INTERNATIONAL JOURNAL
OF
CONSERVATION SCIENCE

ISSN: 2067-533X Volume 17, Issue 2, 2026: 487-500 www.ijcs.ro

DOI: 10.36868/IJCS.2026.02.05

INNOVATION METHOD FOR RESTORATION AND COMPLETION OF SCAGLIOLA IN HISTORICAL ROYAL PALACES IN CAIRO, EGYPT, CASE STUDY

Mohamed Mostafa ABDELMEGEED[1*], Emad IBRAHIM[2]

[1] Faculty of Archaeology, Conservation Department, Fayoum University, Egypt
[2] Faculty of Archaeology, Department of Archaeology and Excavations, Ain Shams University

Abstract

Historically, scagliola was used during Renaissance civilization to imitate natural stone inlaid work; the so-called 'stucco marble' became very decorative for wall surfaces as a substitute for colored natural marble. It plays a significant role in the history of interior design in royal palaces in Egypt in the 8th and 9th centuries. The paper presents an innovative interdisciplinary study focusing on the restoration of the interior decorative elements used during the Baroque and Rococo periods in royal palaces in Cairo, Egypt (restoration project of Zafaran Palace 2018:2025). This work has the objective of presenting a new method to restore scagliola by evaluating the current situation of the decaying scagliola in Zafaran Palace and explaining the alteration mechanisms of deterioration phenomena. A representative number of samples were analyzed by means of visual, microscopic, and laboratory analysis using digital microscopy, SEM-EDX, and XRD techniques. The evaluation study indicates, on one hand, the weakness of the internal structure and the appearance of fine cracks. On the other hand, the SEM-EDX technique shows significant differences in density/porosity detected with a non-uniform distribution of constituents. Moreover, the monological investigation shows that scagliola is composed of calcium carbonate (calcite, $CaCO_3$) as a main component. Otherwise, the paper presents a new method to complete the missing parts in scagliola elements by using glass microballoons, which are mixed with Paraloid B-72 dissolved in toluene. Required colors (color oxides) and zinc were added to the mixture to match the Scagliola's appearance and texture. The analytical investigation proved that the suggested material is very fruitful as a completion method. This is because it is free of defects that affected the archaeological scagliola; moreover, it matches the color, texture, and brightness of the archaeological scagliola.

***Keywords**: Micro-balloons; Decorative elements; SEM-EDX; Deterioration; Zafaran Palace; Conservation; Polymer*

Introduction

The art and the technology of emulating different kinds of natural marble are known as stucco marmo (or scagliola, in Italian). Scagliola is an artistic technique used to imitate the appearance of natural marble. The origin of scagliola dates back to the 17th century in Europe, where it first appeared as a method to imitate engraved marble and stone [1-4]. Historically, scagliola was used during Renaissance civilization, especially in the first half of the 17th century in Europe, to imitate stone inlaid work; the so-called 'stucco marble' in this period became very decorative for wall surfaces as a substitute for colored natural 'marble' (i.e., mostly dense limestone types). Otherwise, the use of scagliola was used widely to cover the columns and walls

[1]* Corresponding author: mmm04@fayoum.edu.eg

[4-7]. All descriptions of the aforementioned centuries refer to the technique, either the German technique that stipulates mixing pigments by adding animal glue in water and mixing while wet or the Italian technique, which mixes the pigments in dry gypsum before adding the glue solution, is barely mentioned in literature as the so-called scagliola [6-8]. The scagliola manufacturing process is complex and requires materials such as gypsum, which is the main component. Animal glue is used to bind the elements and is usually extracted from animal sources like animal hides. Natural and synthetic pigments are also used to achieve the desired marble color and pattern. Water is used to mix gypsum and glue, forming a paste that can be easily shaped and applied to different surfaces. Once the paste is completely dry, the surface is sanded using sandpaper or specialized polishing tools to create a smooth, glossy finish. This process may be repeated several times to achieve optimal results [7-12].

In Egypt, during the 18th and 19th centuries, especially under the rule of Muhammad Ali and his dynasty, European architectural styles heavily influenced the country. Engineers were brought from Europe to design and construct palaces for the rulers and nobility during this period. *Zafaran* Palace, which is the subject of the study, is an excellent example of this influence (see Fig. 1).

Fig. 1. Zafaran palace (1870 AD)

Scagliola deteriorates through phenomena like disintegration/disaggregation, leading to a granular texture; cracking and delamination, causing pieces to splinter and separate; discoloration (blackening, sugaring) due to chemical reactions, pollutants, or dirt absorption; and pitting or erosion, creating small holes on the surface. These issues are often caused by factors such as atmospheric pollution, high humidity, temperature changes, and the presence of soluble salts.

