Heritage For Peace

The Conservation of Hala Sultan Tekke, Larnka – Cyprus

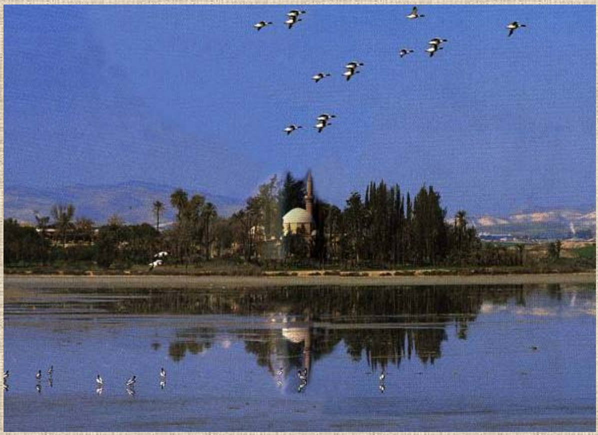
International ICOMOS Committee

CIVVIH - ANNUAL MEETING
NAPLES, ITALY

3 – 6 September 2012

Prof. Saleh Lamei

CIAH



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"The two most important and symbolic shrines on the island of Cyprus are currently being restored in a project that may offer a creative form of archeological diplomacy to bring together the island's sundered halves."*

* Recitation from *"Diplomacy through Archaeology of Old Temple and Modern Politics."* by Caroline Williams, *Cairo Times Magazine – October 2002*

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"The ambitious plan involves the ***Hala Sultan Tekke***, a Muslim shrine located in the Greek Cypriot south, and the ***Apostolos Andreas Monastery***, a Christian shrine in the Turkish Cypriot controlled north." *

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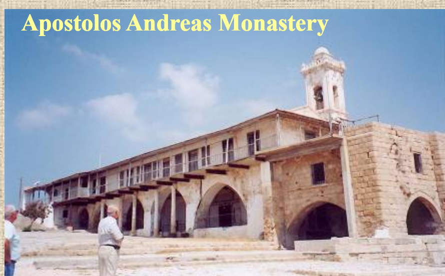
"Both sites were major pilgrimage destinations until the events of 1974 divided the island, and mounting restrictions left the shrines abandoned." *



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"Through a gift of $5.5 million from the US Agency for International Development (USAID) and the United Nations Development Program (UNDP) this collaborative restoration initiative offers hope for Cyprus's future." *

His Excellency Donald K. Bandler US Ambassador to Cyprus during his visit to the Hala Sultan Tekke Mosque

His Excellency Donald K. Bandler US Ambassador to Cyprus during inauguration ceremonies for launching the two projects

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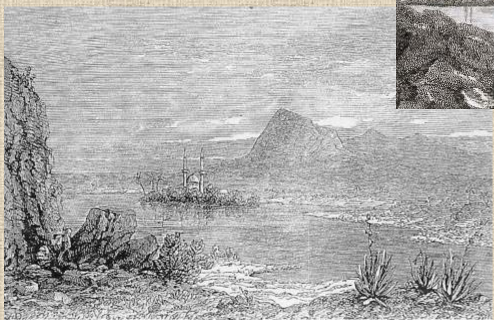
Tekke Site in 19 th Century

Henry Light: View of Salt Lake at Cyprus, engraving, from the book "Travels in Egypt, Nubia & Cyprus in the year 1814, 1818".



Amadée Damour: Tekkyé of Umm Haram, engraving, from Le Monde Illustré, 1878.

