

# Analytical Study for the Archeological and Historic Buildings and Facilities Restoration Projects

Matreen M. Mustafa

Department of Architecture, Canadian International College, Cairo, Egypt

Email: matry\_44@hotmail.com

**Abstract--**In Egypt, many obstacles obstruct the archeological and historic buildings and facilities restoration projects with respect to the ability to meet the relevant requirements and take the best restoration decision in spite of the status of the archeological and historic building. Due to the significance of such matter, this thesis will unveil the differences between the archeological and historic buildings and facilities as well as the factors of damage affecting thereon. In addition, this thesis will discuss the means to be used in detecting the damage in the archeological and historic buildings and facilities and the problems witnessed upon to perform the restoration projects thereof, noting that some of these problems were solved through preparing a programmed standardization system for these projects. This requires analyzing the archeological and historic buildings and facilities restoration projects in four stages to be described herein to identify the inputs and outputs of the programmed standardization system.

**Index Terms**—archeological and historic buildings and facilities – cost estimate of works – restoration projects - programmed standardization system

## I. INTRODUCTION

In most of the Arab Countries, the archeological and historic areas witnessed cultural and social changes that led to the demolition of its urban structure due to the misuse, lack of cultural awareness, destruction of services and overpopulation. This led to the deterioration of such areas. The significance of such legacy appeared upon the rise of cultural awareness in the peoples who felt the importance of such marginalized legacy, as our cultural and constructional heritage represents a great fortune that shall be kept. The international conventions stipulate that the best way to keep such legacy is to adopt the best practices in the maintenance and restoration works and to consider same an obligation of the present towards the future [1]. Such works include different kinds of treatments originated from a mindful perspective of the nature of the work and methods of restoration to be well known by the team assigned to restore the archeological and historic buildings [2]. Therefore, handling such areas requires a special care for the internal and external conservation, environment of the archeological and historic buildings. Internal conservation, environment

means the entity in charge of the conservation, i.e. the Supreme Council of Antiquities [3].

External conservation, environment of the archeological and historic buildings is determined according to the culture of the people living in the archeological area surrounding the building. [4].

Conservation is represented in the operations required to be made to the building to conserve its current position and historic features, e.g. facades, materials, general shape, finishing and constructions. During such operations, the building's facade shall be supported, protected and maintained. Revival is a special operation in which the image of the building at a certain era will be regained by removing any elements added to the building in subsequent eras. All the reparations made to the building shall be recorded. Restoration of the building elements is the optimum solution for these treatments, as the demolished parts are rebuilt and the eroded parts are replaced with materials similar to the archeological ones with respect to nature, shape, appearance, and the missing parts are completed. This will support the building or strengthen the ramshackle parts, e.g. ceilings and sills. In such cases, restoration works shall be executed to the extent that the archeological constructional style and design shall be maintained. Furthermore, the foundations shall be supported, injected and insulated and the anti-collapse walls shall be made, and the water leakage and moisture problems shall be solved, in addition to any other constructional works that maintain the historic value of buildings and their stability.

This thesis considers the problem, objective and differences between the archeological and historic buildings and facilities as well as the factors of damage negatively affecting thereon. In addition, this thesis will discuss the means to be used in detecting the damage in the archeological and historic buildings and facilities and the problems witnessed upon to perform the restoration projects thereof. Moreover, the thesis will discuss the methodology of research and the stages of analytical study of the archeological and historic building restoration projects. Eventually, the thesis will clarify the conclusion and results.

## II. RESEARCH PROBLEM

When the problems of the archeological and historic buildings and facilities restoration projects were

considered, the Researcher noticed the poor level of restoration works, drawings and specification preparation, the existence of more than one estimated cost of the restoration of one archeological and historic building. Moreover, he noticed the consultants' deficiency in determining the technical problems of the building or the exaggeration there of. Therefore, the Researcher concluded that it is necessary to prepare the programmed standardization system for the archeological and historic building restoration projects. The present thesis is submitted for obtaining the PhD in Architecture, as to the programmed standardization system for the archeological and historic building restoration projects.

### III. OBJECTIVE OF THE RESEARCH

This research aims at reaching the inputs and outputs of the programmed standardization system for the archeological and historic building restoration projects by analyzing several archeological and historic building restoration projects (Research Sample).

