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EVALUATING THE STRUCTURAL AND ARCHITECTURAL DAMAGE OF INHABITANT ISLAMIC STRUCTURES IN CAIRO, EGYPT: A CASE STUDY

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ABSTRACT

Islamic Cairo is a city where history comes to life and where architectural marvels proliferate, making it the city with the greatest concentration of heritage architecture in the world. Many types of structural and architectural deterioration phenomena are typically observed in Cairo's historic structures as a result of the dangers posed by numerous activities. A structural and architectural deterioration action is the misuse and reuse of historic buildings for residential purposes. Change and conversion in structural system (such as creating new apertures for ventilation or removing a column or pillar or even a wall) in addition to misuse and disregard for the historical and aesthetic value of these buildings are the primary causes of their deterioration. The purpose of this paper is to discuss the fundamental concepts involved in achieving appropriate structural and architectural damage assessment of historic Islamic buildings in Cairo, with application to the 16th-century "*Takiyya al-Sulaymaniyya*" Numerous factors, such as seismic excitation, construction defects, fires, transformation, etc., have contributed to the building's extensive structural damage. The report describes the structural system as well as the resulting damage. In addition, it investigates the causes of injury using numerical analysis and other methods. *Takiyya al-Sulaymaniyya*

KEYWORDS:

Deterioration phenomena, Misused, Conversion, Cracking, Soil settlement, Arch thrust, Finite element method (FEM).

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تقييم الأضرار الإنشائية والمعمارية للمباني الإسلامية العامرة في مدينة القاهرة بمصر "دراسة حالة"

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الملخص

القاهرة هي المدينة التي بُعث منها التاريخ كما تعد مدينة عجائب العمارة التي تحوي العديد من المباني التاريخية والأثرية التي تتميز بتنوعها المعماري والإنشائي. وتتعرض المباني الأثرية داخل مدينة القاهرة بصوره دائمة للعديد من مظاهر التلف المعماري والإنشائية كنتاج للتعرض للعديد من عوامل التلف المختلفة. ويعتبر إعادة الاستخدام والاستخدام الخاطئ من جانب قاطني هذه المباني (في حالة المتبنى الأثرية المعاد استخدامها كمسكن) من أهم العوامل التي تعرض تلك المباني للعديد من مظاهر التلف المعماري والإنشائي نتيجة الاستخدام الخاطئ او نتيجة الجهل بقيمة هذه المباني ومحاولة التغيير والتبديل في النظام الإنشائي والمعماري لهذه المباني لتتماشى مع متطلبات العصر الحديث. وتقدم هذه الورقة البحثية عمليات تقييم وتقدير مظاهر التلف المعماري والإنشائي التي تتعرض لها المباني الأثرية المعاد استخدامها كمسكن وذلك تطبيقا على مبنى التكية السليمانية (القرن السادس الميلادي) كأحد أبرز المباني الأثرية التي تعرضت لهذه الظاهرة نتيجة تعرض المبنى لبعض العوامل ومنها الاستخدام الخاطئ والتغيير والتبديل في النظام الانتشائي وتأثير الهزات الأرضية......الخ. وقد قامت منهجية تقييم التلف المعماري على دراسة النظام الإنشائي والمعماري لهذه التكية الى جانب دراسة خواص مواد البناء ودراسة التربة إلي جانب دراسة وتحليل عوامل التلف وتحليل مظاهر التلف باستخدام الطرق الرقمية (طريقة العناصر المحددة) .

الكلمات الدالة:

ظواهر التدهور؛ سوء الاستخدام؛ التحويل؛ التكسير؛ تسوية التربة؛ الدفع القوسي؛ طريقة العناصر المحددة (**FEM**).

INTRODUCTION

Historic Cairo is regarded as one of the most notable world heritage cities in the globe. Cairo is home to numerous historical districts and significant monuments that demonstrate the architectural riches of the city, not only as the capital of the Islamic world but also as an urban marvel. As such, Islamic Cairo was inscribed on the list of world heritage sites in 1979. The structural response of an existing masonry building to structural damage factors such as seismic actions is strongly influenced by a number of parameters, including plan distributions, the texture and quality of the masonry walls, plan regularity, the distribution and size of openings, floor characteristics, and the connections between vertical and horizontal elements. [1,2,3]

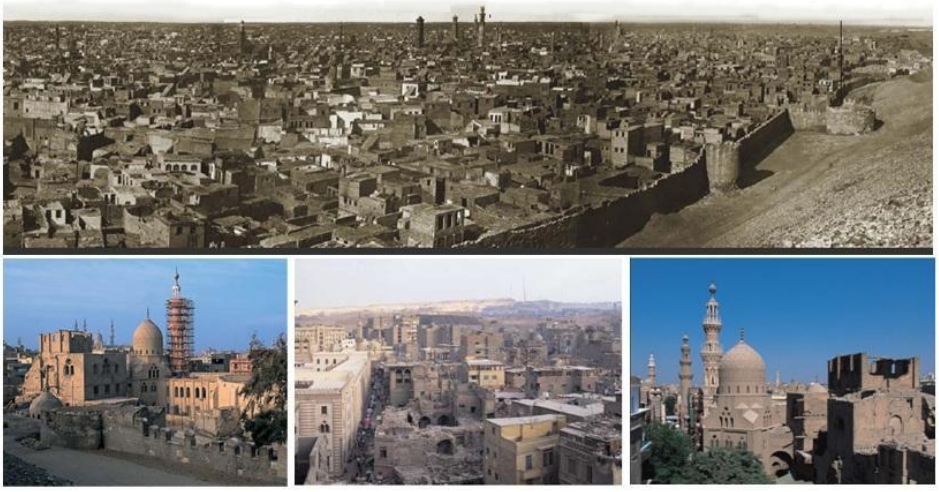

Figure 1: Historic streets, alleys, and buildings in historic Cairo (UNESCO 2012)

Structural and architectural damage occurs in historic masonry buildings when stresses due to the action or effect of external forces exceed the strength of the materials at locations of the structural elements' significant parts, either because the actions/forces themselves increase beyond expected limits or because of the deterioration of building materials. Due to the acting forces and the type of construction materials used, the structure undergoes substantial changes, including partial demolition. Due to their low deformability, brittle materials fail without warning in the form of cracking, whereas ductile materials manifest considerable.

Deformation occurs prior to failure, providing ample warning of the imminent catastrophe. [4,5,6,7]

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1. Binda L., A. Saisi, C. Tiraboschi, *Investigation procedures for the diagnosis of historic masonries*.
2.Piazza M., Baldessari C., and Tomasi R., *The role of in-plane floor stiffness in the seismic behavior of traditional buildings*, The 14th World Conference on Earthquake Engineering.
3. Anand S. Arya, Teddy Boen and Yuji Ishiyama, *Guidelines for Earthquake resistant non-Engineered construction*, International Association for Earthquake Engineering (IAEE).
4. ICOMOS, *Recommendation for the analysis*, conservation and structural restoration of architectural heritage.
5. Valluzzi M., Cardani G., Binda L., Modena C, *Seismic vulnerability methods for masonry buildings in historical centers*: validation and application for prediction analysis and intervention proposals.
6. Urquhart Dennis, *Conversion of Traditional Buildings Application of the Scottish Building Standards part 1 Principles and Practice,* Guide for Practitioners Technical conservation research and education group.
7. Anand S. Arya, *Teddy Boen and Yuji Ishiyam*a, op. cit.

