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RESTORATION AND PRESERVATION OF ARTISTIC ELEMENTS APPLIED ON ISLAMIC ARCHITECTURAL FAÇADE OF SHAHIN AGHA SEBIL, CAIRO, EGYPT

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Abstract

Shahin Agha Sebil one of the most important Sebils in Egypt from during the Ottoman period, contains artistic elements, applied on Islamic architectural façade. The facade had many weathering forms since many centuries, so that many deterioration and degradation phenomena were appeared at load bearing walls, arches, and artistic elements. Some of the stone blocks were completely destroyed, the walls was darkened and severely damaged mainly due to the effects of the air pollution, groundwater, and to the presence of salts which have caused significant detachments of the artistic elements. This paper describes the actual conservation state of the Sebil facade and its deteriorations and degradations. Also, it describes the treatment methods of the Sbil façade and its artistic and architectural elements. Prior to the preservation intervention, the materials were characterized by X-ray Diffraction, X-ray Florescence, and observation of thin section by transmitted Light Optical Microscopy (LOM), Polarized Microscope, Scanning Electron Microscope (SEM) attached with Energy-Dispersive X-ray Spectroscopy (EDX) to identify their components. After the material characterization, the architectural and fine restoration were carried out corresponds, re-back, replacement and completion of the stone blocks or artistic elements of stone, cleaning, injection grouting, restoration and completion of lost parts of the stone blocks and the mortar between blocks.

Keywords: *Shahin Agha; Sebil; Cracks; Limestone; Preservation; Restoration; Replacement.*

Introduction

Sebil (Turkish term for a drinking fountain, also used to refer to a small kiosk with attendant who dispenses water, or sherbet, from behind a grille) of Shahin Agha (No. 328), was built in 1675AD/1086 Hegri, during the Ottoman period, by Shahin Ahmed Agha during the regime of Hussein Pasha Gounbolad (1673-1675/1084/1086) or Ahmed Pasha Al-Dfterdar (1675-1676/1087-1676) [1]. The external architecture of this Sebil consists of one main façade in the Western-North side, overlooking the Mukhtar Pasha Street as it shown in Figure 1a. It has the main entrance which is an open door, closed by a wooden shutter (does not exist anymore), topped with straight threshold (architrave) from dovetailed stone Vousoir (Senga), followed by relieving arch (Relieving arch is an arch built over a lintel or architrave to take off the super incumbent weight. The earliest example is found in the Great Pyramid, over the lintels of the entrance passage to the tomb: it consisted of two stones only, resting one against the other). It

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is surrounded with the straight threshold by Player Fret (Geft) with Circular Meimehs. Rectangular window follows that to light up Aldrkah when the door is closed; covered with screen of wooden grilles and adjacent to this portal entrance, the second portal is serving to home extension. To the left of the main entrance, the main Sebil façade distinguishes from the bottom by Sadrvav (Sebil window) covered with grilles of metal, and behind it, marble plates dedicated to put the drink cups. Above of the Sadrvav (Sebil window), we can find straight threshold stone of dovetailed Stone Vousoir, followed by Relieving arch, topped with discharging arch from dovetailed Vousoir from striped stone and with founding text of four lines. The architect collected between the Sadrvav (Sebil window), the threshold, the arch and the founding text in one membership by bringing them within the Fret border with hexagonal Meimeh (Fig. 1).

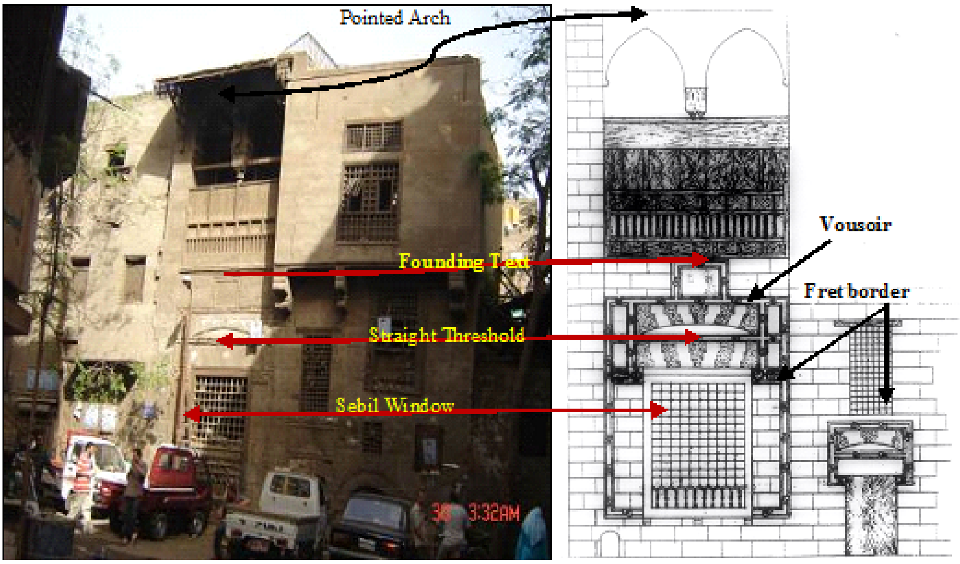

Fig. 1. Shahin Agha Sebil: The main façade with the Exciting Plan of Shahin Agha Sebil facade.