### IV. METHODOLOGY OF THE RESEARCH

The methodology of research is determined in the analytical methodology based on induction and inference in relation to the archeological and historic building restoration projects. The study includes twelve archeological and historic building restoration projects that are selected for analysis based on several factors, namely:

- The restoration project directly expresses the restorative treatments to the extent that the current position of the restoration treatment of every item on the archeological and historic building restoration project's cost estimate will be determined.
- The cost estimate shall include more than one item of works to consider the possibility of performing more than one treatment in the restoration process and determining the restorative treatments that may be combined together. For instance, the walls, in the construction work item, need building, rebuilding, completion, cracks treatment, joints filling and plastering. In the finishing works, the walls need plastering and coating. In the restoration works, the walls need wet packs for removing the salts.
- The restoration project shall include the latest technology and innovative methods for restoring the archeological and historic building.
- The cost estimate of restoration project shall include the items of restoring the archeological and historic building(s).
- Experienced engineering consultants shall prepare the cost estimate for restoration project, provided that such consultants shall have a great experience in the field of archeological and historic building restoration.
- The available restoration projects shall be taken into account for research analysis and study.

### V. DEFINITION OF THE ARCHEOLOGICAL BUILDING

The archeological and historic buildings are the ones registered under the Law No. 117 of 1983 and highly protected as per the international laws and conventions. In most cases, such buildings attract the interest of the whole world. These buildings represent the most important touristic destinations [5].

It is worth noting that Article 1 of the Law No.3 of 2010 Promulgating the Antiquities Protection Law stipulates that:

"In application of the provisions of this Law, any real estate or chattel is considered an antiquity whenever it meets the following conditions:

- To be the product of Egyptian civilization or the successive civilizations or the creation of art, sciences, literature or religions that took place on the Egyptian lands since the pre-historic ages and during the successive historic ages till before 100 years.
- To be of archaeological or artistic value or of historical importance as an aspect of the different aspects of Egyptian civilization or any other civilization that took place on the Egyptian lands.
- To be produced and grown up on the Egyptian lands and of a historic relation thereto, and also the mummies of human races and beings contemporary to them are considered like any antiquity which is being registered in accordance with this Law.[6]

Moreover, archeological and historic buildings are the ancient buildings that represent ancient ages and constitute a historic register of a certain community. Hence, such buildings reflect a message from the past that needs to be discovered through study.

Examples of the archeological and historic buildings:

Aslam Al Selehdar Mosque "Fig. 1," Cairo's Northern Wall "Fig. 2," and Al-Hakim bi-Amr Allah Mosuq "Fig. 3,"

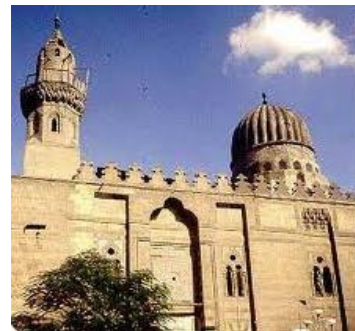


Figure 1. Aslam Al Selehdar Mosque El-Darb El-Ahmar, Cairo [7]



Figure 2. Cairo's northern wall [7]



Figure 3. Al-Hakim bi-amr Allah mosque el-gamaleya, Cairo [8]

## VI. DEFINITION OF HISTORIC BUILDINGS

Historic Buildings are the buildings registered under Law No. 144 of 2006 and include buildings that have either a cultural, artistic, architectural or symbolic value; buildings related to a national figure or national history; buildings that are considered a tourist landmark; buildings with significant architectural style [9]. The best way to deal with such buildings depends on recognizing and identifying the type of damage and problems that affect them to easily determine the manner and extent of restoration required to preserve such buildings and improve their condition [5]



Figure 4. House of the former president Anwar Al Sadat [10]



Figure 5. Bayt Sukkar [10]



Figure 6. Mohamed Mahmoud Khalil Museum [11]

Examples of Archeological Buildings include the house of the former president Anwar Al Sadat "Fig. 4," Bayt Sukkar, at Al Mahjar street, Cairo "Fig. 5," Mohamed Mahmoud Khalil Museum "Fig. 6," and Bayt Al-Suhaymi "Fig. 7,"



Figure 7. Bayt Al-Suhaymi [12]

## VII. DAMAGING FACTORS AFFECTING ARCHEOLOGICAL AND HISTORIC BUILDINGS AND FACILITIES [5]

The damage and deterioration affecting buildings and facilities resembles the illness and diseases that affect human beings. Many damaging factors adversely affect archeological and historic buildings and facilities.