Determining the causes of the structural and construction damage, as well as the related responsibilities, and presenting such data that could be used to evaluate the structural damage phenomena to *Takiyya al-Sulaymaniyya*. As will be explained in the following chapters, our strategy was based on a historical and structural evaluation and analyses of the building's structural and construction system, observed damage, building materials, and numerical investigation.*Takiyya al-Sulaymaniyya*

BULDING CHARACTERISTICS

HISTORICAL DOCUMENTATION

Historic Cairo is an urban ensemble that extends from street to alley to lane and encompasses a large number of historic buildings ranging from religious structures such as mosques and churches, to service buildings such as bathes (hammams) and structures for the charitable dispensation of water (sabils), to commercial building such as shops (khans), as well as residential structures such as palaces and houses (manazel). *Takiyya al-Sulaymaniyya* is one of the famous historic buildings in Cairo built in 950 Hegira 1543 A C located in *EL-Sorogia* street on the left-hand side of Bab-*Zeweala* (*Zeweala* gate) in *Sayeda Zeinab* district. Prince Soliman Basha built *Takiyya al-Sulaymaniyya*, and its name (*Solimania*) divers or back to his name. *Takiyya al-Sulaymaniyya* building, which is a two-storey building with box or square shape in-plan geometry, is a typical urban structure of the Othman period in Cairo as shown in Fig. 2.

Figure 2: show *Takiyya al-Sulaymaniyya* main entrance and the right-side façade

Limestone, rubble (cobble), semi fired brick, and ashlars natural masonry stones which may have had a polished, droved, or broached finish is the building materials used to build *Takiyya al-Sulaymaniyya*. The building can be considered as a historic load-bearing masonry structure. It is an excellent example of residential and religious architecture initially influenced by the Othman architecture of the 16th century. It comprises basement (underground shops), ground floor, and first floor. The plan of the building deems to be mix of different Islamic architectures plan; it looks like the plan of Islamic house as it contains rooms for student living and sleeping, these rooms looking into the courtyard.

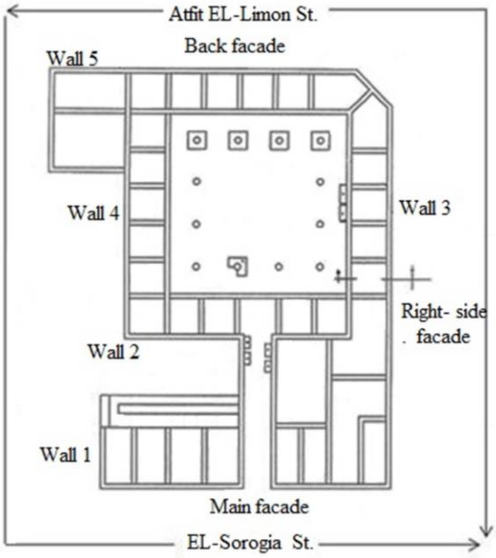

Figure 3: plan of *ELTikia Solimania*

On the other hand, the plan of *Takiyya al-Sulaymaniyya* looks like mosque plan as it contains Mehrab (niche or sanctuary) and Minber (rostrum) for pray. Otherwise, Takiyya al-Sulaymaniyya has in front of its main façade 6 small shops called in Arabic *Hawaneet* used in commercial purposes.[8] Over the years, the building was used as a shelter for accommodation of poor people. Henceforth the building remained completely forlorn and derelict. As a result of the long period of neglect and lack of maintenance it has sustained damages to a considerable extent.[9]

Figure 4: show some of inhabitants' activity inside the building.

ARCHITECTURAL AND STRUCTURAL SYSTEM

Takiyya al-Sulaymaniyya is a two-storey masonry building with basement consist of 8 small shops lies in front of the main façade which looking into El-Sorogia Street (Fig.

8. Abdelmegeed M., *Study the causes of cracks in Kobbit Elsabaa Banaat, Cairo, Egypt*, 4th international congress on science and technology for safeguard of cultural heritage in Mediterranean Basin held in Cairo
9. Abdelmegeed M., Badogiannis E., Kotsovos G., Vougioukas E., *Assessment of physical and mechanical properties of historical and traditional masonry buildings: a case study*, International Journal of conservation science (IJCS).

3). These shops divided into 4 shops in the right-side of the entrance while the other 4 shops in the lift-side of the entrance as shown in Fig. 5

Figure 5: shows the 8 small shops "Hawaneet" in the main façade of Takiyya al-Sulaymaniyya

The right façade which lies in Atfet El-Limon Street (see Fig. 3) has the second or branch entrance. Otherwise, the other façade in Atfit El-Limon Street hasn't any architectural features it is a sold wall without any openings (doors or windows) and the fourth façade essentially forms the fence separating the building from the adjacent property. Inside the building (ground floor) there are 12 small rooms looking into the courtyard as shown in Fig. 6, these rooms used in the beginning as a living room to the student who study religious sciences but later these rooms used as a shelter to dervishes "who shout and always says long live Sultan). The first floor is constructed upon half of the area of *Takiyya al-Sulaymaniyya* and now it is completely closed as it is approximately destroyed (see Fig. 7).

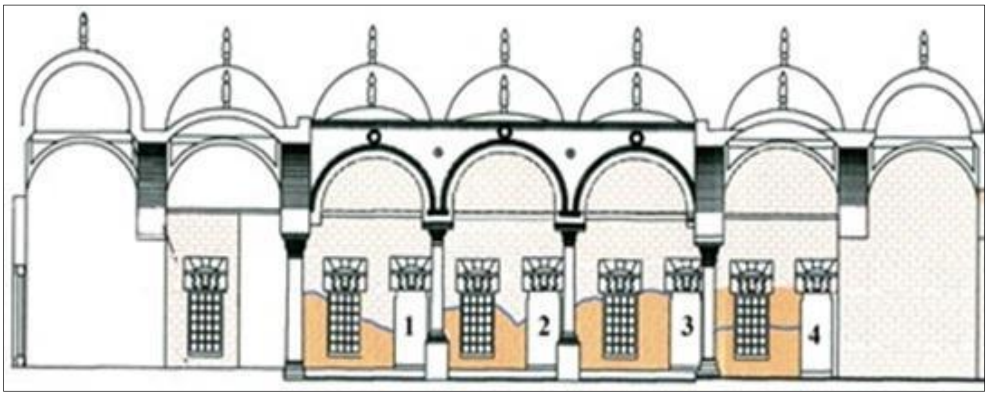

Figure 6: shows rooms on the ground floor.