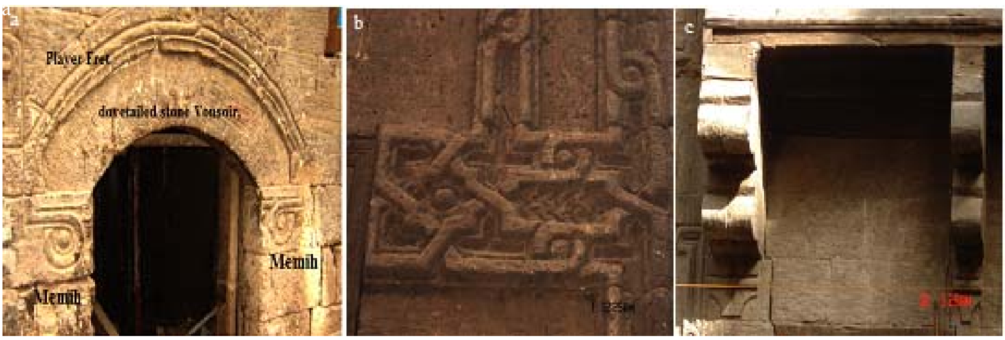

Fig. 2. The artistic and architecture elements at the façade of Shahin Agha Sebil, **a**-Player Frit, dovetailed stone Vousoir and Mehima **b**- Player Frit c. Cantilever (Corbel)

Above this group, we found the Quttab façade that overlooks the street through two pointed arches based on stalactites cantilever (Corbel). The part of the main façade of the house (no.27) was distinguished by architectural integration between home and Sebil. The facade wall assembly consists of a bearing limestone wall (Multiple-leaf walls). It has been built from two external stone block leaves with a void of varying thickness between them. The space between the two external leaves was filled with a loose low strength materials made of pieces of stone and mortar (Fig. 3). The thickness of the wall varies in the range of 450–600 mm. The artistic elements (Fig. 2) on the façade of Shahin Agha Sebil have suffered severe effects, some of them being collapsed (totally or partially) and several damage patterns were observed. The aim of this current work is to study and evaluate the current state of the stone façade of Shahin Agha Sebil, and to study the façade materials in order to identify its components and introduce a scientific study for its architectural and fine treatment.

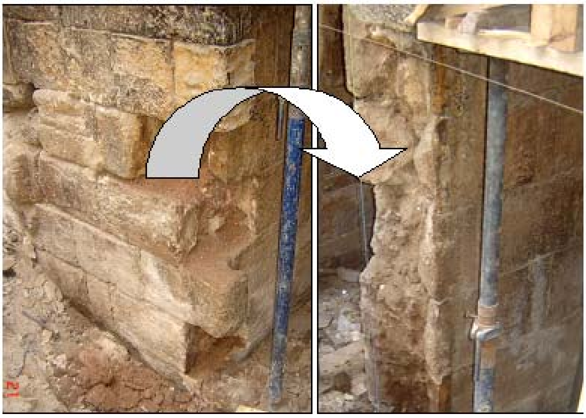

Fig. 3. The facade wall assembly consists of a bearing limestone wall (Multiple-leaf walls)

Conservation State

Detailed survey of stone decay phenomena was carried out on the façade of Sebil in order to establish the typology, causes and processes of the major weathering forms observed. Several weathering forms were identified and recorded at the plane of the façade (fig.4).

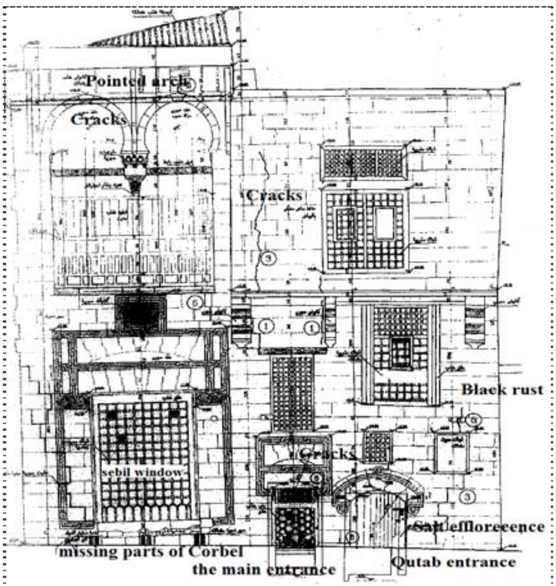

Fig. 4. The plan of the façade of Shahin Agha Sebil shows the missing parts and cracks.

The façade of Sebil shows some clear indications of yielding cracks and partial collapse at several locations as a result of the physiochemical and architectural effects of deterioration factors. The structural damage is represented by walls cracking, stone surface decay, partial collapse of some parts of the wall and rock disintegration especially noted at lowest parts and mass wasting from architecture elements of the façade. Most of current damage conditions of the facade are mainly due to the earthquake, which occurred on October 1992. Almost all the causes of damage and deterioration appeared on the facade are related to the problems that affect the multiple leaf masonry walls. Also, Age of the building, it had survived for nearly 350 years' time-stresses effect on construction materials, lack of maintenance during its service life, loss of mechanical characteristics of the walls at foundation level due to moderate aggressive environment (ground water and soil) [2]. So, many vertical, diagonal and fine cracks in the walls were noticed as shown in Fig.5, which led to dangerous deterioration in the architectural elements like arches, gifts and threshold. More cracks were found at top of the façade. The cracks at top of facade and at the end of facade are indicating thermal movements. Vertical cracks generally indicate poorly bonded material or material that has lost its cohesion and is therefore weak. Diagonal cracks indicate failure of shear, due to ground settlement or subsidence, shear cracks may combine with thermal cracks. Crack wider at bottom-ground may be sliding horizontally as well. Fine cracks also appeared due to wind and salt crystallization [3].