Although scagliola usually showed a higher mechanical and physical resistance than ordinary gypsum plasters. However, in some cases, it was also more durable when compared with other materials used for the same aims, namely natural stones [13-15]. Although the inventory of this type of heritage material hasn't yet been focused, the few studies about scagliola highlight its importance and show plenty of examples of high-quality art works (16-17). Studying the methods, techniques, and properties of the materials used in its implementation is one of the paramounts of this study to prevent the loss of many elements and to establish a methodology of restoration and completion of scagliola in historical buildings.

Materials and methods

Case Study

Zafaran Palace is located in Ain Shams University, district of El-Abasia, in the middle of Cairo Governorate, Egypt. Its construction started in the beginning of the 19th century (1870) on the ruins of *Al-Haswa* Palace, which dates back to the era of Muhammad Ali Pasha. However, Al-Haswa Palace was neglected and collapsed; after that, Khedive Ismail Pasha ordered the building of *Zaafaran* Palace on the remains of *Al-Haswa* Palace. The construction and decorative processes of the palace were constructed and conceived by the Egyptian engineer Maghrabi Bey Saad to be one of the most important palaces in Egypt [5], [18], [19].

Fig. 2.. *Examples of decorative and architectural elements in Zafaran Palace*

Zafaran Palace was built with limestone, and its facades were coated with artificial limestone blocks. It consists of four floors, a basement, two main floors, and a roof. The area of the basement is 1504 m², while the areas of each of the ground and first floors are 1377 m². The palace has two main entrances: one in the northern façade and the other in the southern façade. Otherwise, there are two subsidiary ones leading to the basement floor. The palace was built, influenced by Baroque art and distinguished by decorative elements of various shapes, which included bouquets of roses and flower branches scattered across the four facades of the palace, which were characterized by the accumulation of plant units as well as the prominent blocks of the facades (see Fig. 2) [20-25].

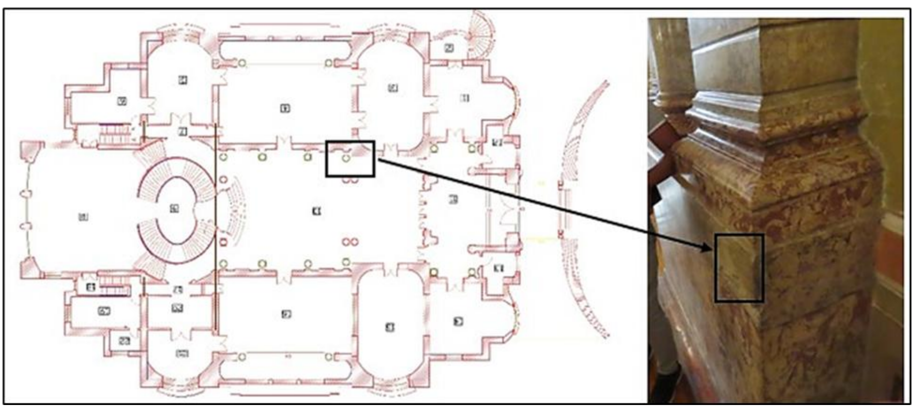

Fig. 3. The collected studied sample's location

Sampling

The collected studied samples, detached due to the occurrence of secession, belonged to a column base located in the main hall of the palace (Figs.3,4). The samples were taken from a fragment of a column and had fallen as a result of being exposed to many fine cracks (crackle).

Fig. 4. deterioration phenomena forms in Scagliola at Zafaran palace

However, micro cracks, cracks, and exfoliation are considered the most visible damage configurations in scagliola units used in the construction of columns and other cladding elements in *Zafaran* Palace (see Fig. 4). The visual survey of scagliola elements in the palace revealed a diversity of characteristic decay forms. The cycle of cooling and heating during day and night has caused exfoliation, deformation, and microcracks due to dimensional changes in the scagliola [24-27]. Otherwise, the main observed deterioration phenomenon is the separation or exfoliation of scagliola parts as a result of their exposure to microcracks. This phenomenon is very similar to the phenomenon of glass cracks (see Fig. 4).

Experimental Method

The experimental methodology and the analytical characterization started with a photographic registration followed by a detailed visual observation using a digital microscope (DM) model Din Capture 2.0 with version 1.5.12. Otherwise, the experimental methodology used in both of the collected samples from the column and samples of those used in restoration and completion works depended on determining the chemical composition using X-ray diffraction (XRD) using a Panalytical X'Pert Pro PW 3040/60 X-ray Diffractometer with nickel-filtered Cu radiation (λ = 1.540 Å, 45 kV, and 40 mA).