Figure 7: first floor in destroyed current situation.

The ground floor roof is bricking doomed roof as shown in Fig. 6. On the other hand, the roof of the first floor is a wooden flat roof (now destroyed). Ventilation strategy in the building depending on the technique of used doomed roof in addition to the use of large windows (every room has a window, so he used doom upon the room to raise hot air in it to escape out by windows opening). Columns in *Takiyya al-Sulaymaniyya* have different column-crown shapes and elevations which proof that the builder takes them from Pharonic, Christian or Greek buildings. One the other hand, columns have approximately one shape despite of having different lengths forcing the builder to use different column bases to compensates the difference in columns lengths as shown in Fig. 8.

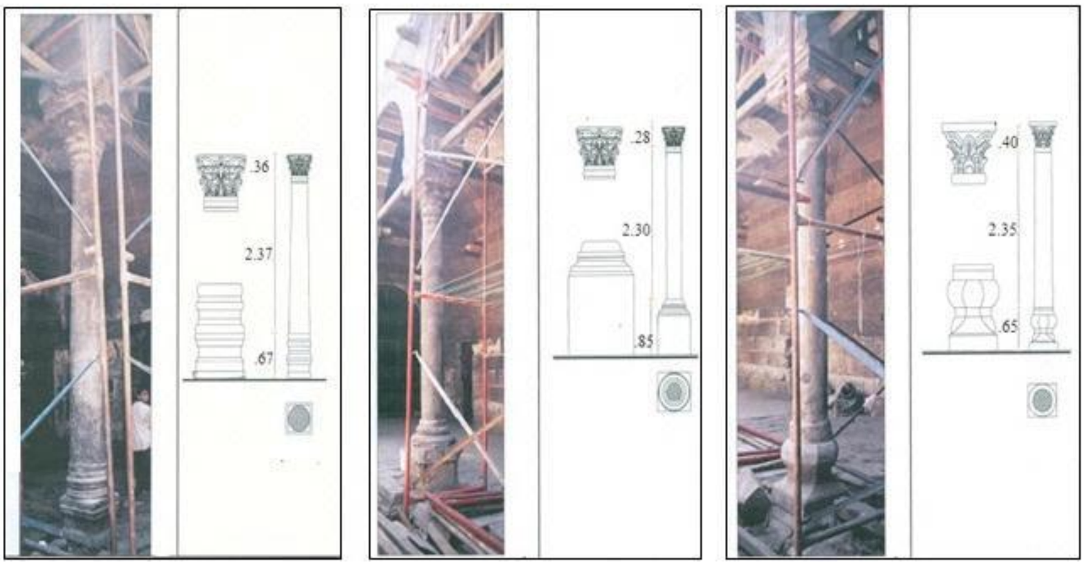

Figure 8: Columns in *Takiyya al-Sulaymaniyya*

Figure 3 depicts the bearing walls comprising the *Takiyya al-Sulaymaniyya* structural system. The building's facade is located on El-Sorogia Street (wall 1), its right-hand side face (wall 3) and wall 5 are located on Atfit El-Limon Street, and its left-hand side (wall 4) serves as a fence segregating the building from the neighbouring property. The basement encompasses the portion of the floor plan contained by walls 1 and 2. The building's planar geometry resembles a box. The floors of the first story are made of wooden beams that are merely supported by recesses formed in opposing walls. Where Roof on the ground floor extends within the portion of the plan bounded by walls 3, 4, and 5, it is a doomed roof (semi-circular and inclined dooms), as depicted in Fig. 9.

Limestone and semi-fired bricks are the primary building materials, with semi-fired bricks used on the ground floor and limestone on the foundation and ground floor. In addition to limestone and semi-fired bricks, the builder used rubbish /Ashlars or un-coursed random rubble stones (stone boulders from various sources, including river stones, field stones and quarried stones, where the stones are often used in their natural round or irregular forms; this is especially true when the materials, expertise or labour required to shape these stones is difficult to locate or prohibitively expensive). As the walls of *Takiyya al-Sulaimaniyya* consist of two Wythes, the builder used these Ashlars to cover the space between them.

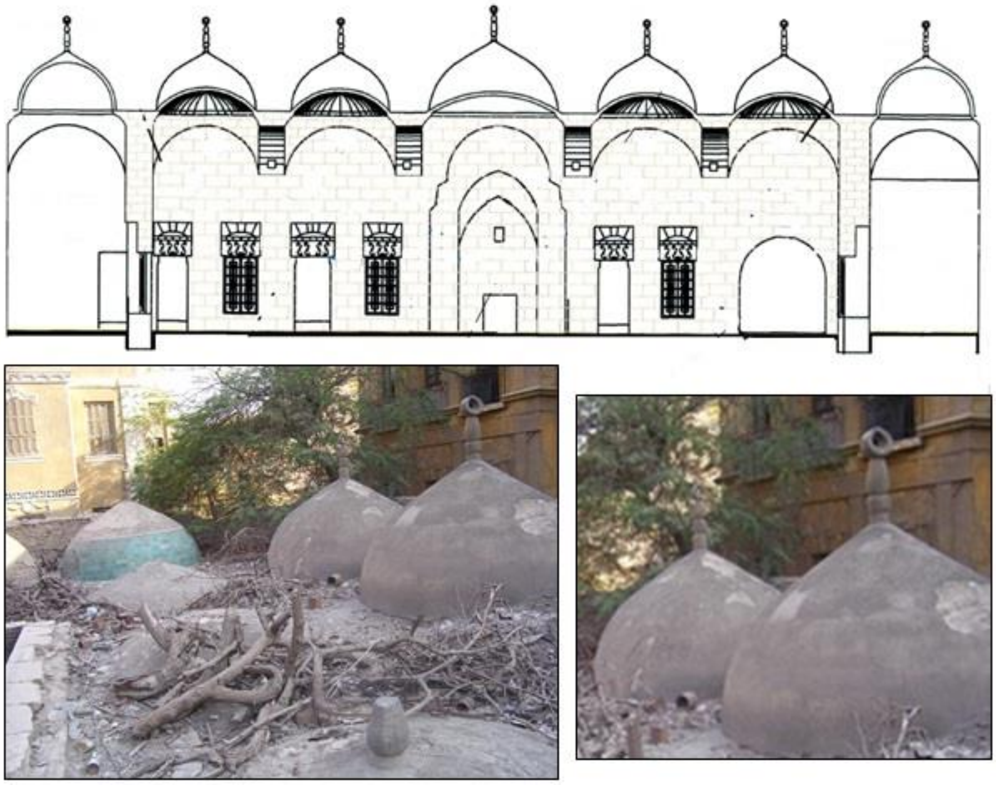

Figure 9: ground floor doomed roof (semi-circle and inclined dooms

DAMAGE IDENTIFICATION AND MAPPING

When thinking of the damage processes or damage mechanisms, the essence of it is the interaction between the building and the surrounding environment; in fact, the continuous change of the surrounding environment plays an important role in the historic masonry buildings deterioration.[10, 11] Historic massive masonry structures frequently exhibit very typical mechanical deterioration phenomena such as the formation of vertical cracking and the local detachment of the outer Wythes or layers in the case of multiple-leaf walls. Such types of damage may occur due to various causes such as, seismic action, foundation settlement, overloading due to structural modifications (e.g. added story or change in the use of the building) chemical, physical and mechanical degradation of building materials. [12,13,14,15]