Damaging factors are detailed here under:

### A. Natural Factors

Underground water and moisture creep through the walls of the buildings in high rates by the capillary action and then dried up leaving salt sediments that corrode the paintings, ornaments and engravings causing its partial or whole fall, deformation or discoloration. Moreover, the organic materials, sulphate and salts that seep into the soil through the underground water, causing instability and decomposition of the soil also affect soil properties.

### B. Urban and Human Factors

It can be reflected in the abuse of lands; performing many detrimental activities, sanitary drainage leakage; high level of underground waters; lack of urban planning; overpopulation; urban sprawl and expansion of squatter settlements around archeological and historic areas; construction of the huge building adjacent to ancient buildings and setting up industrial workshops near or inside archeological buildings and misusing them.

### C. Technological Factors

It includes heavy traffic, vibration and noise resulting from traffic, vehicle exhaust emissions, which in the presence of moisture transform into sulfuric acid resulting in corrosion of stones and bricks.

## VIII. PROBLEMS FACING RESTORATION PROJECTS OF ARCHEOLOGICAL AND HISTORIC BUILDINGS [13]

There are many problems facing contracting companies performing archeological restoration projects due to the poor performance of the various sectors of the Supreme Council of Antiquities, according to Article (11) of the presidential decree No. 82 of 1994 [14]. "Fig. 8," shows the different problems in restoration projects of archeological and historic buildings and facilities

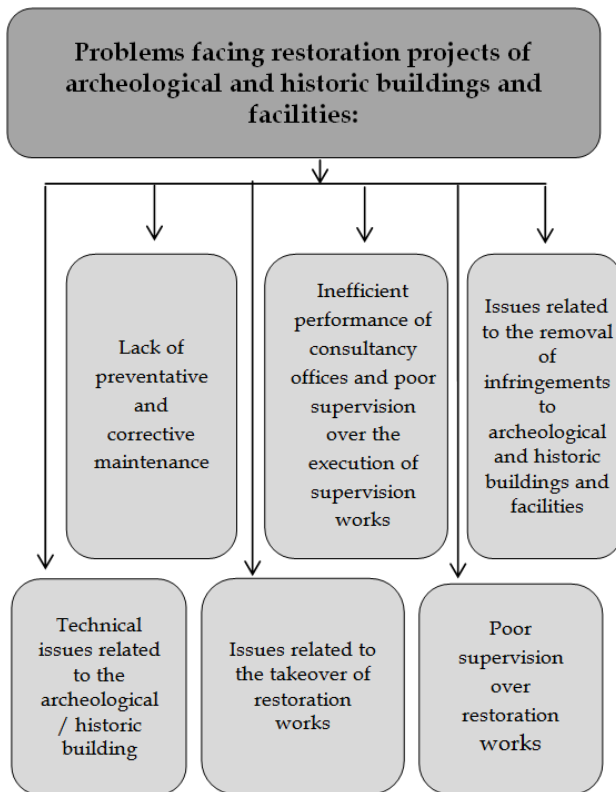


Figure 8. Problems facing restoration projects of archeological and historic buildings and facilities – prepared by the researcher

#### IX. ANALYTICAL STUDY OF ARCHEOLOGICAL AND HISTORIC BUILDINGS RESTORATION PROJECTS

The analytical study aims to highlight the current position and restorative treatments for the cost estimate of archeological/ historic building restoration projects to be analyzed, regarding each element of the building, its boundaries, sanitary drainage and electrical aspects of each item in the cost estimate of restoration projects.

The analytical study is made in four stages that can be clarified as follows:

##### A. First Stage: Study the Archeological and Historic Building and Facilities Restoration Projects

Twelve restoration projects of archeological/historic building were studied to recognize the historic background of each building and previous restoration procedures before the preparation of the cost estimate. The study includes the internal and external inspection of the building, preparation of projections, facades and architectural sectors. It also includes an accurate check of ornaments, observation of the stability and balance of the building, inspection of the foundations of the building, study utilities, networks, the location of the building; analysis of the soil and weather conditions. This study was made to identify the current position and damage of each element in the building and the area around it, in addition to the status of electrical and sanitary drainage in each restoration project.

A sample of the study includes:

- Madrasa Al-Sultan El-Ashraf Barsbay& El-Qadi Yehia Zein-Eddin Mosque,

Murad Pasha Mosque, Mosque of Sharaf Al Deen and his Brother [15].