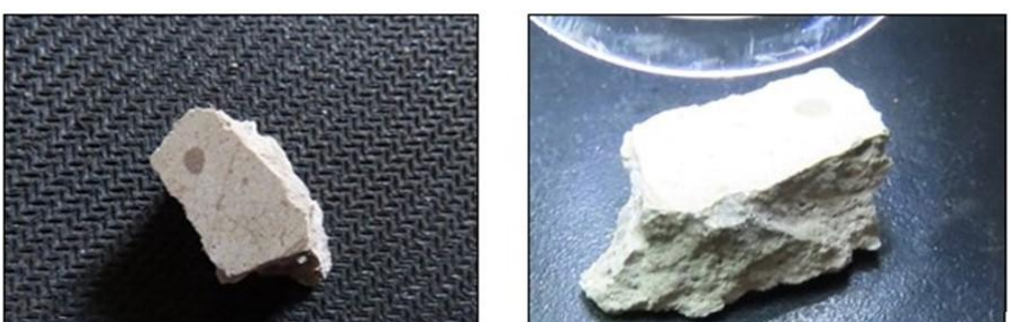

Fig. 5. The collected samples, where A. layer 1, the "external layer," and B. layer 2, the "external layer"

Afterwards, the samples (the historical ones and the samples used in completion works) were dried at 40°C for ~12 h to allow the detection of possible hygroscopic compounds or soluble salts whose crystalline fabric could be damaged if the samples were dried at a high temperature. Then, the samples were split into many fractions to be used in the various techniques, and each sample layer was also analyzed separately. Moreover, to determine the morphological features of Scagliola samples, a Scanning Electron Microscope (Philips XL 30 SEM) at 30 kV (kilovolts) was used to investigate the samples. All of the previous tests helped define the chemical composition, mineralogical components, decay patterns and products, and also defined the causes of the deterioration in scagliola units. Otherwise, to determine the properties of the proposed or innovative materials used in completion works.

Results and discussion

Visual Observation

Direct or visual observation of the building materials in their current state is a fundamental and essential stage of the building material assessment actions. This phase is usually carried out by highly skilled and experienced experts to provide an initial understanding of the building material and to give an appropriate direction to the subsequent investigations and restoration procedures [27-30].

Generally, the samples are composed of two layers, an external layer that is shiny, smooth, and of brownish or gray color (Layer 1). And an inner one with white color (Layer 2). Table No. 1 shows the conclusion results of the visual observation and the current situation of scagliola, whether it's the outer surface or the inner layer, which consists of gypsum. This initial observation with the naked eye indicates the weakness of the internal structure of scagliola units and the appearance of fine cracks, which exposes it to falling and loss. The visual characteristics observation, as shown in Figs. 5A and 5B, exhibits a small fracture that is clear with a slight difference in color and texture.

Table 1. The visual characteristics of the aspects observed

Layer No.	Layer location	Visual Description
A	External layer “1”	Finishing, smooth, and shiny brownish decorative plaster layer (Fig. 5A) having small pink spots with what seemed to be aggregates of different colors (gray, light brown, and pink). Otherwise, it has a group of microcracks. Its texture is smooth and looks like marble texture
B	Inner layer “2”	It is a white to off-white layer. Also, it suffers from crumbling and weakness in its surface granules, turns into white powder as soon as it is rubbed.

Using a Digital Microscope (DM) to study the previously mentioned observations, it was noted that the slight difference in color and texture starts diagonally between the two layers, indicating the very thick element was produced in two steps, one by one directly, as the interface between them is almost imperceptible. As it was observed that this area is less noticeable, looking directly into a fractured sample, a preferential fracture pattern through a smoother surface is clearly visible (Fig. 6).

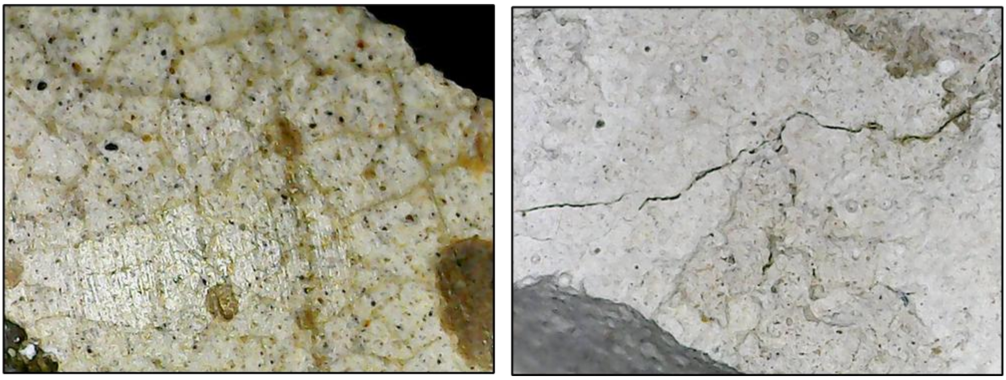

Fig. 6. Digital microscopy: images show the different texture and structural morphologies of the two layers of scagliola samples

SEM and EDX (morphological illustration and chemical composition)

For the purpose of getting further insight into the scagliola microstructure, thin-section polished and fractured surfaces were observed by SEM-EDX. Using SEM, significant differences in density/porosity of the two main layers are clearly detected (Fig. 7). The SEM image reveals a highly granular and heterogeneous structure. The surface is composed of irregularly shaped particles of varying sizes, ranging from very fine to larger aggregates. This indicates a composite material with a non-uniform distribution of constituents. Moreover, SEM captures (Fig. 7) indicate that scagliola samples had wide ranges of deterioration and fault features. The deterioration features included cavities, microcracks, small fissures, and smoothing in the outer surface of calcite grains. SEM photomicrographs show that the morphology has mainly prismatic, needle-like, and stocky crystals. There are also visible interstitial spaces, which offer a moderate level of porosity that may influence the physical and mechanical properties of the scagliola, such as strength and resistance to deterioration factors.