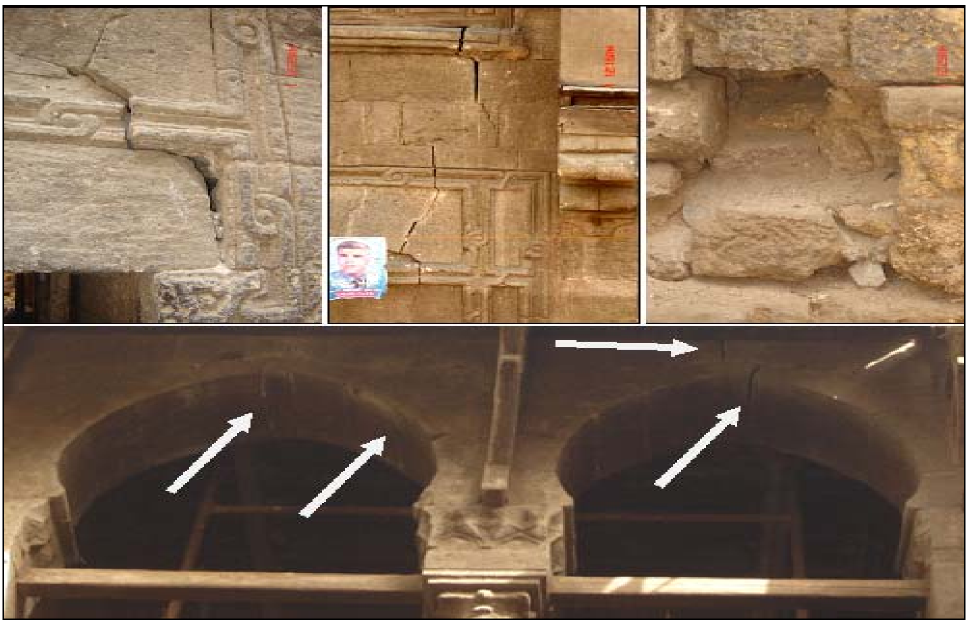

Fig. 5. Examples of cracks, deformation of architectural and artistic elements at the facade of Shahin Agha Sebil.

Sebil façade has deformation, buckling, leaning and brittle with loss of stiffness in the structure elements (Fig.6). Serious internal stress and vertical loads are the main cause of damage or collapse of structure (cracking, deformations, leaning, crushing, etc.). Also, the movement of core material may also be a source of new stresses, thus making the faces unstable, according to Drysdale et al [4]. Deformations may not only result from taking uploads, but from seasonal changes in temperature or internal heating, from changes in moisture content of materials and from differential settlements, movements of the ground or alterations to the structure that introduce a new pattern of equilibrium [3].

Fig. 6. Photograph of decay features common at Sebil facade **a** - buckling and leaning, **b** - deformation, brittle failure with loss of stiffness in the structure elements of the façade (lost cantilever (Corbel), **c** - Scars of flaking, **d** - hard crust and scares of flaking **e**-Efflorescence's to light-colored crust tracing the surface, **f** - soiling by particles from the pollution.

Rising contaminated ground water table caused many problems for the foundations of the Sebil walls, leading to uneven settlements of the foundations and structure. Cracks in a facade allow water to penetrate into the assembly thereby increasing its moisture stress and deterioration. The groundwater provides a constant source of moisture that seeps into Sebil site by capillary action up into the façade wall. Cairo City has been constructed on hills and low-lying areas frequently affected by flooding sewage water, which then degrades the Islamic Historical buildings. Also, they have been flooded by lakes and canal water; e.g., the former Egyptian canal. This water has had varying effects on the foundations and walls of the Islamic monuments [5]. The main of stone deterioration of the Sebil façade results from combination of raised groundwater level and the capillary transport of salt laden water due to the actual level of humidity and its continuous mechanism. Sewage water plays a major role in the formation of halite, either on the stone surface or in its pore system. The pressure of salt crystallization enhances the growth and development of micro and macro fractures and consequently leads to granular disintegration, scales, spalling, flaking prevail inside and breaks up stone surface and also decrease the overall strength of the stone especially in the lower parts of the walls. White salt efflorescence and yellowish brown iron staining can be noted in many points (Fig. 6d-e). The precipitation and growth of halite ($NaCl$) on stone surfaces and in pore systems is due to the seepage of underground water and it is widely observed in our study of the artistic elements of Shain Agha façade. $NaCl$ is able, by a process of hydration and dehydration, to promote the disintegration of surfaces by its action on other salts. So a lot of stone blocks have seriously lost their internal cohesion and resistance and a big percentage of these stone become powdered, brittle, while other blocks were completely lost, in addition to the loss of mortar joints which threaten the physical structure of the architectural elements of the façade. The essential alteration factor for Shahin Agha facade was atmospheric pollution from the center of Cairo located in urban (polluted) environments. Black crust and soiling was coated the surfaces of Sebil building materials. This made up of matters present in aerosols and particulates, which are derived by dry and/or wet deposition processes. Soiling or blacking of building materials is a visual nuisance resulting from the darkening of exposed surfaces by the accumulation of particulate matter [6]. It is related to the surface area covered by carbonaceous fine particles which contain dark elemental carbon [7, 8]. Generally the black crust and accumulate of dirt coating the surfaces of building materials which lead to degradation of the stone surface as result of the reaction between the dirt and the stone surface which affect the facade visibility and its aesthetic value [9]

Materials and Methods

Samples

The samples under investigation were carefully acquired and isolated from a variety of zones in the Sebil facade and were chosen for the purpose of identifying the material elements that make up the limestone, mortar and deterioration products *e.g.,* residual salts and black rust on the wall surface. These require proper consolidation, cleaning and conservation treatment in order to restore to some degree the original splendor of the Islamic heritage.

