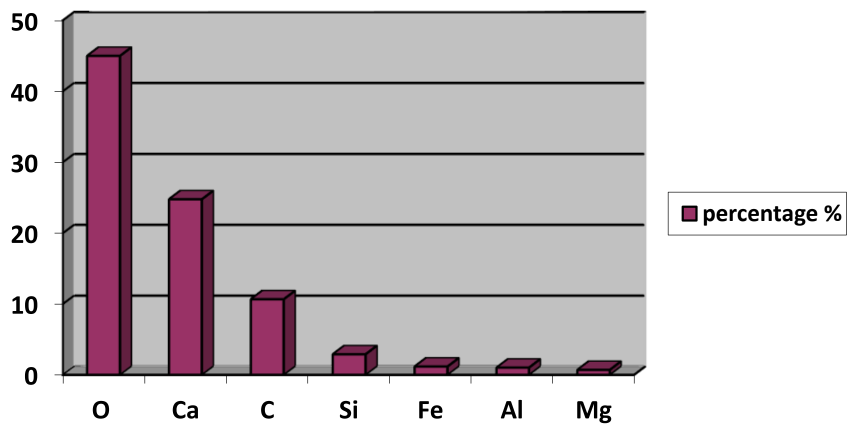

Figure 13. A graph of the marble sample elements and their percentages

4. RESTORATION OF THE SELECTED MARBLE DECORATIVE UNIT (ACANTHUS)

4.1. Cleaning Processes:

Cleaning is usually the first step in the conservation and restoration process. It is one of the most difficult processes commenced when preserving archaeological objects. Any cleaning must be carried out with a great high consideration of the experiments have essentially been done on original objects with distinct cleaning challenges , mechanical cleaning is the first choice in cleaning processes , it depends on the use of tools such as scalpels, chisels, spatulas , brushes with different softness, and others to remove dust and dirt attached to the surface , cleaning operations may precede initial consolidation process, if the surface is too weak to tolerate mechanical cleaning, it is more conservative on the surface of the antique because no chemicals are used during it. In the event that it is not possible to completely remove the dirt and there are some stains on the surface, chemical cleaning is required, where some dilute acids and alkalis are used, as well as some organic solvents such as trichloroethylene, ethyl alcohol and acetone (It is forbidden to use dilute hydrochloric acid to clean marble, as it reacts with calcium carbonate ($CaCO_3$), which is the main component of marble, and leads to an outburst on the surface). In addition to use modern methods of cleaning such as enzymes and ultrasonic cleaning, there is laser cleaning, which is one of the effective methods for cleaning marble if it is under control, YAG laser is the type of laser which is used in the cleaning of organic and inorganic artefacts, one of the advantage of YAG pulsed laser's use is well precised controlled and can be cleaned layer by layer or localized, it's very important to know the chemical composition of the stone object surface before and after laser cleaning, the cleaning process by laser depends on its thermal effect in burning dirt on the surface without affecting the marble's surface and the patina layer (Al Sekhaneh, W., *etal*., 2015).

The marble decorative unit was mechanically cleaned by soft brushes to remove the heavy dust on the surface, and chemically cleaned with ethyl alcohol diluted with distilled water at a ratio of 3:1 to remove dirt on the surface, rinsing was done with distilled water to remove traces of the cleaning solution on the surface, (Fig.14:15).

4.2. Consolidation Process:

Before performing the consolidation process, the marble must be free from the presence of dissolved salts in order to ensure the penetration of the consolidant into the stone (Rinne, D., 1976), most of consolidation materials are synthetic resins, they are polymers constructed of a chain or network of repeating single units which is called monomers, that combine with themselves or with other similar molecules or compounds to form polymers. These resins can be divided into two types of polymers: thermoplastic and thermosetting resins (Hamilton, D.L., 1999). There are also alkoxy silane materials such as: Rhodorsil 224 (alkyl-alkoxy siloxane), Wacker OH100 (Wacker-silicone-OH, non-hydrophobic product containing Tetraethoxysilane and oligomers), Tegovacon V, Ethyl silicate: (TEOS) tetraethox silane (Abdel –Tawab , N.A., 2012). The traditional consolidation materials have been converted into nanomaterials with nano particles in order to improve the properties of these materials in penetration and strengthening , such as: Nano Paraloid B-72 and Nano Estel (silica nanoparticles) (Adam, M.A.M., *etal*., 2022), nano calcium hydroxide (Nano lime) and nano titanium dioxide (Nano TiO_2) can also be used to consolidate marble objects (El Hady, M.A., *etal*., 2019), conventional consolidants can be mixed with nanomaterials to improve their properties and achieve the desired goal of the consolidation process (El-SAYED, S.S.M., & Maky, A.R.Y., 2022).