Ref.: Rita Severis : Traveling Artists in Cyprus, 1700-1960, UK 2000

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Tekke Site in 19 th Century

Hugh Sinclair: Mosque of Umm Haram, 1878, water colour. Private Collection

Anon: Larnaka,1871, watercolour. Private collection

Ref.: Rita Severis : Traveling Artists in Cyprus, 1700-1960, UK 2000

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Tekke Site in 19 th Century

I.L.Wilson: The Tekke of Umm Haram, c.1880, watercolour. Private collection

Ref.: Rita Severis : Traveling Artists in Cyprus, 1700-1960, UK 2000

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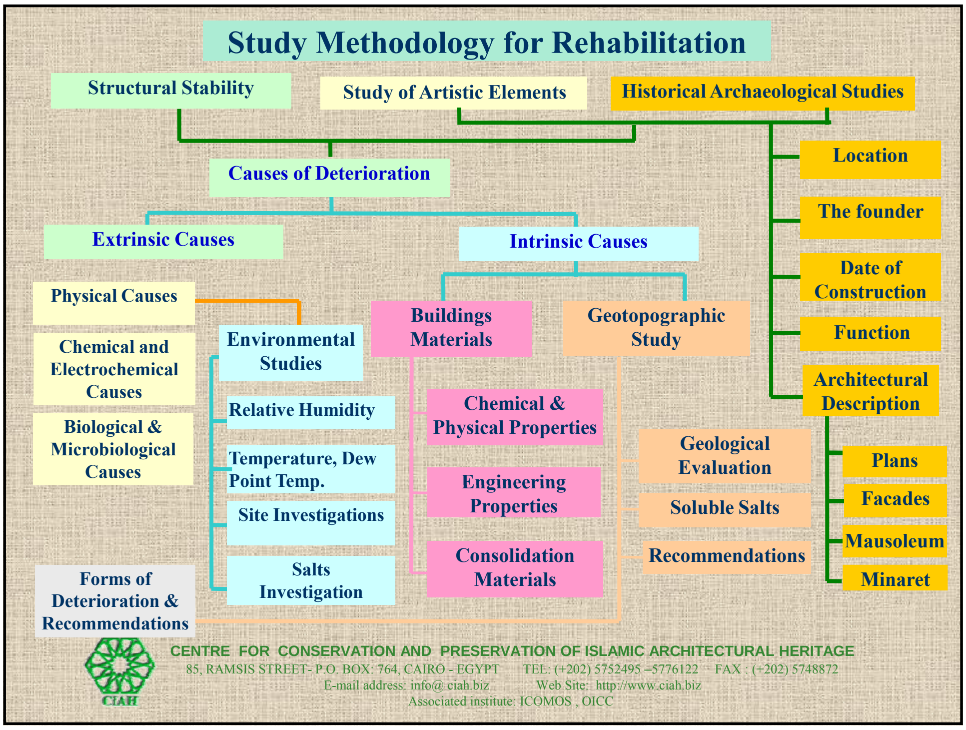
Study Methodology for Rehabilitation
Structural Stability
Study of Artistic Elements
Historical Archaeological Studies
Location
The founder
Date of Construction
Function
Architectural Description
Plans
Facades
Mausoleum
Minaret
Causes of Deterioration
Extrinsic Causes
Intrinsic Causes
Physical Causes
Chemical and Electrochemical Causes
Biological & Microbiological Causes
Environmental Studies
Relative Humidity
Temperature, Dew Point Temp.
Site Investigations
Salts Investigation
Buildings Materials
Chemical & Physical Properties
Engineering Properties
Consolidation Materials
Geotopographic Study