L.O.M. Examination

Different stone and mortar samples were embedded in a transparent epoxy resin and the cross-sections were ground and polished using a polishing machine and different grades silicon carbide grinding paper. Observations and photographs of the samples' surface were achieved using a Zeiss, Axio Can MRC5 Stereoscopic microscope with Discovery V.20 camera.

Petrographic examination

The minerals characteristics, texture, cement materials and digenetic features of building materials samples were further examined by using a polarized optical microscope. Petrographic thin sections were prepared and optically analyzed by using (Olympus BX51 TF japan) attached with digital camera under magnification 20X up to 40X.

Scanning electron microscope (SEM-EDX)

Various samples of limestone collected from some blocks and mortar were investigated via scanning electron microscopy, by SEM JEOL JSM 6400, coupled with an energy dispersive X-ray spectrometer (EDS), to reveal details of the digenetic processes and micro-scale features in the limestone. Small samples were coated with gold.

X-ray diffraction (XRD)

The identification of the mineral composition of the samples was made by X-ray diffraction patterns, using a Philips X-ray PW 1840 diffractometer. The patterns were run with Ni-filtered, Cu Kα radiation (λ = 1.54056 Å) at 30 kV and 10 mA. The scanning was limited from 2Θ = 1 to 2Θ = 80◦ range.

Study of physical and mechanical properties of limestone:

Cubic samples (4×4×4cm) of limestone were taken from the deteriorated block from the inner wall of the Sabil facade to evaluate the physical properties (bulk density, porosity and water absorption) and mechanical properties(compressive strength), then dried at a temperature of 105°C until constant weight was achieved.

Results and discussions

L.O.M. Examination investigation

Optical microscopy revealed a wide range of deterioration features as shown in (Fig. 7a-h). Dust, smoke on the surface of calcite grains, eroded pits, cavities, loss of internal cohesion, efflorescence salts and the presence of some iron oxide (limonite and hematite) were noticed.

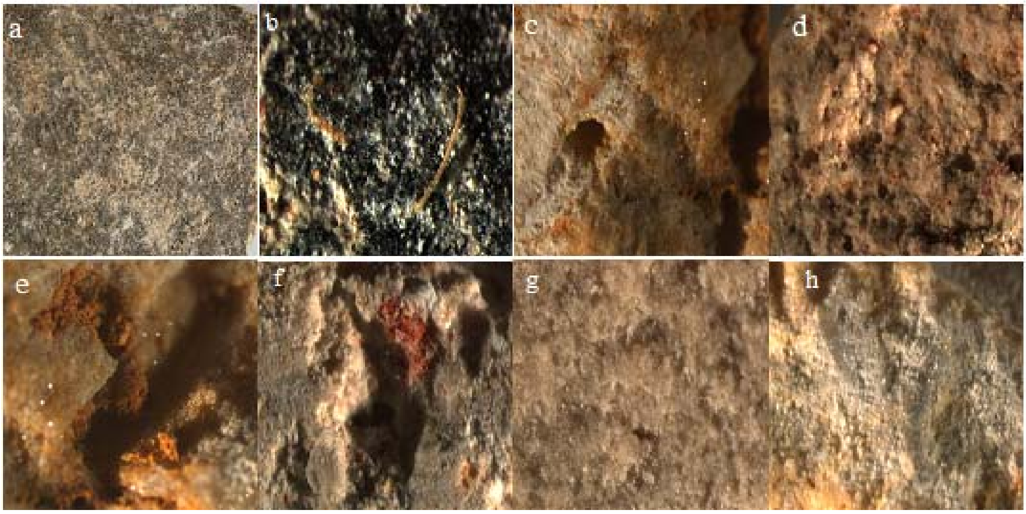

Fig. 7. Micrograph of investigated samples by LOM **a-** dusting form covering all stone surface **b-** smoking in outer surface of limestone **c-** eroded pits **d,e** cavities, voids and iron oxide as limonite **f** cavities and hematite, **g** loss of internal cohesion, **h** efflorescence salts.

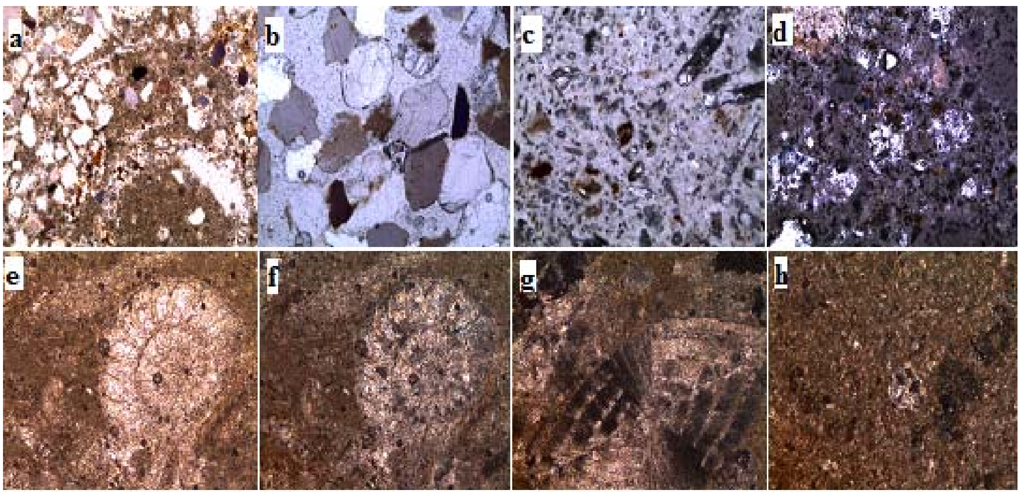

Fig. 8. Optical micrographs: **a** - Fine grained calcite (micrite), **b** - Quartz grains as sub rounded to angular, **c** and **d** - iron oxides and fossil fragments, **f** - Gypsum. Clay minerals and some fine grained quartz, **e:h** - Nummulite, shells and fossils fragments.