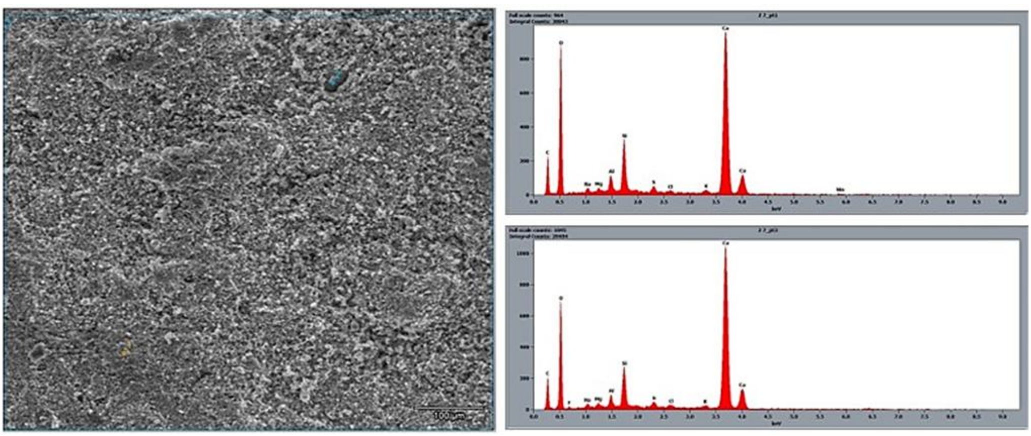

Fig. 7. Shows SEM photo-micrographs of investigated samples showing quartz grains embedded in the calcite matrix

Mineralogical Characterization

Based on previous observations and results, it was found that scagliola has potential areas of weakness where environmental degradation or weathering could have a more marked effect.

Further studies, such as elemental analysis using Energy-Dispersive X-ray Spectroscopy (EDX), are recommended to recognize the mineralogical characterization or chemical composition of the particles of the scagliola and to better understand the interactions between the different components and the deterioration products/results.

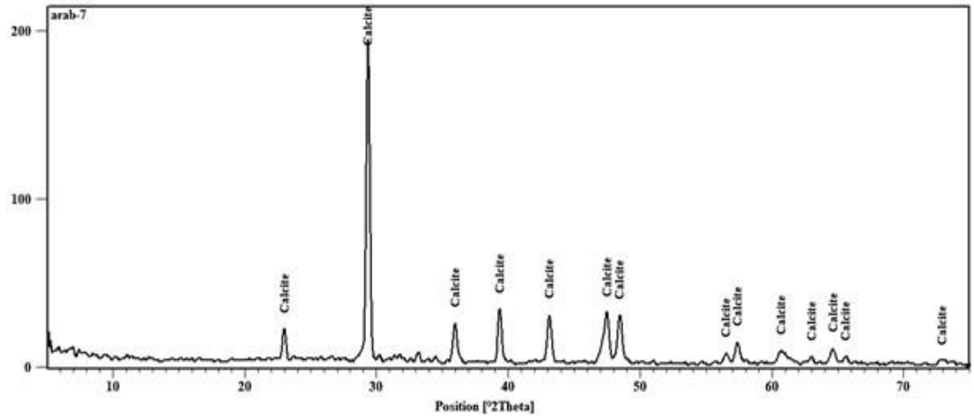

Fig. 8. Images and EDX spectra, referring to calcium carbonate ($CaCO_3$) (Calcite), besides other impurities

The EDX spectrum shows prominent peaks corresponding to the elements present in the sample. The main elements detected include, 1) Oxygen (O): The highest atomic percentage, indicating the presence of oxides or compounds with significant oxygen content. 2) Calcium (Ca): A major component, suggesting that the material may contain calcium-based minerals such as calcite ($CaCO_3$) or other calcium compounds. 3) Silicon (Si): Present in a moderate amount, likely indicating silicate minerals or the use of silicon-containing materials. 4) Carbon (C): Indicates organic content or the presence of carbonates. 5) Aluminum (Al), Magnesium (Mg), Potassium (K), Sulfur (S), Sodium (Na), and Chlorine (Cl): Present in trace to moderate amounts, suggesting a complex composition that could include various mineral phases or additives. Otherwise, Table No. 2 shows the weight percentage of each element in the sample. Calcium (34.60%) and Oxygen (50.89%) make up the bulk of the sample, supporting the idea of a calcium-rich material like calcite.