Geological Evaluation
Soluble Salts
Recommendations
Forms of Deterioration & Recommendations
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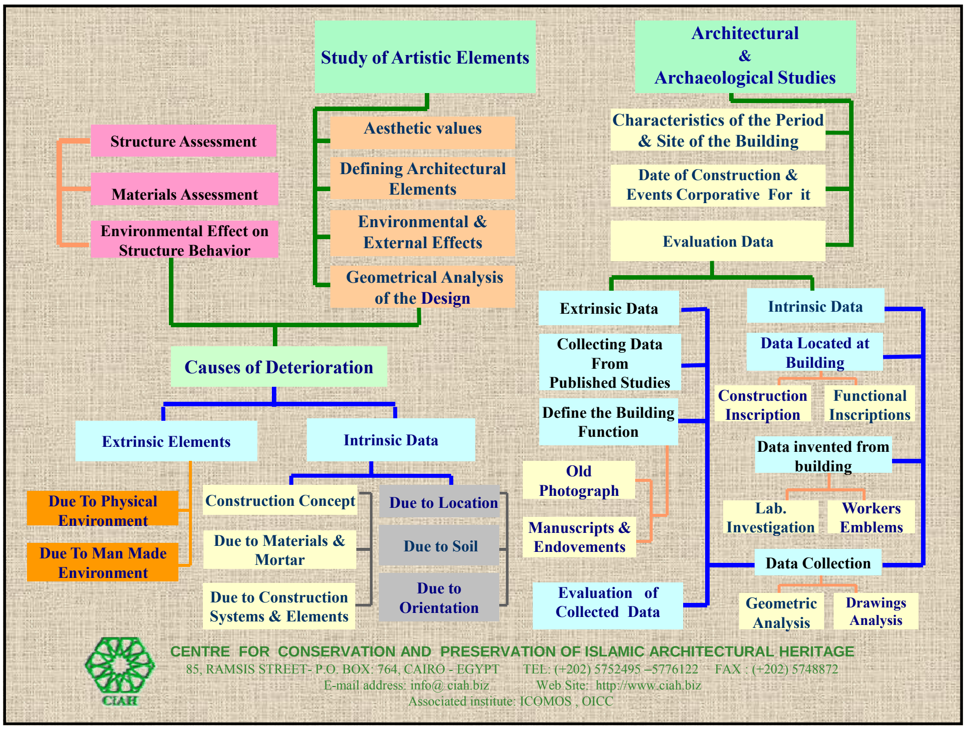
Study of Artistic Elements
Architectural & Archaeological Studies
Aesthetic values
Defining Architectural Elements
Environmental & External Effects
Geometrical Analysis of the Design
Structure Assessment
Materials Assessment
Environmental Effect on Structure Behavior
Characteristics of the Period & Site of the Building
Date of Construction & Events Corporative For it
Evaluation Data
Extrinsic Data
Collecting Data From Published Studies
Define the Building Function
Old Photograph
Manuscripts & Endovements
Evaluation of Collected Data
Intrinsic Data
Data Located at Building
Construction Inscription
Functional Inscriptions
Data invented from building
Lab. Investigation
Workers Emblems
Data Collection
Geometric Analysis
Drawings Analysis
Causes of Deterioration
Extrinsic Elements
Intrinsic Data
Due To Physical Environment
Due To Man Made Environment
Construction Concept
Due to Materials & Mortar
Due to Construction Systems & Elements
Due to Location
Due to Soil
Due to Orientation
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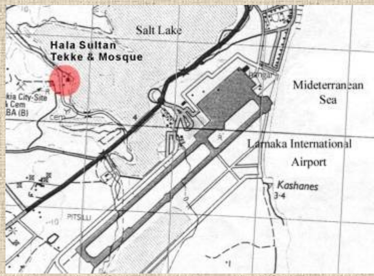
Location