Petrographic investigation

Examination of thin sections of the limestone samples under plan polarized light microscope (PLM) displayed fine-grained calcite crystals, on top of iron oxides, clay minerals and numerous grains of quartz that were also found occurring as sub rounded to angular. These component;ts increase the rate of stone decay. The study showed also Nummulite, shells and fossils fragments as shown in figure 8. Studies indicated that, the limestone used in Shahin Agha Sebil is Nummulitic limestone, which formed in the Middle Eocene from Mokkatam formation.

SEM-EDX Examination

The obtained results showed that there is a wide range of deterioration features in the samples. Microscopic investigation revealed dissolution of cements occurred on the limestone, which lead to an increase in porosity (Fig. 9a-b). Moreover, the physical structure of stone has seriously collapsed and most stones became fragile and lost their cohesion (Fig. 9c). The SEM investigation showed that the soluble salts deeply move into the stone and destroyed their mineral constituents, the calcite crystals being seriously deformed and they have lost their original crystalline form (Fig. 9d, m, e). Sodium chloride in long and needle form and calcium sulphate were found between calcite crystals and the other mineral constituents of stone (Fig. 9f,g and h). Also, the study showed eroded pits, small fissures, micro cracks, dusting, splitting and micro exfoliation and cavities (Fig. 9i). The SEM investigation of the mortar samples which were taken from between stone blocks in the Sebil façade showed that two kinds of mortar were used: lime mortar, which consists of calcite and sand (Fig.10a-b) and gypsum mortar (Fig.10c). SEM photomicrographs showed the collapse of internal structure, voids, loose of binding material and NaCl salts crystallization between mineral grains. NaCl precipitation caused a considerable increase in the porosity of the building stone, increase of cavity and pore sizes, increase production and acceleration of micro fracture growth in the surface of the lime mortars and stones due to crystal pressure, and acceleration of the rate of stone exfoliation.

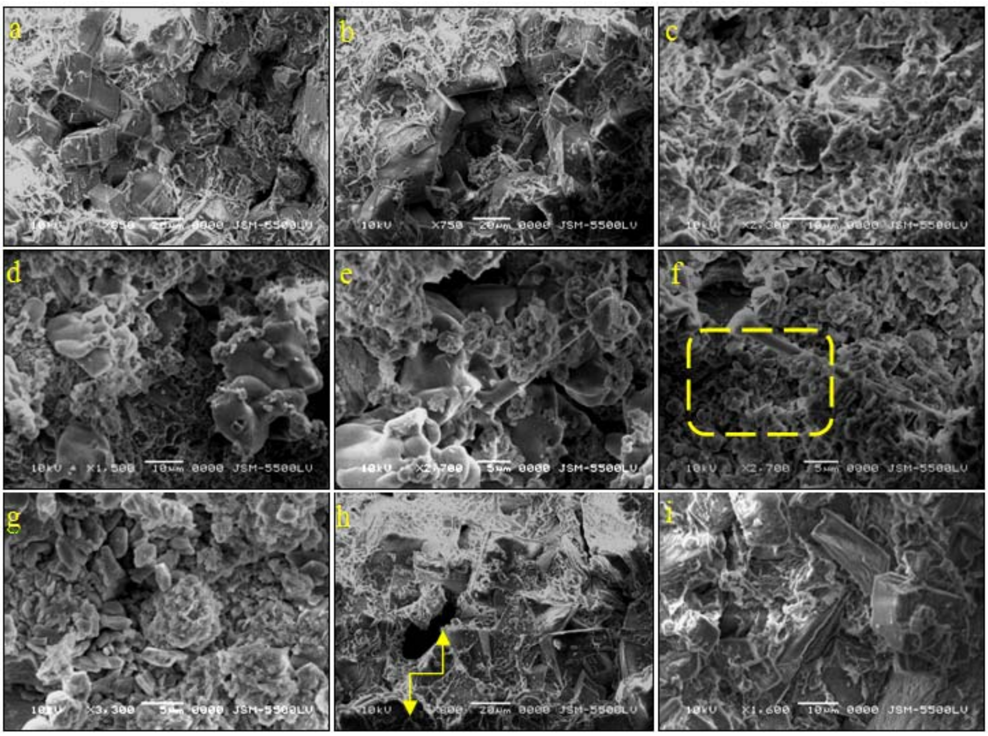

Fig. 9. SEM images: **a, b and c** - dissolution of cements and loss of cohesion between calcite crystals**, d, e** – porous crystalline salts, **f** - crystalline salts are long and then needle form, **g-** sulphide salts, **h** and **i** - splitting and exfoliation.