The purpose of the consolidation process is to increase the mechanical properties of the marble, as cracks and gaps were observed on the surface of the sample, which indicates the weakness of the marble and its need for strengthening. The selected object was consolidated with Wacker (OH)100 diluted with ethyl alcohol with concentration of 3% by four cycles of consolidation, the consolidation processes were carried out by brushes and over the course of four days (each cycle is for one day only, until completely dry) , (Fig.16:17).

4.3. Loss- Compensation or Completion process:

The Loss- compensation or completion process is carried out in order to preserve the artefact that has lost a part of it, which is the main goal in addition to the aesthetic aspect, completion is done by adding a filler, which is stone powder or any recent material similar in properties to the type of stone, to an adhesive, after recognizing the shape and dimensions of the missing part , examples of adhesives include acrylic , epoxy and polyester resins (JORJANI, M., *etal*., 2008), the chosen adhesives should be reversible with solvents (RICCARDELLI,C., *etal* ., 2014), The completed part must be homogeneous with the original and distinct from it according to (Article 12) of the Venice Charter (Replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence) (INTERNATIONAL CHARTER FOR THE CONSERVATION AND RESTORATION OF MONUMENTS AND SITES (THE VENICE CHARTER 1964)).

As for completing or loss – compensation of the missing part of the decorative unit, there was no ancient document showing the shape of the missing part or its dimensions in the records of the museum store, also there is no similar decorative unit from the same era. According to Venice charter 1964 and other international conventions, it is not possible to complete the missing part by guessing, as the restoration is not a falsification of historical evidence (Article 12- Venice charter 1964).

Figure 14. During mechanical cleaning of the marble decorative unit

Figure 15. Chemical cleaning with ethyl alcohol and distilled water (3:1).

Figure 16. Consolidation of the selected object with Wacker (OH) 100 (3%).

(A) **(B)**

Figure 17. (A). Before restoration processes (B). After restoration processes

5. Conclusion

The Acanthus plant decoration is one of the most important decorative units through the ages, this plant is characterized by the distinctive shape of its leaves, the decoration underwent some modifications, especially in Islamic eras. The museum store in Al-Fustat – Ministry of Tourism and Antiquities – Egypt have a marble plant ornament representing the Acanthus plant, bears the number 131/1 in the museum store's record and engraved in marble (grey color), this unit has many aspects of damage such as heavy dust, dirt, loss, and weakness in marble, samples of marble were taken , examined and analyzed to identify its components and evaluate its current condition, it was found through the examination by stereomicroscope that there are gaps and cracks that are clearly spread and showed on the surface , the scanning electron microscope (SEM) shows that there are many cracks inside the sample's surface , as for analysis by x-ray diffraction (XRD) , the main component is calcium carbonate (Calcite) 92% , Muscovite 5% and Fraipontite 3% as impurities , the EDAX elemental analysis confirms the x-ray diffraction analysis.

Restoration and conservation processes such as mechanical cleaning by soft brushes to remove the heavy dust on the surface, and chemically cleaned with ethyl alcohol diluted with distilled water at a ratio of 3:1 to remove dirt on the surface, rinsing was done with distilled water to remove traces of the cleaning solution on the surface, consolidation processes are carried out by Wacker (OH)100 diluted with ethyl alcohol with concentration of 3% by four cycles of consolidation.

The research recommends the necessity of preserving this decorative unit after its restoration and conservation by packing it with acid-free materials, a relative humidity ranging between 45-55 %±5% and a temperature of 15-25 ° C, and in the pollutant free environment (Ulas, E.B., *etal*.,2015).

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LIST OF ACRONYMS:

- **XRD:** X- Ray Diffraction.
- **SEM :** Scanning Electron Microscope.
- **EDAX :** Energy-dispersive X-ray spectroscopy.

REFERENCES

[1] Elnawawy , A., & Belal, R., (2021), Islamic Heritage as a Framework for Creating Sustainable Art work , Journal of Architecture , Arts , and Humanistic Sciences , Special Issue (2)- The Seventh International Conference "Heritage, Tourism and Arts between Reality and Hope", 1917.

[2] Minissale, P., Magro, V., Raimondo, F. M., (2019), Why did Acanthus mollis, native to West Mediterranean, become a so relevant artistic and symbolic element arising from ancient Greece? Flora Mediterranea , 29, 120.