- The Tekke of Hala Sultan, is located about four miles from Larnaca, on the west bank of the Salt Lake.
- It has two ancillary buildings (guest house for men and women) to the west direction behind the main entrance gate.



- The mausoleum of Hala Sultan which is detached to the south wall of the mosque.
- An open cemetery to the south of the mausoleum of Hala Sultan .

SITE PLAN

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Historical background

Umm Harām (Hala Sultan)

Umm Harām (honorable lady) bint Milhan al-Ansari al-Khazradji, first she was married to 'Amr ibn Qais who was killed in the battle of Uhud bei Medina (3H. / 624 A.D).

She married later 'Ubāda ibn as-Sāmit, who was one of the Prophet's close companions .

Umm Harām was the aunt (Khāla) of Anas ibn Mālik; one of the most profilic traditionists, according to his statement, in the age of ten his mother, Umm Suleim – the sister of Umm Harām- gave him to the prophet and became a faithful servant.

According to Anās, she was a close favorite companion to the Prophet and was promised by him to share in the holy war, and to be in paradise.

In 27 H./647 A.D. during the reign of Caliph 'Uthmān. Umm Harām accompanied her husband 'Ubada ibn as-Sāmit on the first sea raid to Cyprus commanded by 'Abdallāh ibn Qais, she fell from her mule and killed on the spot and buried there. The Tekke was built later on same place.

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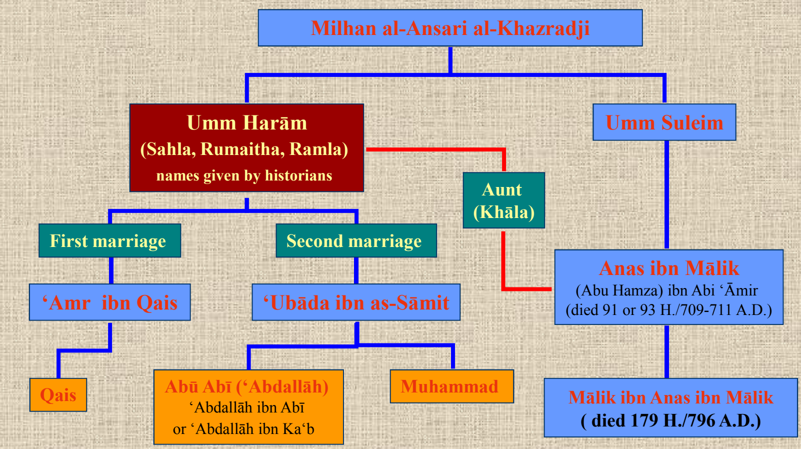

‘Ubāda ibn as-Sāmit was one of the Prophet’s close flowers. He was sent by *Caliph ‘Umar* as a religious teacher to Hims (Syria) and was the first Judge in Jerusalem. In 27 H./647 A.D., ‘Ubāda took part in the expedition to Cyprus organized by *Mu‘āwīya*, the governor of Syria, during the reign of Caliph ‘Uthmān.
He returned to Jerusalem and died there (34 H./654 A.D.) and buried in cemetery of *Bāb ar-Rahma*.

Building Monography

Foundation of the Tekke:

- After the Ottomans invaded Cyprus in 979H. / 1571 A.D., they identified Umm Harām (honorable lady) bint Milhan al-Ansari al-Khazradji grave and took care of it.
- From traveler’s description in 1683 A.D., we know that the grave existed.
- In 1760 A.D., after the great plague in Cyprus, Mehmet Aga, the governor of Cyprus enclosed the tomb with a wooden screen.
- In the following year the governor ‘Ali Agha replaced the wooden screen by a wall with two bronze gates.

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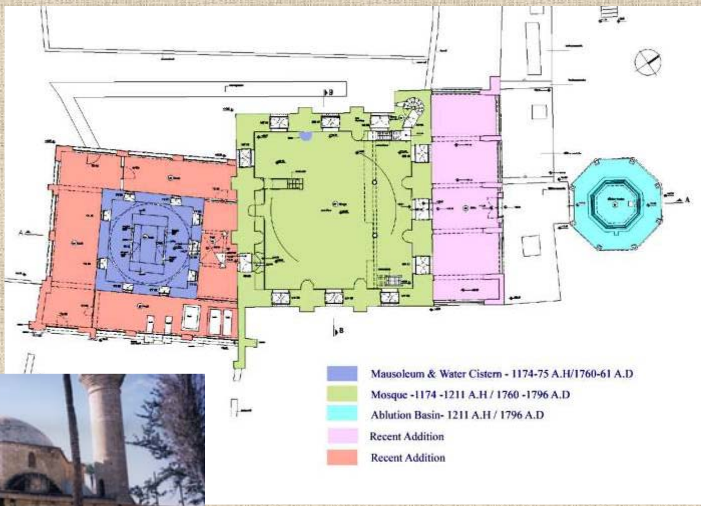

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First Building Phase:

According to the historic inscription, Sheikh Hasan erected a mausoleum on her grave in 1174 H./ 1760 A.D., as well as the water cistern, which later was included within the mosque's area.