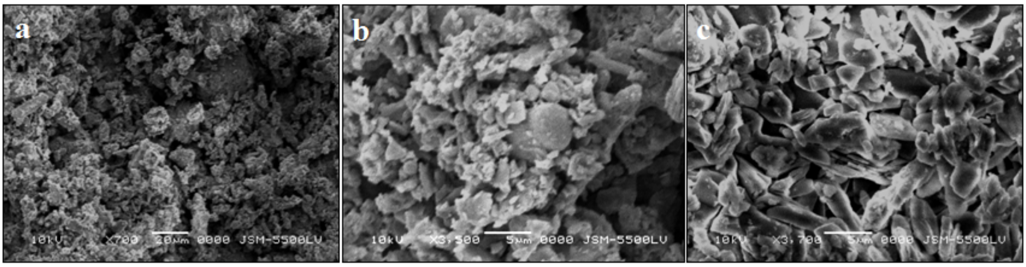

Fig. 10. SEM photomicrographs of mortar sample showing the collapse of internal structure, voids, loose of binding material and salts crystallization between minerals grains.

Elemental Analysis by SEM-EDX

EDX analysis of altered limestone from Sebil façade commonly consisted of Ca, Si, Mg, Fe, Ti, Sr, Fe, Mg, Cl and Na. EDX microanalysis of the sample (A1) showed that Ca, Si and Fe are the major ions contained, while Mg, S, Cl and Na are secondary elements. Traces of Al, K and Ti were also found. EDX microanalysis of the sample (A2) showed that Ca, Mg and Si are the major ions with minor elements of Al, K and Na. Cl and S were also detected. EDX microanalysis of the sample (A3) showed that Ca and S are the major ions contained with minor elements of Na and Al, Si, Fe and K also detected. EDX microanalysis of the sample (A4) showed that Ca, Mg and S are the major ions with minor elements of Si, Fe, Na and Cl. Al, Ti and K. EDX microanalysis of the sample (A5) showed that Ca and Si are the major ions with minor elements Mg and Cl. Na, S, Ti, Sr and K were also detected. Considering the above results, shown in table 1, it can be claimed that the transition of heavy metals (Fe, Ti and Sr) generally increased in the outermost surfaces of the black crusts relative to the sample taken from the interior [10]. This is attributed to polluted gases derived mainly from diesel engine exhaust, which is primarily composed of soot and metallic particles bearing Fe and Fe-S as major elements and Ti and Sr as trace elements. These elements play a major role in the catalytic oxidation rates of SO_2 [11].

Table 1. Chemical analysis in weight per cent of the weathering limestone samples collected from the Sebil of Shahin agha façade.

A1

Elements	ms%	mol%
Na	1.5945	2.6355
Mg	4.4120	6.8926
Al	0.6131	0.8635
Si	8.5433	11.5591
S	1.0136	1.2013
Cl	2.6443	2.8343
K	1.2280	1.1934
Ca	68.5576	65.0009
Ti	0.5582	0.4428
Fe	10.8354	7.3728

A2

Elements	ms%	mol%
Na	0.1393	0.2256
Mg	8.5581	1.0957
Al	0.7942	3.5075
Si	9.3848	12.4392
S	0.6280	0.7291
Cl	0.7747	0.8135
K	1.1981	1.1407
Ca	69.0614	64.1451
Fe	9.4614	6.3068

A3

Elements	ms%	mol%
Na	1.5557	2.4998
Al	0.1265	0.1732
Si	0.2444	0.3215
S	29.5108	33.9996
Cl	1.0315	1.0748
K	0.5472	0.5170
Ca	65.7383	60.5902
Fe	1.2455	0.8239

A4

Elements	ms%	mol%
Na	1.0131	1.6865
Al	0.2479	0.3516
Si	1.5350	2.0918
S	16.0019	19.1011
Cl	1.9820	2.1397
K	0.6680	0.6539
Ca	75.6159	72.2085
Ti	0.1612	0.1288
Fe	1.7138	1.1745
Sr	1.0612	0.4636

A5

Elements	ms%	mol%
Na	0.5063	0.8633
Mg	0.9242	1.4902
Si	4.2015	5.8641
S	0.7495	0.9163
Cl	1.2912	1.4276
K	0.6234	0.6250
Ca	89.6336	87.6653
Ti	0.0993	0.0812
Fe	0.7275	0.5106
Sr	1.2435	0.5563

Results of Mineralogical Analysis by XRD

The collected limestone and mortar samples were studied by XRD in order to determine their mineralogical composition. XRD patterns of the studied samples are given in Figure 11 and Table 2, and show that the samples consists essentially of calcite $CaCO_3$, Dolomite $(Ca,Mg)CO_3$, small amount of halite NaCl, Quartz SiO_2, Gypsum $CaSO_4 \cdot 2H_2O$, Anhydrite $CaSO_4$ and traces of iron oxide. According to this study, we claimed that the stone in the façade consisted of calcite as a major minerals and high ratio of dolomite (Dolomitic limestone) and small amounts of Quartz and iron oxide. The presence of halite and gypsum is related to salts. The presence of anhydrate is the result of the transformation of gypsum ($CaSO_4 \cdot 2H_2O$) by thermal weathering.