The presence of silicon (4.27%) and smaller amounts of other elements indicates additional mineral phases or impurities. The atomic percentage data further confirms the dominance of oxygen and calcium, with other elements contributing in smaller proportions. The high calcium and oxygen content, along with significant carbon, suggests that the sample could be composed mainly of calcite ($CaCO_3$), a common component in scagliola and natural stone. The presence of elements like silicon and aluminum hints at the inclusion of silicate minerals or other inorganic fillers that could have been added to modify the material's properties. The high concentration of calcium and oxygen indicates that the material may be prone to environmental factors like acid rain, which can dissolve calcium carbonates. The presence of multiple elements could affect the material's porosity and long-term stability. Impurities or secondary phases may influence how the material reacts to environmental stressors.

Table 2. The weight percentage of each element in the scagliola-tested sample

Element	C	O	Mg	Al	Si	Na	S	Cl	K	Ca
Per % - 1	6.04	54.58	0.52	1.59	4.55	0.76	0.71	0.28	0.47	29.9
Per % - 2	4.56	40.44	0.38	1.13	2.47	0.54		0.28		47.28
Per % - 3	5.05	50.85	0.61	1.35	4.27	0.73	0.73	0.45	0.34	34.6

Furthermore, the mineralogical composition of scagliola and deterioration product phases were recognized by XRD (Fig. 8). X-Ray Diffraction analysis proved that they are occurring in one phase composed of calcium carbonate (calcite, $CaCO_3$) as a main component of the scagliola.

Restoration and completion of Scagliola

As mentioned before, scagliola in *Zafaran* Palace imitates marble in shades of pink and gray. It is generally in good condition, but it suffers from color fading, craquelure, microcracks, forfeiture, and looseness. Stains, dust, and other dirt stuck to the surface of scagliola can be cleaned mechanically using soft brushes and scalpels depending on the state of the artifact and the kind of stains or chemically using different organic solvents such as alcohol, acetone, toluene, and dimethylformamide with various molarities.

As for cases of forfeit and losing parts, the use of traditional methods in completion works (i.e., lime, glue, etc.), which were previously used in the palace's completion work, proved to be inadequate and were subject to cracking and loss once again. Furthermore, the aforementioned tests and analyses have proven scagliola's weakness in resisting deteriorating factors. Therefore, the paper aimed to innovate a new method to complete the missing parts of scagliola more resistant to the factors of damage and deterioration. The new completion material is matching the artifact in appearance and texture.

The innovation completion method depends on using glass microballoons, which are a very fine white powder mixed with Paraloid B-72 dissolved in toluene. The mixture is stirred well, and then the required colors (color oxides) are added to match the scagliola's appearance to complete the missing sections. To improve the consistency, zinc is added to the mixture. The following steps were applied to achieve the proposed completion method:

- <u>*Surface Preparation*</u>: to ensure the substrate of scagliola is clean, dry, and free from dust or loose particles, a cotton ball soaked in a 90% acetone solution was used to clean the surface of the completion area of scagliola.
- <u>*Binder Preparation:*</u> Paraloid B-72 is dissolved in toluene (concentration rate 20%) to create a strong adhesive binder. The solution was stirred well to ensure that paraloid was fully dissolved, resulting in a uniform liquid binder.
- <u>*Adjusting Consistency*</u>: Gradually a small amount of zinc was added to the binder. This addition helps in achieving the desired consistency, making the mixture easier to work while maintaining its strength.
- <u>*Mixing the microballoons Compound*</u>: the glass microballoons (microballoons are white, very fine, and light hollow glass balls used with epoxy and polyester resin). Its bulk density (140-150 g/l), specific density (0.20 g/cm³), and particle size distribution (50 µm and particle sizing 200 µm) were combined with the prepared binder in a suitable container. The mixture must blend thoroughly until the mixture is smooth and homogeneous (Fig. 9)

Fig. 9. The mixture of the proposed method application

- *Color Matching*: in this step pigments were added to the mixture to replicate the appearance of marble. The colors were blended carefully to achieve the desired effect.
- *Application of the proposed mixture*: the proposed mixture was applied to the clean surface of the missing parts of scagliola using a spatula or trowel. Spread it evenly and work it into the surface, filling any gaps or imperfections. Smooth out the mixture to match the surrounding areas.
- *Shaping and Texturing*: While the mixture is still workable, shape or texture the surface as needed to replicate the natural veins and patterns found in marble.
- *Curing*: The curing time may vary depending on environmental conditions and the thickness of the applied layer. Therefore, the applied, completed material was left for more than three months to dry completely before samples were taken for study.
- *Sanding and Polishing:* Once cured, sand the surface with fine-grit sandpaper to achieve a smooth finishing.

Assessment of the efficacy of the proposed completion mixture

To determine the effectiveness and compatibility of the proposed mixture to complete the missing parts of the scagliola elements used in *Zafaran* Palace, many tests were done to determine its compatibility with the original archaeological scagliola.