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10. Sharma, R., and Maitis, *Conservation of ashlars monuments challenges and need for new strategies, in Conservation*, preservation and restoration.
11. Valluzzi Maria Rosa, Binda Luigia, *Modena Claudio*, *Mechanical behavior of historic masonry structures strengthened by bed joints structural repointing*, Construction and Building Materials.
12. ICOMOS, *Recommendation for the analysis*, conservation and structural restoration of architectural heritage.
13. Valluzzi Maria Rosa, Binda Luigia, *Modena Claudio*, op. cit.
14. Honeyborn David B., *Weathering and decay of masonry" in conservation of building and decorative stone*.
15. Anand S. Arya, Teddy Boen and Yuji Ishiyama, *Guidelines for Earthquake resistant non-Engineered construction*, International Association for Earthquake Engineering (IAEE).

Figure 10: Out-of-plan-failure and cracking in wall 1

From visual observation, it has been established that the *Takiyya al-Sulaymaniyya* suffer significant structural damage in the perimeter masonry walls, such as out-of-plan failure in wall 1 in first floor (main façade), soil settlement and arch thrust, failure in localized regions and large deflections of the bearing members of the roof structure, active deep cracks between perpendicular/vertical walls, collapse of walls and corner wall connections (see Figs 10, 11, and 12) .Beside the above deterioration phenomena there are a lot of inclined cracks distributed in the building structural units, detachment of mortar and wall plaster, damp rise in the walls due to rise of groundwater level under the building, finally due to the daily misused of inhabitants the building suffers a lot of deterioration phenomena. As mentioned above, the building suffers a lot of active cracks in walls and dooms. Cracks were surveyed visually and photographically. The survey campaign revealed a distribution of deep vertical cracks crossing the lime mortar between limestone courses inside and outside of the building.

Figure 11: soil settlements

Figure 12: Daily trade activity in EL-Tikia EL-Solimania shops

As shown in Fig. 13, the near vertical cracking suffered in the region of the connection of intersecting bearing walls occurred at some distance from the connection itself. Otherwise, dooms suffer active deep cracks as a result of soil settlement. Dooms cracking indicate that the movement of the soil under the columns bases lead to move the columns down towards the settlement which lead to increase the moment in dooms side more than the opposite side leading to increase tensile force rather than tensile strength of mortar and the result is active deep cracks in the dooms as shown in Fig. 13.

Figure 13: Active vertical cracking in dooms and perpendicular walls connection reigon

Otherwise, the timber roof is supported on the peripheral walls on short isolated wooden planks not tied together so as to create a bracing system capable of preventing the horizontal displacement of the roof support, which is restrained entirely by friction across the wall width, the latter eventually leading to failure in the form of cracking in wall 1 (main façade) in the first floor. On the other hand, the building built with different kinds of masonry units (stone, semi-fired brick, and Ashlars) at the different stories; as a result, the lateral rigidities of each story differ, and such differences in stiffness and loads increase the risk of failure, and the absence of floor/roof diaphragm increased the out of plan failure as shown in Fig. 14.

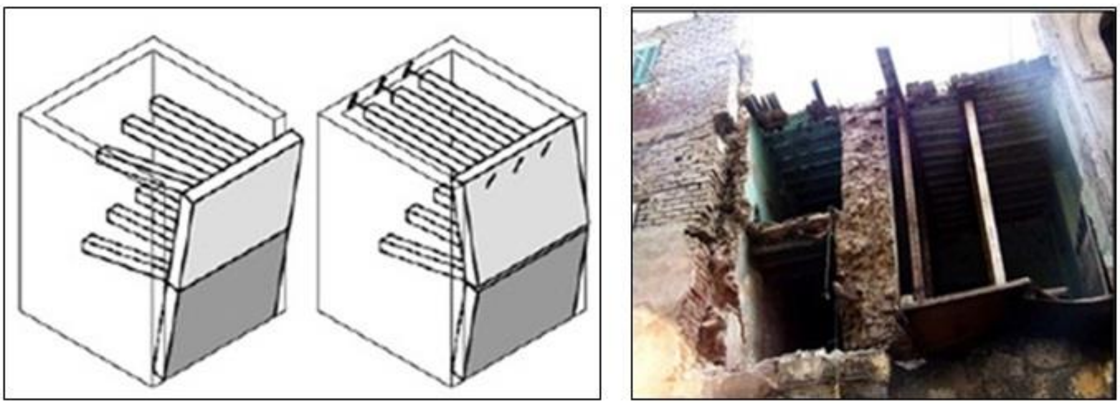
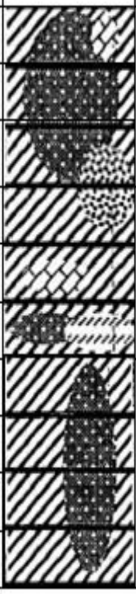


Figure 14: out-of-plan failure in wall 1 (main façade) at first floor

SOIL SURVEY

Small exploration shafts or soil core drilling must be done for the geometrical survey of the soil strata in order to identify soil properties. In-situ and laboratory tests on the soil under the building foundations are also needed in order to predict settlements causes or the state of stress and strain applied on the soil under the building foundations to understand the causes of a collapse or settlement.[16,17,18] One can notice soil settlement clearly in many places inside *Takiyya al-Sulaymaniyya* building (the courtyard and Kiblah Ewan) as shown in Fig. 11. To identify the causes of soil settlement three soil core drilling were made in different settlement points and the results of these soil core drillings shown in table No. 1, 2, and 3. The first soil core drilling "boreholes" shown in table 1 located in the middle of North-east nave, this nave is the most affected one by soil settlement and arch thrust. Soil settlement under the bases of columns supported the arch led to columns moving down in the direction of the settlement and the result is arch thrust.

Table 1: shows the results of soil core drilling No. 1

Depth m	Soil section	Soil Strata classification
1		Dust, brick pieces, silt and mud (rubbish soil)
2		
3		
4		Brown mud, brick and pottery pieces, silt, and brittle cohesive mud
5		
6		
7		Brittle cohesive mud, cohesive mud with silt and lime-mud
8		
9		
10		

Otherwise, the soil core drilling No. 2 (second soil core drilling) shows that the level of ground water began to appear in the first meter of the soil core drilling and the continuous change in the ground level helps in the swelling and shrinking of the mud soil under the building foundation. Groundwater can be an undulating up and down during the year. This movement helps in dissolve the organic compounds in the mud and rubbish soil under the building which lead to soil settlement and the result is arch thrust.