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Second Building Phase:

The mosque was built between 1174 H./ 1760 A.D. and 1211 H./ 1796 A.D. , the date on the ablution basin standing just to the north of the mosque in front of the mosque's entrance, built by the governor Kabudān Pasha Mustafa Aghā as-Silāhdār

- Probably the mosque was built first as a gathering place for worship without a minaret,; the decision of building the minaret was probably undertaken during the building of the mosque.
- Originally there was an engraved inscription on the mosque entrance lintel; probably it was dated

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Third Building Phase:

- According to the inscription on the main portal of the Complex, the ancillary buildings were founded by the Governor of Cyprus (probably Sayyid Muhammad Aghā) in 1228 H./ 1813 A.D..
- Drinking fountain was built two years later by the governor Sayyid Muhammad (Amīn) Aghā in 1230 H./ 1815 A.D. After building the ancillary buildings (for men & women), the left window in the west mosque's façade was converted to a door, giving access for women to reach the women area on the podium.

- According to The Islam Ansiklopedisi, the Tekke was build 1797 A.D. by the governor Mustafa Aghā as-Silāhdār, one year after building the ablution basin, and the mosque was the last building added to the complex in 1231H./1816 A.D..

which could not be accepted for two logic reasons:

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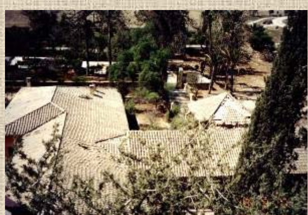
- **First :** the completion of the complex according to inscription of the main portal is 1228 H./ 1813 A.D., three years before the date mentioned in Ansiklopedisi and the drinking fountain is also one year before 1230 H./1815 A.D..
- **Second:** If the mosque was the last building added to the complex, then there was no need to make changes, transforming window to a door and closing the entrance from the minaret to the podium ; the ablution basin located on mosque's entrance axis; is more attributed to the washing's ritual needed before praying in the mosque which is dated 1211 H./ 1796 A.D. and probably the mosque is founded just before.

Vertical building joint between minaret and mosque' west wall is very clear

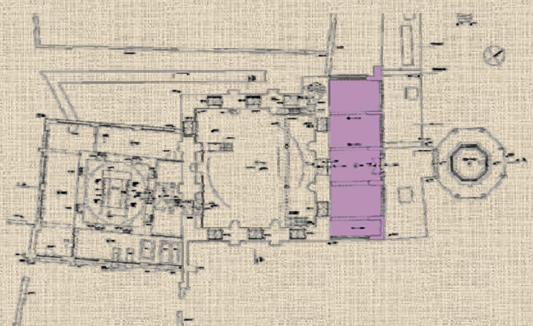
Building joint between mosque and mausoleum walls

Tekke North Façade

- The portico in front of the mosque's north façade is later addition.
- In 1959 A.D. the ancillary buildings were restored by Evkaf and a library was installed inside the mosque.



Ancillary buildings



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Studies Preliminary
to
Rehabilitation Plans

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Scope of Work

- **A phased rehabilitation programme for the Tekke Mosque was proposed to UNESCO.**

Phase One:

Data Collection, Diagnostic studies

Phase Two:

Project Preparation, Complete Technical Specifications and Tender Documents.

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Teams Entrusted With The Project Implementation :

- GEOLOGICAL SURVEY DEPARTMENT OF CYPRUS, GSD (CYPRUS)
- INSTITUTE OF GEOLOGY & MINERAL EXPLORATION (GREECE)
- TECHNOCONTROLLI, Srl (ITALY)
- CENTER FOR CONSERVATION AND PRESERVATION OF ISLAMIC ARCHITECTURAL HERITAGE, CIAH (EGYPT)
  - STRUCTURAL ENGINEERING CONSULTANT, SEC (EGYPT)
  - COSMOS-E ENGINEERS & CONSULTANTS. (EGYPT)
  - CONSULTANT, FACULTY OF AGRICULTURE -CAIRO UNIVERSITYE. (*For Bio Deterioration Study*) (EGYPT)
  - CONSULTING, FACULTY OF SCINCE -CAIRO UNIVERSITYE. (*For Pollutant and Aerosols Study*) (EGYPT)

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Studies , investigations and Rehabilitation Plans

Preliminary investigations and studies were undertaken to cover the mosque's history, structural elements, building materials, soil composition, and causes of deterioration.