As shown in Table 3, direct or visual characteristic aspects were done to identify the compatibility and incompatibility, or in other words, the similarity and dissimilarity between the proposed mixture and the original scagliola. After approximately three months after applying the proposed completion mixture, a comparison was made between the two aforementioned materials to determine an appropriate direction to the subsequent investigations of appearance as well as texture, and the results were as shown.

Table 3. The visual characteristics aspects test between the original scagliola and the completed one

Comparison point	Compatibility	Incompatibility	The differences
Color	√√	√	- The color of the proposed mixture is one degree darker than the original scagliola, but it can only be noticed up close.
Texture	√√	-	- There is no difference in texture.
Shiny	√√	-	- Both of the two materials (the original scagliola and the completed one) have the same degree of brightness.

In order to have more understanding of the texture and the microstructure of the completed scagliola, thin section preparations were observed by SEM-EDX. The perfection of the microstructure of the completion part assessed by SEM is already illustrated in Fig. 10. At higher magnifications of SEM, it was noticed that the structure, or the morphology, of complete scagliola is very distinct and has prismatic, squat, stocky crystals (Fig. 10).

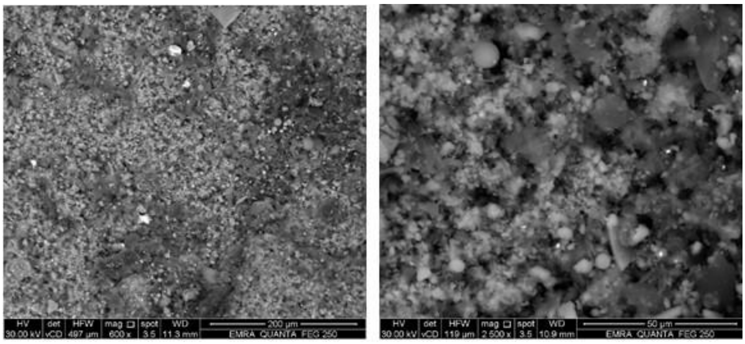

Fig. 10. Shows SEM photo-micrographs of completion scagliola samples

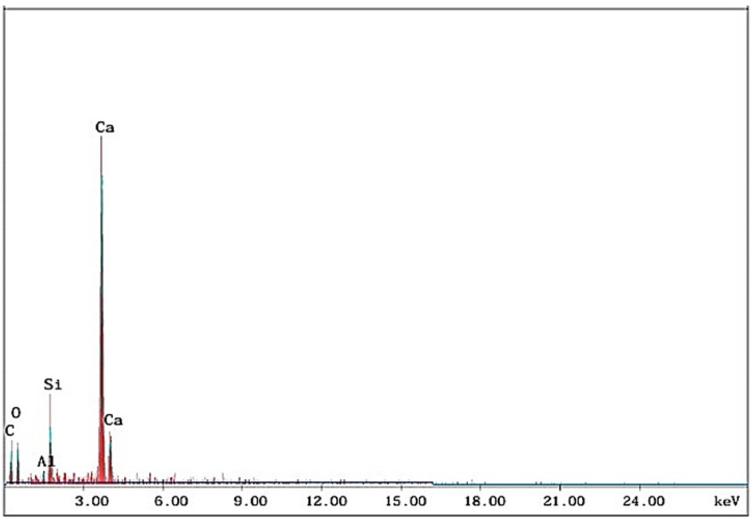

Fig. 11. EDX spectra, referring to calcium carbonate CaCo3 (Calcite), besides other elements

The perfection of the interface between the original and completed scagliola appears that the morphology of both is fairly close. However, the completed one is characterized by more compact grains and the absence of cavities and gaps between the grains (see Fig. 10). And accordingly, it is clear that the completion method is considered better in resistance than the original scagliola, which contains a percentage of cavities and gaps. Furthermore, the EDX spectrum shows prominent peaks corresponding to the elements present in the sample taken from the completion materials. As shown in Fig. 11 and Table 1, the main elements detected include Calcium (Ca): a major component, suggesting that the material may contain calcium-based minerals such as calcite ($CaCO_3$); Oxygen (O): indicating the presence of oxides or compounds with significant oxygen content; Silicon (Si): present in a moderate amount, likely indicating silicate minerals or the use of silicon-containing materials; and Carbon (C): indicating organic content or the presence of carbonates.

Table 4. The weight percentage of each element in the tested sample

Element	Ca (Calcium)	O (Oxygen)	C (Carbon)	Si (Silicon)	Al (Aluminium)
Wt. %	70.55	16.06	6	5.82	1.04
At. %	49.54	28.24	15.3	5.83	1.08

On the other hand, the mineralogical composition was recognized by XRD (Fig. 12). X-Ray Diffraction analysis proved that they are occurring in one phase composed of calcium carbonate (calcite, $CaCO_3$) as a main component of the scagliola.