16. Binda L, Gatti G, Mangano G, Poggi C, Sacchi Landriani G., *The collapse of the Civic Tower of Pavia: a survey of the materials and structure.*
17. Binda L., A. Saisi, C. Tiraboschi ,*Investigation procedures for the diagnosis of historic masonries*, Construction and Building Materials.
18. Abdelmegeed M., *Study the causes of cracks in Kobbit Elsabaa Banaat*, Cairo, Egypt, 4th international congress on science and technology for safeguard of cultural heritage.

Table 2: shows the results of soil core drilling No. 2

Depth m	Soil section	Soil Strata classification
1		Dust, brick pieces, silt and mud (rubbish/fills soil)
2		
3		Brown cohesive mud, and pieces of bricks (rubbish)
4		
5		Pieces of limestone and mud
6		Brown brittle mud mixed with rubbish/fills soil
7		
8		
9		
10		Bright cohesive mud mixed with lime powder
11		
12		
13		
14		
15		

Table 3: shows the results of soil core drilling No. 3

Depth m	Soil section	Soil Strata classification
1		Dust, and brittle brown mud mixed with rubbish or soil
2		
3		
4		brittle brown mud mixed with rubbish or soil, and cohesive mud
5		
6		
7		

DAMAGE ASSESSMENT BASED NUMERICAL ANALYSIS

The analysis methods proposed for masonry elements up to the second half of last century were essentially based on the techniques of graphic statics and on the principles of structural mechanics available at that time. [19,20] Finite element method is usually adopted to achieve sophisticated simulations of structural behavior. A mathematical description of the material behavior, i.e. the relation between the stresses and strains at any point with the structure is necessary for this purpose. [21 ,22]

19.Valluzzi M., Cardani G., Binda L., *Modena C, Seismic vulnerability methods for masonry buildings in historical centers: validation and application for prediction analysis and intervention proposals*.
20. Binda L, Gatti G, Mangano G, Poggi C, Sacchi Landriani G., *The collapse of the Civic Tower of Pavia: a survey of the materials and structure.*
21. Valluzzi M., Cardani G., Binda L., Modena C (2004*) " Seismic vulnerability methods for masonry buildings in historical centers: validation and application for prediction analysis and intervention*.
22. Frunzio G., Monaco M. and Gesualdo A., *3D F.E.M. analysis of a Roman arch bridge*.

The identification of the causes of damage is based on the results obtained by finite element analysis of the building, in its initial state, under the service loading and in its current situation under the effect of deterioration phenomena. The analysis results are expressed in the form of diagrams indicating the development of internal stresses. The aim of the numerical work described in the following is, on one hand to evaluate the building structural behavior, establishing a relation between the intensity of deterioration factors effect on *Takiyya al-Sulaymaniyya* building and different damage phenomena especially cracking. On the other hand, to establish whether the deficiencies in the building's structural characteristics identified in a preceding section are indeed the underlying cause of the damage. The commercial program (SAP2000) was used in order to perform the iterative procedure adopted, where linear dynamic modal analysis by response spectrum is used at each step.

MATERIAL PROPERTIES

Since the analysis performed was linear, elastic properties are sufficient for providing an adequate description of material behavior. The masonry bearing walls were assumed to be homogeneous and isotropic. [23] The mechanical characteristics of the samples were established from uniaxial compression tests. The samples chiseled out of the walls were machined to form cubes, whereas those cored out from larger stones machined to form cylindrical specimens. As indicated in Table No. 4 the samples were collected from foundations limestone, paved stone or tiles in ground floor, and walls limestone.

Table 4: Masonry mechanical characteristics

Data	Material type	Specimen place		
		foundations	Paved stone	walls
Diameter (cylindrical specimens)	Limestone	95 cm	95 cm	95 cm
Height (cubic specimens)	Limestone	120 cm	124 cm	110 cm
Compressive strength (cylindrical specimens) kg/cm2	Limestone	65	94	137
Compressive strength (cubic specimens) kg/cm2	Limestone	73	96	140

During compressive strength testing to limestone the following was observed:

- All the specimens collected from foundations, paved stone, and walls were cracked in vertical direction.

23. Abdelmegeed M., Badogiannis E., Kotsovos G., Vougioukas E., *Assessment of physical and mechanical properties of historical and traditional masonry buildings: a case study*, International Journal of conservation science.

- Compressive strength of limestone specimens has different values, where the specimens collected from foundations and paved stones have low values on the contrary the specimens collected from walls have high values when comparing with Compressive strength values of foundations.
- Limestone compressive strength in Takiyya al-Sulaymaniyya building have low values due to the hard attack of deterioration factors to limestone specially the rise of ground water which affected on foundation limestone, and this is clear in the effect of ground water effect on the compressive strength value to foundation limestone which was half value comparing with limestone walls value (as shown in table No. 1)

NUMERICAL MODEL

A numerical method was carried out to characterize the dynamic behavior of the structure. A nonlinear dynamic analysis was conducted using SAP 2000 software. Structural elements and materials were chosen which gave the most realistic simulation of the building's behavior. The numerical method was performed considering that the building was not occupied. So only the mass of the building structural elements was considered, without including any live load, to have a better simulation to the real structure behavior of the building. Figures from 15 to 18 show the results obtained from stress analyses by finite element method to Takiyya al-Sulaymaniyya building. On the other hand, the figures provide an indication of the deteriorated shape of the architectural and construction elements of the building and the distribution of tensile and compressive stresses in these elements which clearly exceeding the strength of the building materials (masonry) used in the construction of Takiyya al-Sulaymaniyya building.

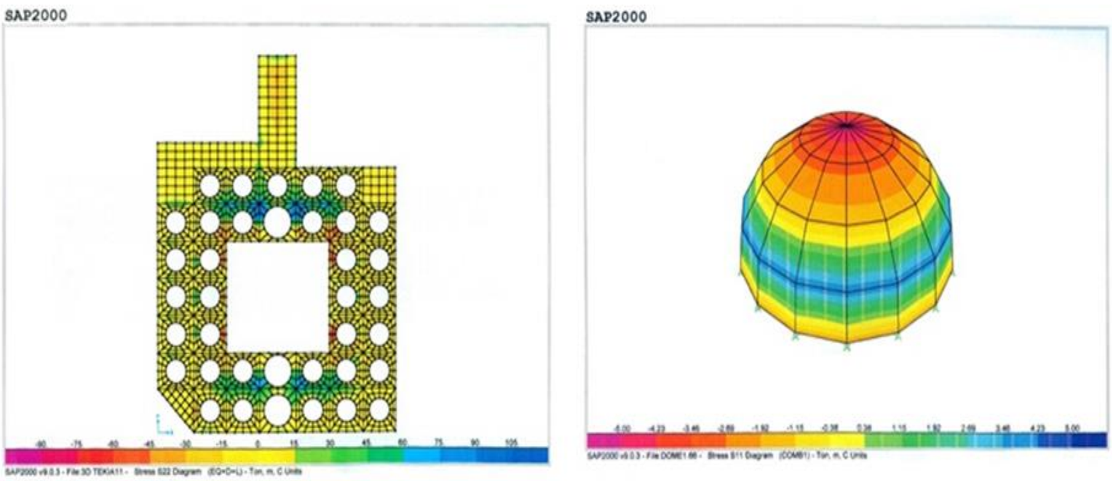


Figure 15: Tensile stresses (in Ton/m^2) exceeding the tensile Strength of masonry developing at the critical parts of the roof (area between small and big dooms)