- Museum of Al- Al-Jawhara Palace in Cairo Citadel [16].
- Khanqah and Madrasa of Sultan Barquq, Madrasa wa-Qubbat al-Nasir Muhammad ibn Qalawun, Madrasa, Sebil and Kuttab El Qadi Abdel Baset, Moheb Al Deen Abu Al Taieb Mosque [17]
- El-Gohary Mosque, The House of Gamal El Din El Dahabi, Sebil and Kuttab Taha Hussein, Waqf Al Mulla, Mosque of Ibn Taghri Bardi [18].
- Bab El Nasr & Bab El Fetouh, Cairo north historic wall from Bab Al Nasr to Darb al-Bazazra [19].
- Mosque of Almoayed Sheikh [20].
- House of Al Gedawy in Esna- Qena [21].
- Mosque of Prince Hassan in Akhmim- Sohag [22].
- Kala'at el Nakhl in Sinai [23].
- New building of the National Organization for Urban Harmony [24]
- Ahmed Ibn Tolon Mosque [25], [26].
- Bayt Al-Suhaymi [27].

The study aimed to recognize the regular works, including (On-site works, concrete, carpentry, moisture and thermal proofing, finishing, fine restorations, landscaping) in addition to electrical, sanitary and other work

##### B. Second Stage: Analyze the Current Position for Archeological and Historic Building and Facilities Restoration Projects

This stage includes the analysis of damage considered in restoration projects of archeological and historic building with regard to restorative treatments included in the cost estimate of restoration projects, and then identify the current position of every restorable element in every item of the works cost estimate. A table describing the current damage and deterioration of the building, its location and technical installations in restoration projects of archeological/ historic buildings was prepared.

The researcher prepared this table (an aspect of the deteriorating current position) based on several factors:

- Re-register the estimate cost of restoration projects of archeological/ historic buildings (research sample) based on a system that divides the items of the cost estimate of such projects into two sections:
  - *First Section:* Regular works: on-site works, concrete works, building, carpentry, moisture and thermal insulations, finishing, fine restorations and landscaping works.
  - *Second Section:* It comprised of several sub-sections being; sanitary drainage, electrical and other works (ventilation, public address, telephone, equipment, networks, control and theft alarm).

On-site works were excluded (observe tilting and structural stability, metal works, substructures, disassembling and removal and excavation and backfilling) as they are required for restoration works, different from other regular works and considered



requirements for restoration works. Therefore, separate table was prepared among the cost estimate of programs, cost estimate system for the archeological and historic building restoration projects.

- Divide the elements of the archeological and historic buildings into two groups to facilitate the analysis procedures; the *first group*: includes the soil, foundations, minaret, flooring, walls, while the *second group* includes the remaining elements of the building.
- As regards the first group of the building elements: Restorative treatments made for regular works in all cost estimates for the archeological and historic building restoration projects (research sample) in concrete, building, carpentry, thermal and moisture insulation, finishing works, fine restoration and landscaping and recognizing the damage based on which the current position of such elements was divided as follows:
  - Soil: Whole and partial deterioration
  - Foundations and Bases of Minaret: Whole and partial deterioration
  - Floorings: Whole and partial deterioration
  - Walls and Hedges: Whole, partial and simple deterioration




As regards the second group of the building elements: The restorative treatments made in the ordinary works were studied in all the cost estimates of the archeological

and historic building restoration projects (Research Sample) based on which the aspects of damage were determined and the current position is defined as a damage without divisions.

- As regards the additions (other works) made to the archeological and historic buildings: These additions include, but not limited to, the firefighting system, fire alarm system, electric heater, fans, air conditioners, public address system, computers, control system and theft alarm. They also include the location coordination works (sanctuary of the building), e.g. pavements, landscaping, walls and gates that are considered as aspects of deterioration, or deterioration and damage or nonexistent. For the current position, they are considered deteriorated or needed.

When the current position had been determined by studying the aspects of deterioration in the archeological and historic building restoration projects, the Researcher analyzed the current position of the archeological and historic building restoration projects. This was made in the light of the restorative treatments made on every element of the building and every item of the cost estimate for every single restoration project, aiming at reaching the projects having the same current position of every restorable element in relation to every item of the works cost estimate

A circle reflecting the restoration projects and its color differs according to the type of every project