[3] GILANI, S.M., SIDDIQUI, K.S., ACANTHUS LEAVES IN GANDHARA ART: A SYMBOL OR A DECORATIVE PATTERN , J.P.H.S., Vol. LXVIII, No. 3 , 9.
[4] El-Weshahy, M., Ellabban, E.A. M. ,(2022), Highlights on the Use of Acanthus as an Ornamental motif from Greco-Roman to Islamic period , JAAUTH, Vol. 22 No. 3, 5.
[5] El Far, M. A.,(2018), The Evolution of the Sculptural Forming Of the Acanthus Plant and Its Role in Applied Sculpture , Journal of Architecture , Arts , and Humanistic Sciences, Vol.3 , No.2, Part.2, 355.
[6] Harrell, J.A., (2014), Stone in Ancient Egypt , Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures , Springer Science+Business Media Dordrecht, 2.
[7] Harrell, J.A., & Storemyr, P., (2009), Ancient Egyptian quarries—an illustrated overview , in Abu-Jaber, N., Bloxam, E.G., Degryse , P. and Heldal, T. (eds.) QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean, Geological Survey of Norway , Special Publication,12, 17.
[8] Harrell, J. A.,(2013), Ornamental Stones , UCLA Encyclopedia of Egyptology, Vol.1 , No.1, 6.
[9] Gamil ,H.M., El-Beblawi, M., Ahmed, M.M., Mohamed, M.T.,(2022), Testing and Assessment of some Egyptian Marble Types , JESAUN, Vol.50, Issue.3, 38-39.
[10] Al Sekhaneh, W., El Serogy, A., El-Bakri, M., (2015), YAG-LASER CLEANING OF ARCHAEOLOGICAL MATERIALS IN JORDANIAN MUSEUMS, Mediterranean Archaeology and Archaeometry, Vol. 15, No .3, 157-158.
[11] Rinne, D., (1976), The Conservation of Ancient Marble, The J. Paul Getty Museum , 20.
[12] Hamilton, D.L., (1999), Methods of Conserving Archaeological Material from Underwater Sites , Anthropology, 605, Conservation of Archaeological Resources I, 11.
[13] Abdel –Tawab , N.A.,(2012), DEGRADATION AND CONSERVATION OF MARBLE IN THE GREEK ROMAN HADRIANIC BATHS IN LEPTIS MAGNA, LIBYA , INTERNATIO JOURNALOF CONSERVATION SCIENCE , Vol.3, No.3, 172.
[14] Adam, M.A.M., El-Sabagh , B.A., Abdel - Ghany , N.A.A., (2022), Evaluation of the Effectiveness of Traditional Materials and Nanocomposites in Strengthening Archaeological Marble Stones in Open Environments, JARCH, Vol.11, 467.
[15] El Hady , M.A., Hemada , s., Algohary , M., (2019), Nano Particles and Nano Composites for Preservation of Historic Marble Minbars with Application on the Minber of Soliman Pasha Al-Khadim Mosque in Salah El-Din Citadel in Cairo, Egypt , Open Journal of Geology, vol.9, P:960.
[16] El-SAYED, S.S.M., & Maky, A.R.Y. (2022), ARCHAEOMETRIC INVESTIGATION TO EVALUATE ACRYLIC, SILICON MATERIALS AND NANO-ADDITIVES AS CONSOLIDATION MATERIAL TO SANDSTONE MONUMENTS OF THE SPHINXES AVENUE (LUXOR, EGYPT) , SCIENTIFIC CULTUTR , 8 , 1, 53.
[17] JORJANI,M., WHEELER, G., RICCARDELLI,C., SOBOYEJO, W.O., RAHBAR, N., (2008), AN EVALUATION OF POTENTIAL ADHESIVES FOR MARBLE REPAIR,

Objects Specialty Group Postprints , The American Institute for Conservation of Historic & Artistic Works , Vol.19, 96.

[18] RICCARDELLI, C., SOULTANIAN, J., MORRIS, M., BECKER, L., WHEELER, G., STREET, R.,(2014), The Treatment of Tullio Lombardo's Adam: A New Approach to the Conservation of Monumental Marble Sculpture , Metropolitan Museum Journal, The Metropolitan Museum of Art, New York , Vol.49, 53.

[19] INTERNATIONAL CHARTER FOR THE CONSERVATION AND RESTORATION OF MONUMENTS AND SITES (THE VENICE CHARTER 1964) , INTERNATIONAL COUNCIL ON MONUMENTS AND SITES (ICOMOS), IInd International Congress of Architects and Technicians of Historic Monuments, Venice, 1964.

[20] Ulas, E.B., Crampton, R., Tennant, F., and Bickersteth, J., (2015), A Practical Guide for Sustainable Climate Control and Lighting in Museums and Galleries , International Conservation Services and Steensen Varming , Sydney/Australia , 17.