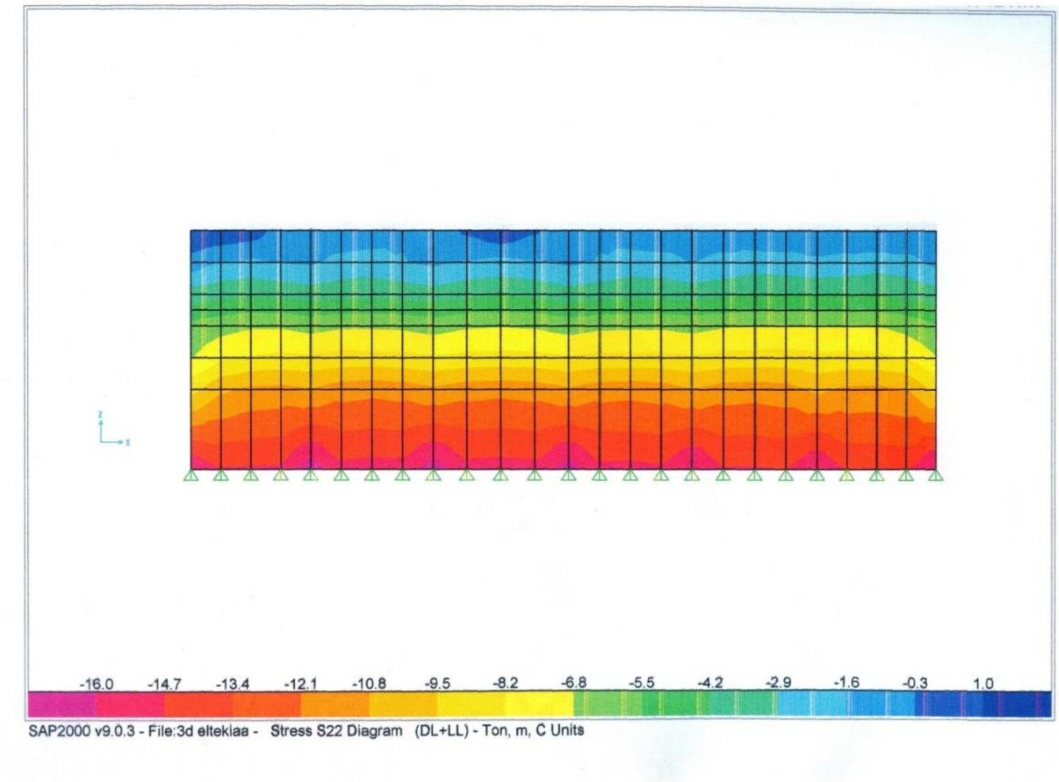
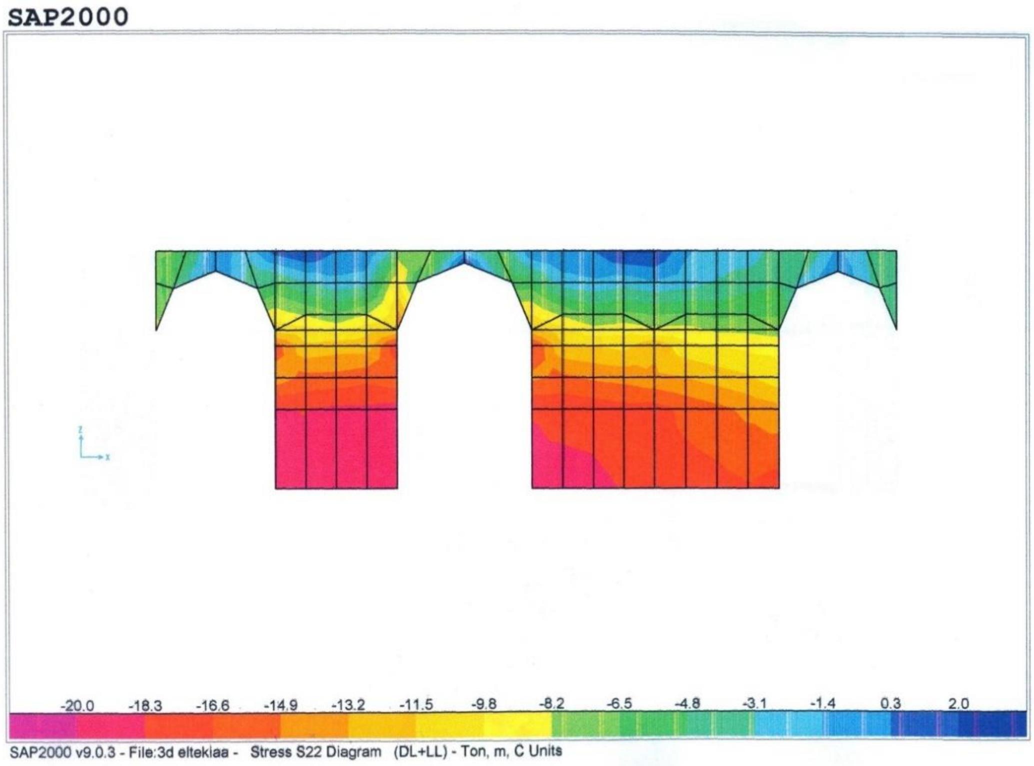


Figure 16: shows the tensile stresses (in Ton/m) exceeding the tensile strength of masonry developing at the wall crowning and the high value of compressive