		Restorations Projects		
		*Chanhah and Madrasa of Sultan Barquq, Madrasa wa-Qubbat al-Nasir Muhammad ibn Qalawun, Madrasa, Sebil and Kuttab El Qadi Abdel Baset, Moheb Al Deen Abu Al Taleb Mosque 	Museum of Al- Al-Jawhara Palace in Cairo Citadel 	Madrasa Al-Sultan El-Ashraf Barsbay& El-Qadi Yehia Zein-Eddin Mosque, Murad Pasha Mosque, Mosque of Sharaf Al Deen and his Reviver 
Ordinary concrete works	Soil partial deterioration	●		●
	Foundations partial deterioration		●	●
	Floorings partial deterioration	●		●
	Soil whole deterioration		●	●
	Foundations whole deterioration			●

Putting a circle against every restorative treatment indicates the existence of treatment in the restoration project. Otherwise, there will be no treatment in the project

Figure 9. Current position analysis table for the archeological and historic buildings restoration projects – prepared by the researcher

*How to prepare and fill in the current position analysis table for the archeological and historic buildings restoration projects:*

The top horizontal cell of the table includes the restoration projects that were previously and successively discussed in Chapter 1 of this Part. The right vertical cell

of the table includes the current position and the items of works based on which the analysis will be made. A circle, having a certain color is to be made one very previous restoration project. Upon checking the cost estimate of every restoration project, the current position will be determined in every restorable element in every item of the works cost estimate. “Fig. 9,” mentioned hereunder represents the table (the current position analysis table for the archeological and historic buildings restoration projects). The current position of Al-Ashraf Barsbay School, Judge Yehia Zein-Eddin Mosque, Mourad Pasha Mosque and Sharaf Al Deen and his Brother Mosque restoration project and Khanqah and Madrasa of Sultan Barquq, Madrasa wa-Qubbat al-Nasir Muhammad ibn Qalawun, “Madrasa, Sebil and Kuttab El Qadi Abdel Baset” and Moheb Al Deen Abu Al Taieb Mosque restoration project, as to the ordinary concrete works, is considered a partial deterioration of floorings. This is the

case in the other restoration projects. Accordingly, the projects having the same current position of every restorable element in every item in the works cost estimate will be reached.

### C. Third Stage: Analysis of the Restorative treatments of Archeological and Historic Buildings Restoration Projects

Under this analysis, the previously mentioned archeological and historic buildings and facilities restoration projects will be studied in the light of the restorative treatments made on the restorable elements in every item of the restoration projects cost estimates for every single project. This analysis aims to reach the projects that have the same restorative treatments or alternatives for every restorable element in every item of the works cost estimate.