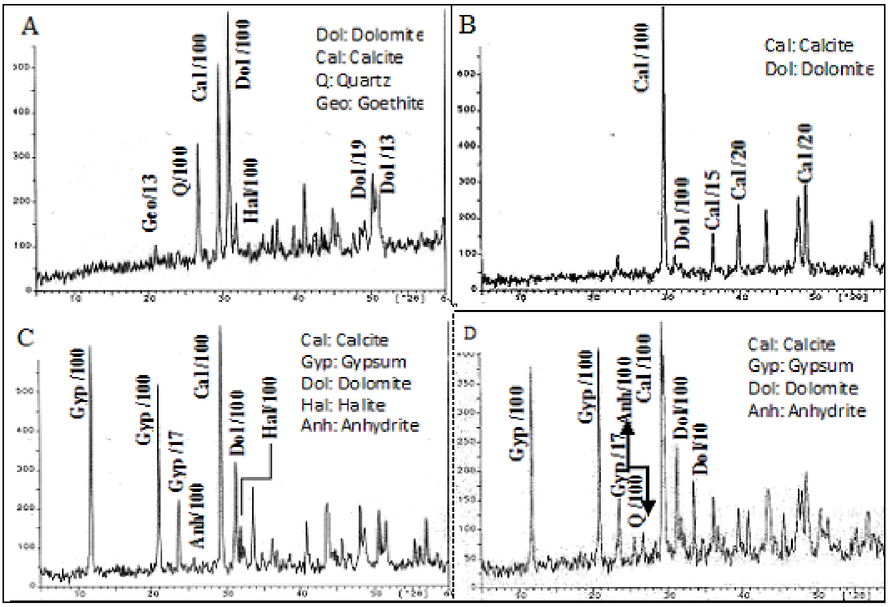

Fig. 11. Patterns of XRD analysis of limestone samples from the façade of Sebil shahin Agha

Table 2. Mineralogical composition of the limestone samples collected from Sebil façade

Component	A1	A2	A3	A4	A5
$CaCO_3$	33.49	-	37.82	40.09	100
SiO_2	20.22	23.14	-	4.53	-
$CaMgCO_3$	42.57	76.86	16.62	7.23	-
NaCl	-	-	7.41	-	-
$CaSO_4.2H_2O$	-	-	35.72	48.12	-
$CaSO_4$	-	-	2.43	-	-
FeOOH	3.65	-	-	-	-
Total	99.39	100.00	100.00	100.99	100

Physical and mechanical properties:

The physical properties detected that the limestone of the facade is characterized by high porosity (13.37%), which gives the stone a high water absorption rate (7.10%) and its consequent ability to absorb water with salt solution and this is the main cause of deterioration. The bulk density of the samples gives 1.66gm/cm^3. The mechanical properties were measured, the results showed that the strength of limestone in the facade characterized by poor mechanical characteristics (by 166.6kg/cm^2 Dry and 149kg/cm^2 Wet). The changes of physical and mechanical properties of the stone were a result of weathering process.

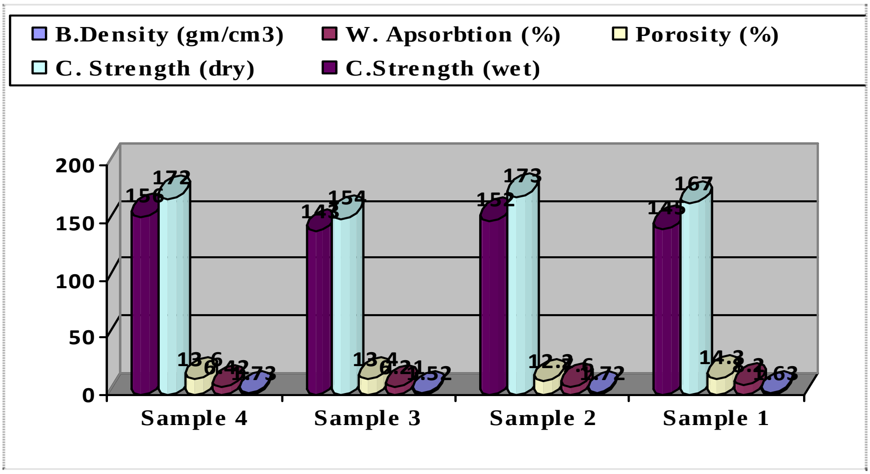

Fig. 12. Physical and mechanical properties of limestone samples from the façade of Shahin Agha Sabil

Treatments

The complex restoration concept for the Shahin Agha was stated in order to safeguard the continuality of the Cultural significance of the Monument (as symbol of national identity and independence, and safeguard Monument's further inclusion in the life of the society)

Stages of preparation to work

- The condition of the facade was recorded before any intervention. Documentation of the archaeological and architectural elements of the façade has been done; previous studies did not contain any lifting architect.
- Site and analytical investigations for structural restoration, analysis of chemical, physical and mechanical characteristics of the building materials such as stones, mortars and binders were carried out.
- Effectiveness test was made to all the suggested methods for conservation work, according to the results of the lab analysis of Sebil martials, for dolomitic limestone, lime mortar, grouting materials and the methods of cleaning and extraction of salts.
- Survey of the crack pattern and deformation of structure were carried out.
- The movement of cracks has been studied by fixing dabs of plaster to the basic masonry.
- Removal of all deteriorated and deformed mortar and stone blocks was done (Fig. 13)

Fig. 13. Removing of all deteriorated and deformed mortar and stone blocks

Architectural restoration

We can summarize the architectural conservation of the Sebil façade in the following steps:

a. Temporary works to prevent the collapse of building elements were carried out by using timber scaffolds. Timber shoring was erected in order to repair a defective arch, improving the temporary structural balance and increasing resistance, to avoid the risk of collapse of the structural and artistic elements of the façade. Shoring is a temporary work designed to resist stresses arising from subsidence, over toppling or bursting and landslip. We used dead shoring, which is designed to take vertical loads and enables walls to be rebuilt and complete the lost elements.

b. Improvement of wall characteristics by lime injection (Grouting): The object of grouting is to strengthen and consolidate decayed wall which is weakened by large fractures and voids as the Sebil façade. Grouting is the insertion of a fluid cementations mix, called grout, with good flow characteristics into the cracks and fissures of walls, [3]. The experimental study proved that the mix of lime+ sand+ white cement (2:1:0.5) mixed with Edibond15% in water gave the best results under the mechanical testing. Before inserting the grout, it was first necessary to clean out the voids and wet all the surfaces. The grout was inserted with an air-operated pump (Fig. 14).