This included:

I - Historical and Architectural Study

II - Site and Building Documentation

III - Environmental Study for the mosque and site.

IV - Mineralogical – Petrological study of Building Materials

V - Geotechnical Investigations

VI - Endoscopic Tests

VII - Sonic Tests

VIII - Storm Rain Drainage Study

IX -Structure and Environmental Monitoring

X -Structure Assessment Study

XI -Soil Structure Interaction Study

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I - Architectural Description.

MAIN ENTRANCE:

- The main site entrance is located at the west side of the site. It is an trefoil arched portal built with ashlar stone. A second pointed arched entrance leads to the complex.
- On the door spandrel are the Tughra of Sultan Mahmūd II, son of Sultan 'Abdal-Hamīd I . The entrance leads to an open court surrounded by the Tekke: the south tract for women and the north tract for men; in the middle of the open court stands the drinking fountain.

Water Ablution Basin:

In front of the wooden portico to the north of the mosque and on its axis stand an octagonal water basin covered by a wooden pitched roof, covered by French earthenware tiles. The roof is supported by eight stone columns.

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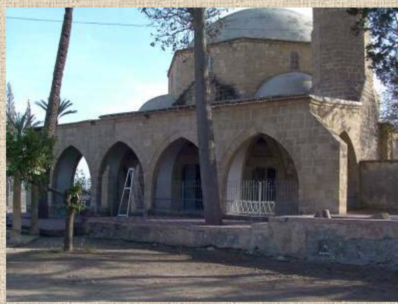
The Northern Portico:

On the north side, adjacent to the north façade, a portico is added, probably in the same time with the covered corridor around the mausoleum; this could be before 1929 (date on the grave stela of Khadīja, wife of Sharīf Husain. The portico has a wooden roof covered by earthen ware tiles.



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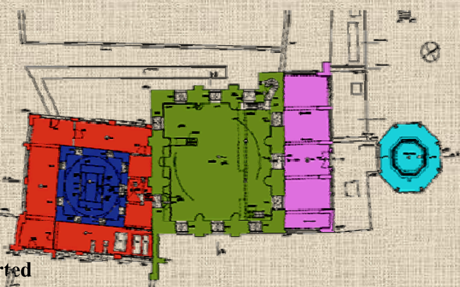
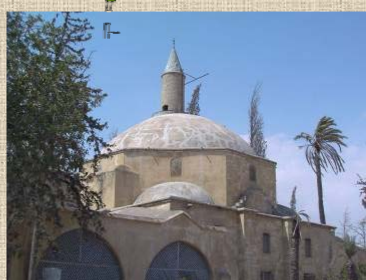
The Mosque:



- The mosque has a square plan about 13.0 x 13.0 m, a central building type, covered by a dome. The transition from square to octagon, transition zone, is formed by eight pointed arches resting on decorated engaged piers.
- The middle semi circular dome is supported in the corners by shallow half domes. The inner height of the mosque is about 13.00m. The attached minaret is located on the north west corner. The mosque's entrance is in the middle of the north façade. On the right and lefts of the entrance there are four windows in two rows. The east and west wall have the same articulation: three big windows in the lower part and three small windows arranged on the upper part of the wall.



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The Podium:

The wooden podium is located on the north side inside the mosque and supported by two marble columns, painted later green.

The Minaret

The minaret stands in the south west corner to the right of the main entrance door; it has two parts:

- A square stool to the height of the mosque; transferred into octagonal shape and turned into a cylinder shaft which ends with a circular balcony.
- A second storey cylindrical short shaft, toped with a typical Ottoman wooden cone, covered by modern steel sheets and crowned with a crescent.