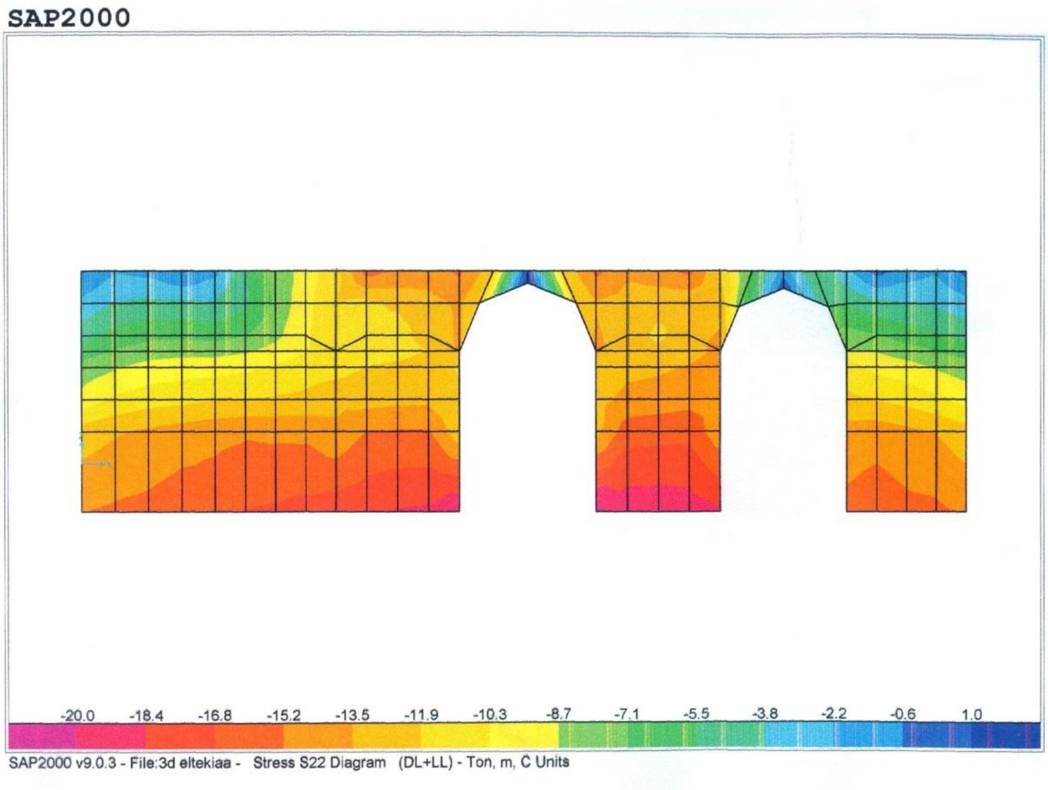
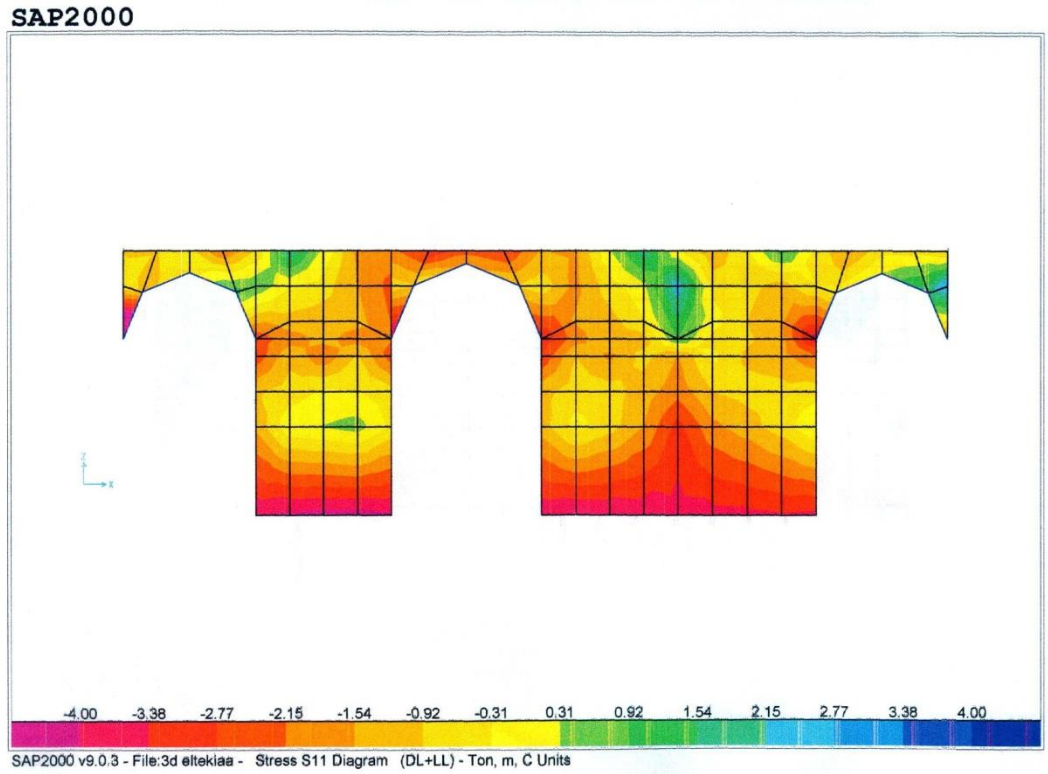


Figure 17: Tensile and compressive stresses (in Ton/m) where tensile stresses exceeding the tensile strength of masonry developing in the region upon the arches and wall crowing. The compressive strength exceeding in the lower part of the wall between the two arches.



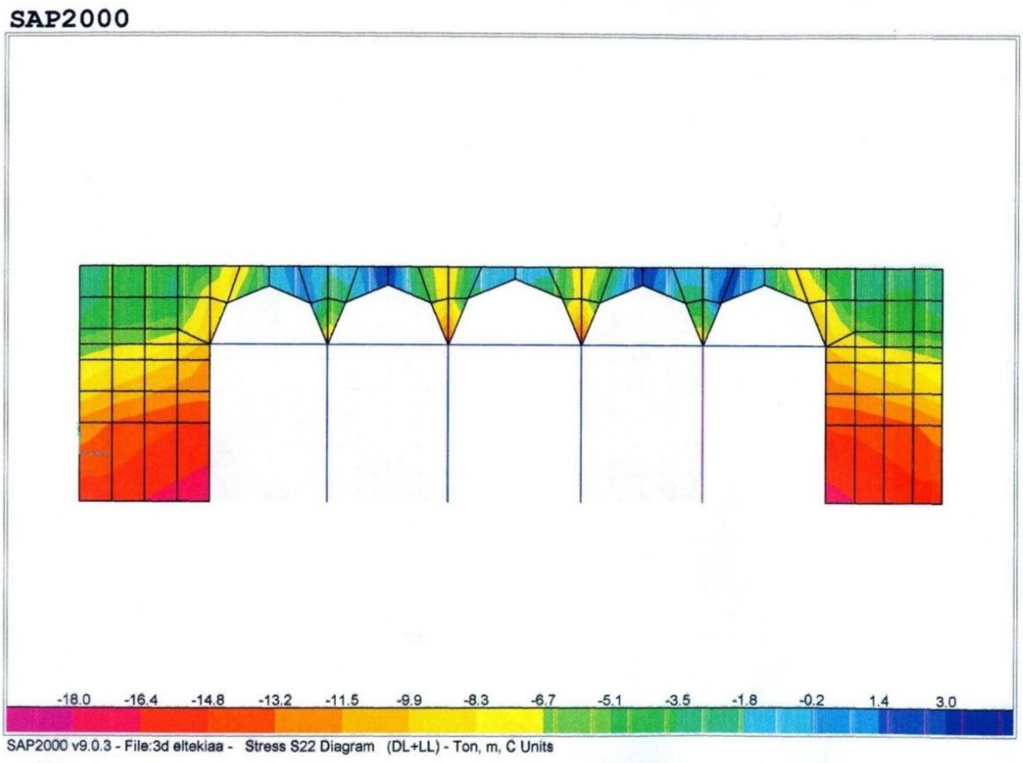


Figure 18: shows the result of tensile and compressive stresses (in Ton/m) in arches Takiyya al-Sulaymaniyya building. Tensile stresses in arches exceeding the tensile strength of its building materials, the same in the wall crowing.