Fig. 14. Grout mixture was injected by air pressure into the open joints in the stonework at the Sebil façade and large areas of walling was need these treatment.

c. Completion the missing parts of architectural and artistic elements by reproduction process: Cantilever (Corbel) below the Sebil window and Meima which was lost and deteriorated were restored by reproduction. Reproduction entails copying an extant artifact, often in order to replace some missing or decayed parts, generally decorative, to maintain its aesthetic harmony. Reproduction of the lost and deteriorated architectural and artistic elements from the Sebil façade was done from dolomitic limestone from Mokattam quarry because the lab analysis indicated similarities between the Sebil stone with these the kind of limestone. Stonecutters carved structural and decorative elements of the façade following the direction of the cut of a stone block and dressed to the original profile and designed to match the original one (Fig. 15).

d. Replacement and reconstructing the missing blocks were done to compensate, anchor and fit the loss of the deteriorated stone on the Sebil façade with the original materials; similar dolomitic limestone bases and lime mortar consisting of 2 sand + 1 lime + ½ white cement. We tried to use the original stone for repair because it had the same appearance and nature and doesn`t damage the original stone physically, mechanically or chemically.

The stone blocks which were used for replacing were dressed to the original profile and designed to match the original (Fig. 16).

Fig. 15. Missing parts completion: a, b - Reproduction of lost Cantilever (Corbel) below the Sebil window from dolomitic limestone, c - using the reproduction corbel for façade conservation.

Fig. 16. Replacement and reconstructing the missing stone blocks of the Sebil façade by dolomitic limestone and lime mortar, **a, b,** and **c** - show the separation of the architectural elements paving to resistance the Multiple-leaf walls behind it, **d, e** - completion and replacement of the lost and deteriorated of the stone blocks at the Sebil façade, **f** and **g** - after restoration**.**

Fine Restoration

We can summarize the fine restoration of the Sebil façade in the following:

a. Cleaning the stones with warm water and soft brushes as seen in figure 17.

Fig. 17. Wet cleaning with warm water and soft brushes

b. Salts extraction: According to the obtained data from the lab analysis and evaluation of the conservation start of the façade, it was found that the salt which threatened the stone was sodium chloride. So, mechanical methods (brushing) were used for removing the fine grains of crystallized salts and scalpels were used to remove thicker layers of salts. Sepollite poultice with distilled water was applied to the stone surface, to draw out the halite salts; this poultice is often favored by conservators of stone used for desalination, to draw out soluble salts or as a cleaning method on substrates such as limestone that respond to water cleaning [12-15]. The poultices completely covered the stone surface to a uniform thickness of about 1.0cm (fig. 18). They were allowed to dry over a period of about 48 hours. During this time, white salt crystals formed on the peaks of the clay poultice. When these salts were removed and tested, they matched with those that had been found in the water droplets. The poultice treatment was repeated five times. It is noticeable: the first and two poultices were easily removed and did not require an intervention layer of clay.

Fig. 18. Salt extraction by Sepollit poultice: **a** - The poultices completely covered the stone surface to a uniform thickness of about 1.0cm, **b** - removing the poultice, **c** - after restoration.

c. Completion of Missing Parts: It was decided to proceed to complete the missing parts of the stone units, especially if they were in poor condition and in need of rapid intervention to avoid future collapse. According to the conservation principles, and architectural/constructive specification of the Shahin Agha facade, the filling and completion material of the joints between limestone blocks should meet the following demands: compatibility with the limestone by the density and thermal expansion (similar to limestone); compatibility with the lead by the expression, appearance, texture and form. The experimental study referred that the lime mortar consisted of 2 sand + 1 lime + ½ white cement + Ediobond 65 (Basic of Latex Botadin Stearin) polymer in water (20%) provides the necessary hermetic joints between stone blocks. So, this works were carried out by conservators with lime mortar. The filling material was applied with a spatula to flatten the putty and smooth it out until it comes well to the edges of the archaeological stone surface (Fig. 20). After finishing, iron oxide was used to approximate its color to the patina of the original parts.

Fig. 19. Completion of missing parts

Fig. 20. The façade of the Shahin Agha Sebil and its artistic and architectural elements after restoration process.

Conclusions

According to field observation and experimental study results of weathering forms on the façade of Shahin Agha Sebil at Cairo, it can noted that all the façade and its artistic and architectural elements are suffering from severe damage and collapsed.

The facade wall assembly consists of a bearing limestone wall (Multiple-leaf walls). It has been built from two external stone block leaves with a void of varying thickness between them.

Most of current damage conditions of the facade are mainly due to the earthquake which has occurred on October 1992. Almost all the causes of damage and deterioration of the facade are similar to those that affect the multiple leaf masonry walls. The age of the building is another important factor to be taken into consideration.

Vertical and fine cracks in the walls were noticed which led to dangerous deterioration in the architectural elements like arches, gifts and threshold. More cracks were found at top of façade. It was required urgent treatment and conservation to avoid a lot of damage.

Architectural conservation of the Sebil façade were carried out as followed: Timber shoring was erected in order to repair a defective arch, improving the temporary structural balance and to increase resistance and avoided risk of collapse of the structural and artistic elements of the façade; Improvement of wall characteristics by lime injection (Grouting); Completion of missing parts of architectural and artistic elements by reproduction process;

Reconstructing and replacing the missing blocks, which was done to compensate the loss of the deteriorated stone on the Sebil façade.

Fine restorations also were carried out at the façade which contain: cleaning process, salt extraction and completion of missing parts.

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