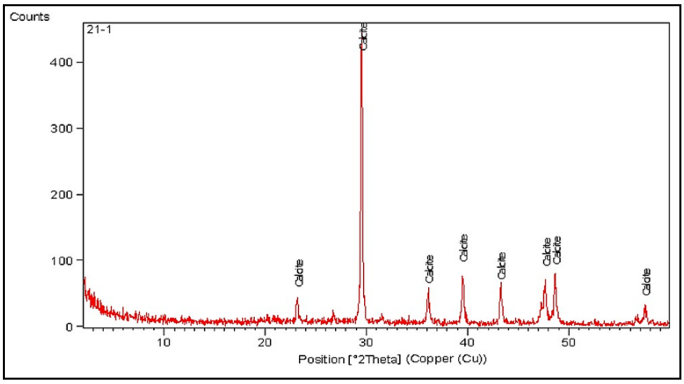

Fig. 12. Shows XRD patterns of completion material sample

The use of the previous analytical approaches to study the suggested completion materials sample proved that the suggested material is very fruitful as a completion method. Such a method is exceedingly valuable for the setting up of restoration methodologies of these worthy decorative elements whose presence in the valuable assets of the cultural heritage in the Egyptian architecture, mainly belonging to the Renaissance era, are significant.

Conclusions

Studying the characteristics of an ancient decorative element must be done by using a multi-analytical approach. These approaches must be designed to be very fruitful in order to have a compilation of quite complete information about the material and the technological features used in its manufacture. Historically, scagliola was used during Renaissance civilization, especially in the first half of the 17^{th} century in Europe, and consequently, it was used in Egypt to imitate stone inlay work (the appearance of natural marble).

In this paper, the methodology of suggesting an innovation method for restoration and completion of scagliola in historical royal palaces in Cairo, Egypt, was designed by identifying the properties of both historic scagliola and suggested completion material samples.

A precise investigation into the microstructure and mineralogical characterization was made using SEM-EDX and XRD techniques. The main obtained results are presented and discussed for the historical scagliola samples and for the completion material used, and the conclusions can be mentioned as follows:

On one hand, the visual observation with the naked eye to the historic scagliola indicates the weakness of the internal structure and the appearance of fine cracks, which exposes it to falling and loss. On the other hand, the SEM-EDX technique shows significant differences in density/porosity of the two main layers clearly detected with a uniform distribution of constituents. Moreover, it includes faults such as cavities, microcracks, small fissures, and smoothing in the outer surface of calcite grains. The monological investigation shows that scagliola is composed of calcium carbonate (calcite, $CaCO_3$) as a main component.

On the other hand, the suggested or innovative materials used in completion procedures consist of glass microballoons, Paraloid B-72 dissolved in toluene, color oxides, and zinc. Samples were taken after more than three months of application and were examined to determine their effectiveness, resistance to deterioration factors, and non-containment of defects existing in the archaeological scagliola, such as caves, gaps, and fine cracks.

The analytical investigation proved that the suggested material is very fruitful as a completion method. This is because it is free of defects that affected the archaeological scagliola; moreover, it matches the color, texture, and brightness of the archaeological scagliola.

References

[1] R. Gárate, *Artes de los yesos, yeserías e estucos*. Madrid, Spain: Instituto Español de Arquitectura, MRRP, Universidad de Alcalá, Munilla-Lería, pp. 45-117, 1999.

[2] E. Pecchioni, P. Malesani, B. Bellucci, and F. Fratini, “Artificial stones utilised in Florence historical palaces between the XIX and XX centuries,” *Journal of Cultural Heritage*, vol. 6, pp. 227-233, 2005. DOI: 10.1016/j.culher.2005.06.001

[3] A. M. Bakr, M. F. Ali, A. Moussa, and A. Said, “Characterization of imitated marble used in historical buildings in Cairo, Egypt,” *Annales Islamologiques*, vol. 46, pp. 323-335, 2012.

[4] C. Wittenburg, *Baroque Artificial Marble: Environmental Impacts, Degradation, and Protection*, ENVIART Research Report No. 9, Poland, 1999.

[5] M. El-Damaty, *Saffron Palace: The Fragrance of History and Orientalism of the Future*. Cairo, Egypt: Ain Shams, pp. 95-98, 2020.

[6] M. Freire, A. S. Veiga, J. Silva, F. Brito, and F. Schlütter, “Natural or artificial? Multi-analytical study of a scagliola from Estoi Palace simulating imperial red porphyry,” *Microscopy and Microanalysis*, vol. 22, no. 6, pp. 1281-1303, 2016. DOI: 10.1017/S1431927616011909

[7] G. Beard, *Stucco and Decorative Plasterwork in Europe*. London, UK: Thames and Hudson, 1983.