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The Mausoleum

The square mausoleum is about 6.50 x 6.50 m and is covered by a middle dome, supported by four shallow half domes.

In each mausoleum wall, there are two small windows with glass shutters. From outside the transition zone, from square to circle is octagonal. In the middle of the mausoleum stand the cenotaph of Umm Harām. On the east side there are 5 cenotaphs; one in marble for Khadīja, the wife of Sharīf Husain, with a grave stela . To the south of it , there is two small cenotaphs and to north two other normal ones; all four are covered with green tissue.

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The Cemetery

On the east side of the mausoleum there is an open cemetery with different cenotaphs and grave stelas:

- Cenotaph of Mustafa Afandī dated 1227 H. / 1812 A.D.
- Cenotaph of Mustafa Aghā(probably governor of Cyprus) dated 1228H./1813 A.D.
- Cenotaph of Mukhtār Afandī, dated 1259 H. / 1843 A.D.
- Cenotaph of Abū Bakr Najīb Afandī, dated Gumādā I 1271 H. / 1855 A.D.
- Cenotaph of Ismā'īl Afandī, dated 17 Safar al-Khair 1281H. / 22.7.1864 A.D.

All inscriptions on cenotaphs and grave stelas were translated from Ottoman to English and Arabic and were published for the first time.

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DECAY DOCUMENTATION :

North façade, Window to the right of the entrance

North façade, Cracked lintel and severely cleaned

East façade, lintel cracked in the middle stone disintegration

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West facades, Window transformed to women entrance door

North façade, main entrance, door recently painted lintel middle field has no inscription as usual (lintel renewed)

North facade , window above main entrance

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East façade, different types of stone deterioration

East facade , Mosque wall , bio-deterioration and discoloring

East facade , Portico, recent plastic repairs

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Mosque East facade

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Mosque East facade , Mausoleum corner

East façade, Dome Transition Zone

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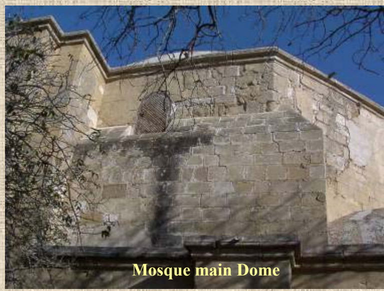
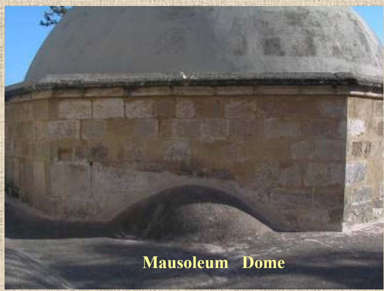
Mausoleum Dome



Mosque main Dome



Mausoleum Dome

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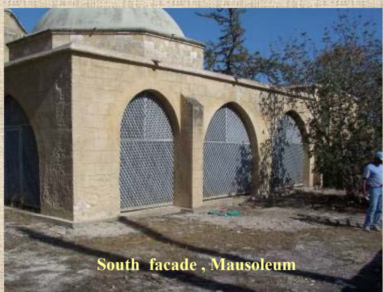
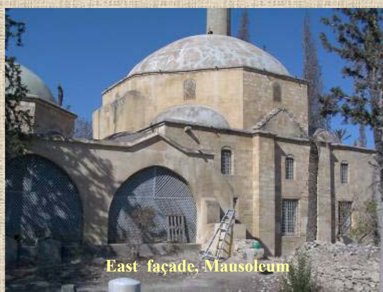
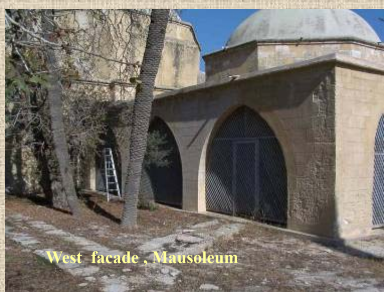