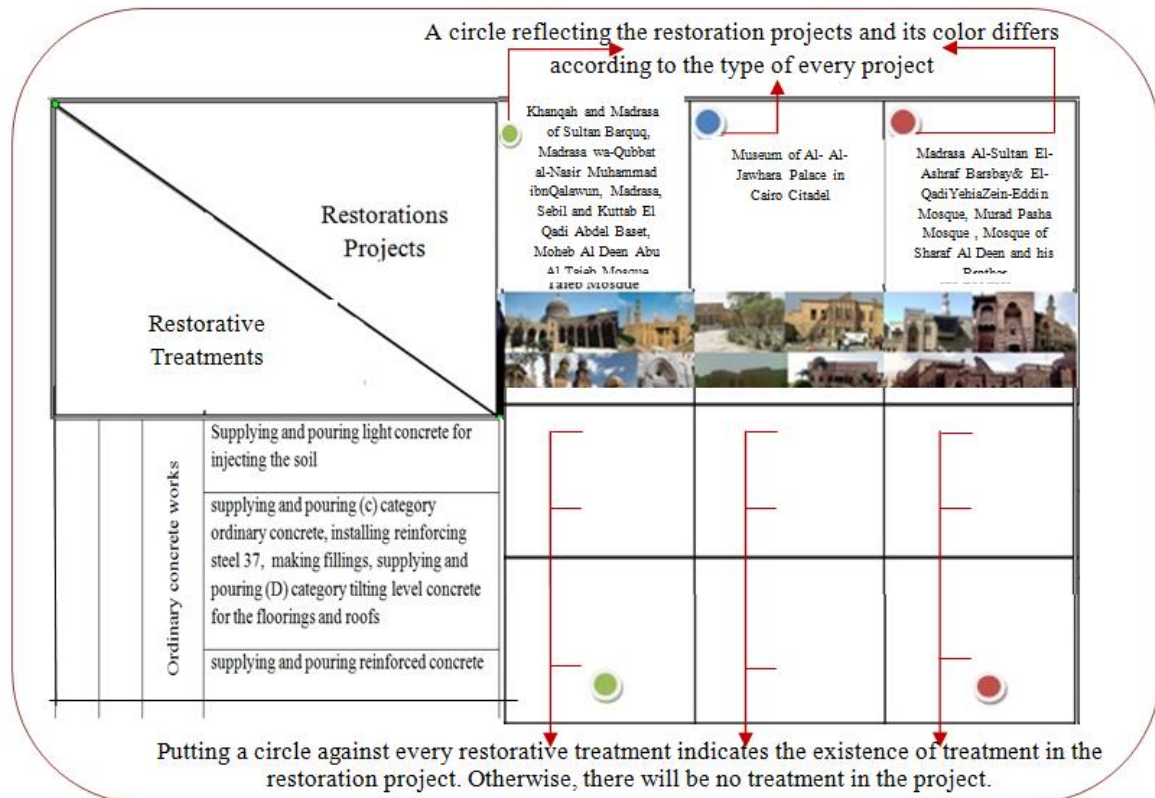


Figure 10. The restorative treatments analysis table for the archeological and historic buildings restoration projects - prepared by the researcher

*How to prepare and fill in the restorative treatments analysis table for the archeological and historic buildings restoration projects:*

The top horizontal cell of the table includes the restoration projects that were previously and successively discussed. The right vertical cell of the table includes the restorative treatments and the items of works based on which the analysis will be made. A circle having a certain color is to be made on every restoration project as previously made in the current position analysis, using the same color of the project. Upon checking the cost estimate of every restoration project, the restorative treatments will be determined in every restorable element in every item of the works cost estimate.

“Fig. 10,” mentioned hereunder represents the table (the restorative treatments analysis table for the archeological and historic buildings restoration projects). The restorative treatments of Al-Ashraf Barsbay School, Judge Yehia Zein-Eddin Mosque, Murad Pasha Mosque and Sharaf Al Deen and his Brother Mosque restoration project, Khanqah and Madrasa of Sultan Barquq, Madrasa wa-Qubbat al-Nasir Muhammad ibn Qalawun, Judge Abdul Basit School, Fountain and Quran Learning Class and Moheb Al Deen Abu Al Taieb Mosque restoration project, as to the ordinary concrete works, are represented in supplying and pouring (c) category ordinary concrete, installing reinforcing steel 37, making fillings, supplying and pouring (D) category tilting level

concrete for the floorings and roofs. This is adopted in the remaining restoration projects. Accordingly, the projects having the same current position for every restorable element in every item in the works cost estimate will be reached.

#### D. Fourth Stage: Analysis of the Current Position and the Restorative Treatments of Archeology and Historic Buildings Restoration Projects

This analysis, respectively includes the total result of analyzing the current position and the restorative treatments of the restoration projects. It also aims to reach the projects that have the same current position and restorative treatments made for every restorable element in every item of the works cost estimate.

*How to prepare and fill in the current position and restorative treatment analysis table for the archeological and historic building restoration projects:*

The top horizontal cell of the table includes the current position, while the right vertical cell of the table includes the restorative treatments and the items of works based on

which the analysis will be made. According to the circles that have different colors and represent every restoration project, the projects that have the same current position and restorative treatments of every restorable element in every item of the works cost estimates will be determined. "Fig. 11," mentioned hereunder represents the current position analysis and restorative treatment table for the archeological and historic building restoration projects. As regards the soil in the ordinary concrete works item, the current position is represented in the partial deterioration of the soil, and the restorative treatments are represented in supplying and pouring light concrete to only inject the soil in Al-Jawhara Palace. As regards the foundations in the ordinary concrete works item, the current position is represented in the partial deterioration of foundations, while the restorative treatments are represented in supplying and pouring (c) category ordinary concrete in only two projects, i.e. Wekalet El Geddawy Restoration Project in Esna, Qena and Nakhl Castle Restoration Project in Sinai. This is applied to the remaining part of the table.