[8] L. Rampazzi *et al*., "The stucco decorations from St. Lorenzo in Laino, Como, Italy: Materials and techniques employed by the Magistri Comacini," *Analytica Chimica Acta*, vol. 630, no. 1, pp. 91-100, 2008. DOI: 10.1016/j.aca.2008.09.052

[9] K. Fuchs and G. Krist, "Scagliola interiors in Vienna (1800–1900): Material, development and conservation," *Studies in Conservation*, vol. 65, Supliment 1, SI, pp. 176-178, 2020. DOI: 10.1080/00393630.2020.1761178.

[10] P. Baraldi, L. Cannalire, and M. Colombini, "A scientific and historical investigation on Italian scagliola," *Studies in Conservation*, vol. 54, no. 1, pp. 23-34, 2009. DOI: 10.1179/sic.2009.54.1.23.

[11] I. C. Sandu *et al*., "Creating the illusion: Marble and stone-like decoration of the main altarpiece of St. Francis Church in Viseu," *International Journal of Conservation Science*, vol. 6, no. SI, pp. 473-486, 2015.

[12] T. Freire, S. A. Silva, M. R. Veiga, and J. de Brito, "Characterization of a 19th-century decorated gypsum plaster piece: The role of microscopy," in *12th Euroseminar on Microscopy Applied to Building Materials*, pp. 416-427, 2009.

[13] F. Wirsching, "Calcium sulfate," in *Ullmann's Encyclopedia of Industrial Chemistry*. Weinheim, Germany: Wiley-VCH, pp. 1-33, 2005. DOI:10.1002/14356007.a04_555.

[14] B. Middendorf, "Physico-mechanical and microstructural characteristics of historic and restoration mortars based on gypsum: Current knowledge and perspective," in *Natural Stone: Weathering Phenomena, Conservation Strategies and Case Studies*. London, UK: Geological Society, pp. 165-176, 2002. Doi: https://doi.org/10. 1144/GSL.SP.2002. 205.01.13

[15] I. Sandu, S. Schäfer, D. Magrini, A. Roque, and S. Bracci, "Cross-section and staining-based techniques for investigation of organic materials in polychrome works of art: A review," *Microscopy and Analysis*, vol. 18, no. 4, pp. 860-875, 2012.

[16] I. Cardoso, "18th-century church altarpieces in the Algarve, Portugal: A comparison of historical documents and microscopical analysis," *InFocus*, vol. 4, pp. 64-86, 2006. DOI: 10.22443/rms.inf.1.17

[17] D. Vogel *et al*., "Characterization and reproduction of historical gypsum plasters and comparison with modern preparations," *ZKG International*, vol. 52, no. 11, pp. 640-648, 1999.

[18] A. Ghobashi, *Architectural Buildings in Khedival Ismail*. Cairo, Egypt: Madbouly Bookstore, pp. 73-79, 2014.

[19] "Zaffaron Palace," Wikipedia. [Online]. Available: https://ar.wikipedia.org/wiki/Zafaran_palace

[20] U. Hameed, "Interior & style: Baroque and Rococo," 2024. [Online]. Available: https://www.researchgate.net/publication/384051667. DOI: 10.13140/RG.2.2.33543.20646

[21] E. Franzoni, E. Sassoni, S. Gardenghi, and R. Martelli, "Marble imitating renders in the monumental cemetery in Bologna: Formulation and compatibility of repair mortars," in *Jardins de Pierre*, Paris, France, pp. 249-256, 2011.

[22] F. Sandrolini, E. Franzoni, and E. Sassoni, "Environmental decay of ancient stucco decoration subject to outdoor exposure," in *Proc. HMC and RILEM TC203-RHM Workshop*, Prague, Czech Republic, pp. 701-709, 2010.

[23] M. Tulliani and C. Bertolini, "Study of degradation causes affecting stucco sculpture from Valentino Castle in Turin," *Materials and Structures*, vol. 38, pp. 425-432, 2005. Doi:10.1617/14125

[24] M. Abdelmegeed and S. Hassan, "Diagnostic investigation of decaying limestone in historical buildings at the Mamluks Cemetery, Egypt," *EJARS*, vol. 9, no. 2, pp. 183-196, 2019. DOI: 10.21608/ejars.2019.66989

[25] A. Bennadji, "Visual documentation process of historic building refurbishment: Improving energy efficiency by insulating wall cavity," in *Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XL-5/W2, pp. 91-96, 2013. DOI: 10.5194/isprsarchives-XL-5-W2-91-2013

[26] M. Khalaf and M. Abdelmegeed, "Assessment of physical and mechanical characteristics of masonry building materials in historic military towers in Alexandria, Egypt," *International Journal of Conservation Science*, vol. 9, no. 4, pp. 677-688, 2018.

[27] Z. Cooper, P. Daly, and L. Ledo, "Existing building retrofits: Methodology and state-of-the-art," *Energy and Buildings*, vol. 55, pp. 889-902, 2012. DOI: 10.1016/j.enbuild.2012.08.018

Received: September 20, 2025
Accepted: May 24, 2026