DISCUSSION

From the evaluation of the current situation of the *Takiyya al-Sulaymaniyya* building and the observed damage and its causes identified both visually and numerically (results of the stress analysis), it can be seen that the building has some positive structural characteristics; however, it also has a large number of structural failures. The positive structural features of the building, such as the ground floor apertures (doors and windows), have been designed with a relatively narrow width and are arranged nearly symmetrically. The building's bearing walls have sufficient thickness to withstand loads and stress. The connection between intersecting walls (large coursed limestone connection) is determined to be sufficiently monolithic. The use of fired bricks in the first floor reduces the loads applied to the walls of the ground floor, and the use of inclined, tiny floor dooms reduces the stresses on the bearing elements. On the other hand, significant shortcomings (structural failures) of the building include faults in the choice of building soil (difficult or filled soil as indicated in tables 1, 2 and 3), the absent or inadequate connected at the intersections of first floor walls and there are no ties or ring beams at the floor and roof levels as shown in Fig. 18, lack of vertical confining element in first floor walls. Otherwise, one of the most structural failures in historic buildings is the lack of diaphragmatic action at the levels of floors and roof that would contribute to the monolithic response of the building under seismic excitation; finally, the lack of bracing at the wall crowning has a negative effect at the bearing wall-roof interaction. Masonry, in structural point of view, exhibits high load-carrying capacity in compression but in the same time it is much lower capacity in tension. In Takiyya al-Sulaymaniyya building large spans are covered by using domes that allow forces to be transferred in compression. These masonry domes, typically found in a state of structural distress appearing in the form of cracking as shown in Fig. 13. Cracks in the dooms due to the development of tension stresses in the top of the dooms because of the effect of soil settlement under the bearing columns bases that created additional tensile forces exceeding the tensile strength of its building materials. The tensile stresses developing at the main façade wall under the design loading conditions were found to exceed the tensile strength of the masonry. This explains the causes of the cracking observed in the building, attributed to the lack of a bracing system to prevent the horizontal displacement of the wooden roof. In T*akiyya al-Sulaymaniyya* building, in spite of using larger limestones at the corners, in order to provide an appropriate connection between the perpendicular walls, Atfit-El-Limon intersecting bearing walls suffered active vertical cracking occurred in the region of the connection itself as shown in Fig.13. Intersecting bearing walls cracking in this region confirms that the region exposure to forces (tensile failure) exceeded the resistance forces to protect these corners from cracking. On the other hand, Figs. 16 to 18 show the high value of tensile stresses in the courtyard wall crowing which exceed the tensile strength of its building materials, this high value of tensile stresses due to the movement of soil (soil settlement) under the columns bases and the presence of many heavy dooms adjacent to courtyard wall crowing (see Fig. 9). Otherwise bearing walls in the building suffered high value of stresses upon them as shown in 16, 17 and 18 the values of the stresses varying from 18 to 20 Ton/m^2. The presence of underground water under the building (in the depth of -1m as described before) with the help of high percentage of pore size of the limestone used in the building the moisture transfers rapidly both vertically and horizontally to limestone (height of moisture movement). So we can conclusion that the main causes of the unsatisfactory or poor resistance of the masonry walls in Takiyya al-Sulaymaniyya are the poor physical properties and the presence of under groundwater that contributing to the deterioration of the building limestone through rising damp followed by salt weathering phenomenon. This phenomenon leads to one outcome type before the effect (alternative hydration and crystallization cycles) and another type after it (full disintegration mechanisms and forms). From observed damages and the methods of damage assessments (material properties and numerical analysis) we can conclusion that the significant shortcoming of Takiyya al-Sulaymaniyya building is the lack of diaphragmatic action at the levels of floors and roof that would contribute to the monolithic response of the building under seismic excitation. Another shortcoming is the use of heavy domes which increase the likelihood of stresses upon the bearing walls.

CONCLUSIONS

Historic Islamic structures may have a single function, such as religious structures (mosques and churches), service buildings (shops, baths, caravanserais), and residential structures (palaces and houses); however, there are also structures with multiple functions, such as Takiyya al-Sulaymaniyya, which was constructed as a religious school and a place to gather dervishes. The Takiyya al-Sulaymaniyya plan is a combination of various Islamic architectural plans; it resembles a home plan as it contains rooms for student living and sleeping. On the other hand, it appears to be a proposal for a mosque because it includes a Mehrab (niche or sanctuary) and a Minber (rostrum) for prayer. Otherwise, Takiyya al-Sulaymaniyya typically has small stores called Hawaneet (small shops) in Arabic that are used for commercial purposes in front of its main facade. Inhabitant archaeological buildings experienced a number of deterioration phenomena as a result of social, economic, and physical factors, such as the misuse and disregard of the historic and aesthetic values of these buildings, low family incomes and an economic base, the aftermath of the 1992 earthquake and a lack of public investment and routine maintenance of city infrastructures, the absence of essential community facilities and services, and the severe assault of environmental factors (grout). Openings (doors and windows) in numerous historic Cairo-Egypt structures were designed with a relatively narrow breadth and a nearly symmetrical arrangement to withstand loads and stress. Wide thickness of bearing walls with the appearance of sufficient perpendicular walls connection (large, coursed limestone connection), the use of fired bricks in the first floor to reduce the loads applied on ground floor walls, and inclined small floor dooms all contribute to the building's ability to resist the effect of deterioration factors and reduce stresses on bearing elements. One of the most common causes of structural failure in Cairo's historic structures is the absence of diaphragmatic action at the floor and roof levels, which would contribute to the building's monolithic response to seismic excitation. The main causes of the unsatisfactory or poor resistance of the masonry walls in Takiyya al-Sulaymaniyya are the poor physical properties and the presence of subterranean water, which contribute to the deterioration of the building limestone via rising humidity and salt weathering. When constructed on poor property soil (fills/rubbish soil), a great deal of significant injury occurred to historic buildings. These phenomena include settlement, wall fracture, and arch thrust, among others. High dead loads can activate time-dependent phenomena (creep), resulting in the overloading of load-bearing elements due to internal stress redistribution, which can lead to unexpected failures in the form of fracture extension and widening. Wall-diaphragm separation caused by inadequate or absent tension ties can result in out-of-plane wall failures; missing shear ties can result in the diaphragm sliding along the in-plane walls and then pressing against the walls perpendicular to the movement, causing corner damage to the walls. Failures of wall diaphragms are frequently associated with narrow walls (such as Two-Wythe walls in upper stories), poor mortar conditions, and insufficient overburden pressure. The rehabilitation of inhabited archaeological structures must be a top priority for the government due to the fact that these structures have sustained a great deal of significant damage, which may lead to the destruction of the buildings and the death of the inhabitants.

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