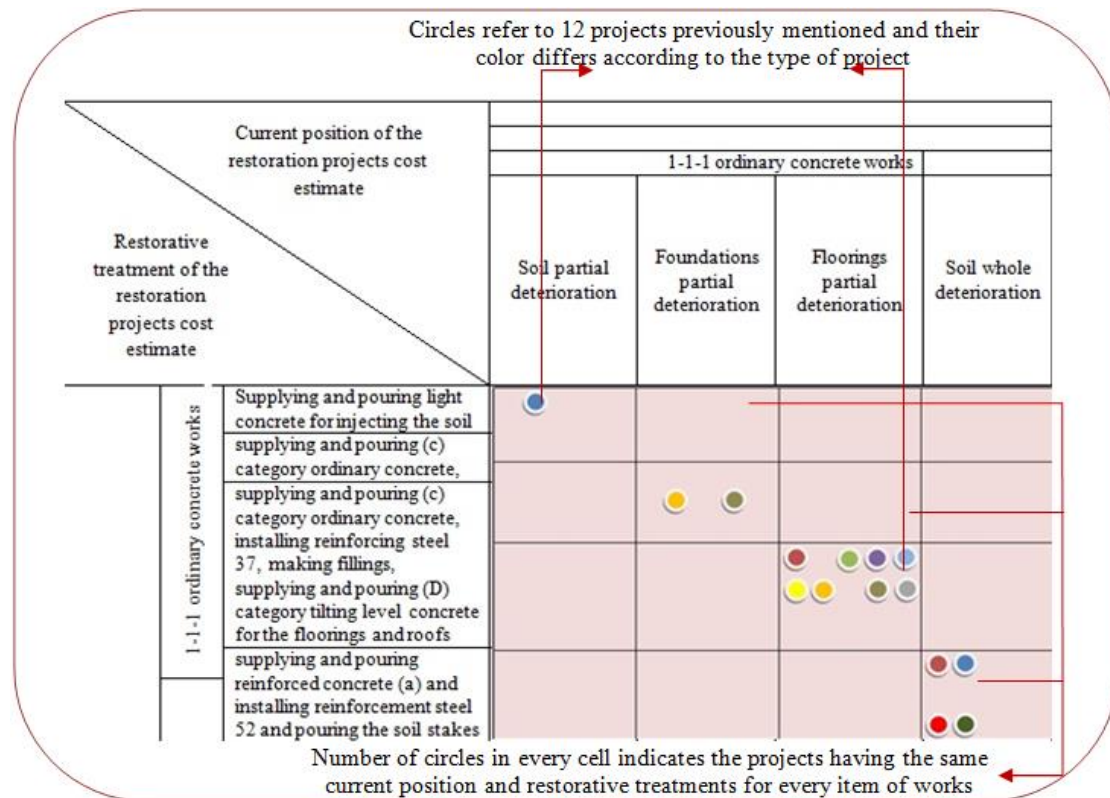


Figure 11. The current position and restorative treatments analysis table for the restoration projects - prepared by the researcher

#### X. CONCLUSION AND RESULTS

Based on the study made on the concept of the archeological and historic buildings as well as the factors of damage negatively affecting thereon, in addition to the means to be used in detecting the damage in the archeological and historic buildings, the problems witnessed upon to perform the restoration projects thereof and the analytical study of the archeological and historic building restoration projects, the following is clarified: -

The main inputs of the programmed standardization system for the archeological and historic building restoration projects are determined and represented in the following: The elements, i.e. elements of the building to be restored, elements of the building location and the sanitary drainage, electric and other elements, Status of the elements with respect to the aspects of deterioration and current position; and, The restorative treatments of the elements to be severally and successively restored according to the items of works. -The main inputs of the programmed standardization system for the archeological



and historic buildings and facilities restoration projects are determined and represented in the following: The restoration project cost estimate, including the final concept of the cost estimate related to the restoration project and the restorative treatments of the archeological and historic building elements, building location elements and technical installations, i.e. sanitary drainage, electric works, ...etc., according to the aspects of deterioration and current status in all the items of the restoration project works cost estimate.

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**Matreen M. Ali** was born in 1982 in Egypt. She currently working as a Lecturer in Architectue Department Faculty of Engineering, Canadian International Collage, Egypt. She received her Ph.D. degree from Faculty of Engineering, Cairo University in 2015, Egypt. Her research areas includes Restoration Projects, Historic Buildings and Heritage Value, Value Engineering, Islamic Architecture. She had more than 6 years of teaching experience as an Assistant teacher and Lecturer and had published two papers in international journals until now.



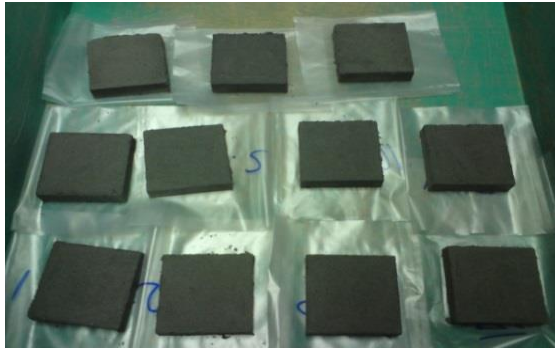


Figure 2. Specimens for small shear box after 28 days curing

Fig. 1 shows the illustration of shear box test conducted. While Fig. 2 and 3 show the sample for big shear box and small shear box after 28 days curing process.

### III. EXPERIMENTAL PROGRAM

#### A. Shear Strength Comparison between Small Shear Box (SSB) and Big Shear Box (BSB) Test

The output data obtained from both type of shear box test were analyzed based on previous and main method and theory. Results obtained have been presented in the form of table and graph to make it easily to understood. For small shear box test, the values of normal stress used were 30 kPa, 60 kPa and 120 kPa, while for big shear box test, 5 Psi (34.474 kPa), 10 Psi (68.948 kPa) and 20 Psi (137.896 kPa) have been selected. The test conducted based on unsaturated sample because for natural soil used, natural moisture content been preferred to apply the real condition of site. For stabilized material, 20% to 30% of water ratio were used respectively. Thus, for the sample results, the failure envelope did not go through zero because tests were done under unsaturated condition, so that little amount of apparent cohesion might occur [15]. This phenomenon happens even in some cohesionless soils, in unsaturated condition that particles bound together by capillary attractive forces. Accordingly, the friction angles were computed from peak shear strength. Friction angles may show curvature dependence with relatively density over a large range of normal stresses, as noted in some triaxial compression tests [16].



Figure 3. Specimens for big shear box after 28 days curing

In shear test, each specimens are subjected to normal stress  $\sigma$  to bedding plane. The test also subjected to the

shear stress  $\tau$  that cause the displacement. The shear stress will increase rapidly until the peak strength is reached. This corresponds to the sum of the strength of the cementing material bonding the two halves of the bedding plane together and the frictional resistance of the matching surfaces. As the displacement continues, the shear stress will fall to some residual value that will then remain constant, even for large shear displacements. For planar discontinuity surfaces the experimental points will generally fall along straight lines. The peak strength line has a slope of  $\phi$  and an intercept of  $c'$  on the shear strength axis. The relationship between the peak shear strength and the normal stress can be represented by the Terzaghi equation [17]:

$$\tau = c' + \sigma' \tan \phi \quad (1)$$

where  $c'$  is the cohesive strength between soft soil and specimens of PFA-Cement-Sand (modified sand column) and  $\phi$  is the angle of friction. The output raw data from shear box test have been analysed, where the peak stresses from stress-strain curve are determined and based on Formula (1), shear strengths are calculated and summarized in Fig. 4 and Fig. 5.

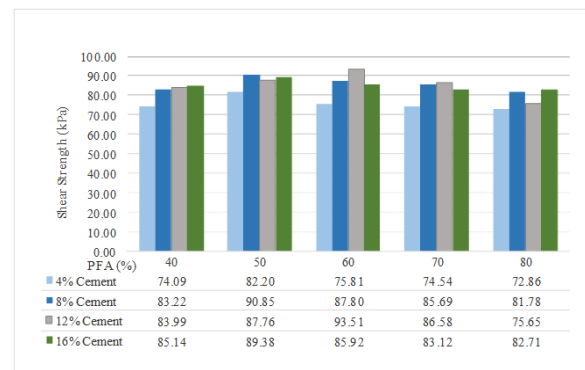


Figure 4. Summary of the shear strength of SSB for sample after 28 days curing process

Fig. 4 shows a summary of small shear box (SSB) data of shear strength for all the samples that been tested after curing process. For all samples, the shear strength are in range above 70 kPa with the highest was recorded is 93.51 kPa where the proportion of materials is 12%:60:28% (cement: PFA: sand).

By using PFA 60%, the value of shear strength almost the highest compared with the other percentage of PFA. For cement used is 4%, the value of shear strength recorded is 75.81 kPa, cement 8%, the value of shear strength recorded is 87.80 kPa and for cement 14%, the value of shear strength recorded is 85.92 kPa. For PFA used is 50% also giving the high value of shear strength where recorded that by using 8% cement and 42% of sand, the shear strength obtained is 90.85%. By using 4% cement, the shear strength recorded is 82.20 kPa where slightly highest compared with 60% PFA. This patent also same for cement used 12% and 16% that recorded shear strength 87.76 kPa and 89.38 kPa that also highest compared with 60% PFA. Thus it can be concluded that by using percentage of PFA between 50% to 60%, and cement between 8% to 12%, give the highest value of