South facade , Mausoleum



East façade, Mausoleum



West facade , Mausoleum

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Mosque East side, detached pier recently plastered

Mosque North wall right detached pier recent plaster on stone

Mosque North wall, mezzanine level

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Mosque west wall,

Mosque west wall detached cantilever pier above cistern

Mosque west wall, wooden curtain to hide (transformed) women entrance to mezzanine

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Mosque South wall, Wooden Minbar

Mosque South wall, mihrab in the middle

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Mihrab, floral decoration grapes & grapes leaf

Floral mihrab decoration
Qur'an verse , 37 (sure 3) Al-'Imrān

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Mausoleum Portico,
Painting disfigured the artistic value

Mausoleum, Dampness in upper part

Mausoleum Entrance

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Mausoleum, Decoration by the Umm Harām Cenotaph

East corridor surrounding the mausoleum, Cenotaph of Khadija wife of Sharif Husain, king of Hijaz

Mausoleum entrance, historic inscription dated 1174 H./1760 A.D.

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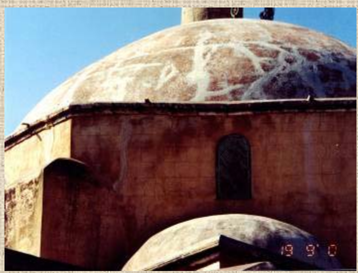
Mosque east upper side
Bad stone moulding work

Mausoleum dome, plastered with cement
and the surrounding corridor
(looking South)



Mosque dome- south east side
dome cracks treated with cement plaster
irregular cracks in transition zone

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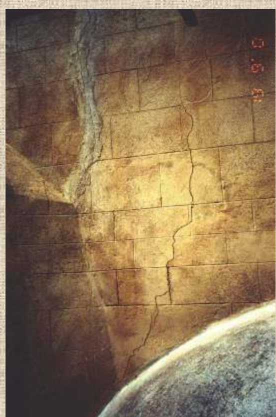
Mosque East Façade
Cracks caused by settlement



Mosque dome cracks in the
transition zone
(South-west side)

Mosque dome transition zone
Stone disintegration, Bad stone
repair & new plastering.

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Insects nest

Decorated engaged piers, cracks caused by rusted metal ties
different stone sizes
different courses height

Marble column supporting wooden mezzanine Level- cracks, green painting disfiguring the shape..

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II - Site and building survey

- Site and building documentation were undertaken by a Cypriot local office to determined different level of the site and the building; results a complete set of drawings, plans, elevation, sections and details, these drawings were revised by CIAH.

SITE PLAN

CIAH
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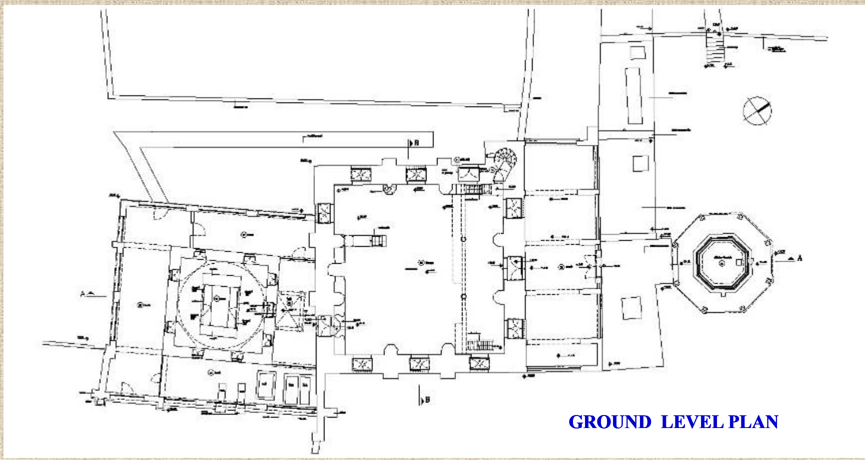

- **Photogrammetry drawings were carried out by Technocontrolli srl & CIAH .**

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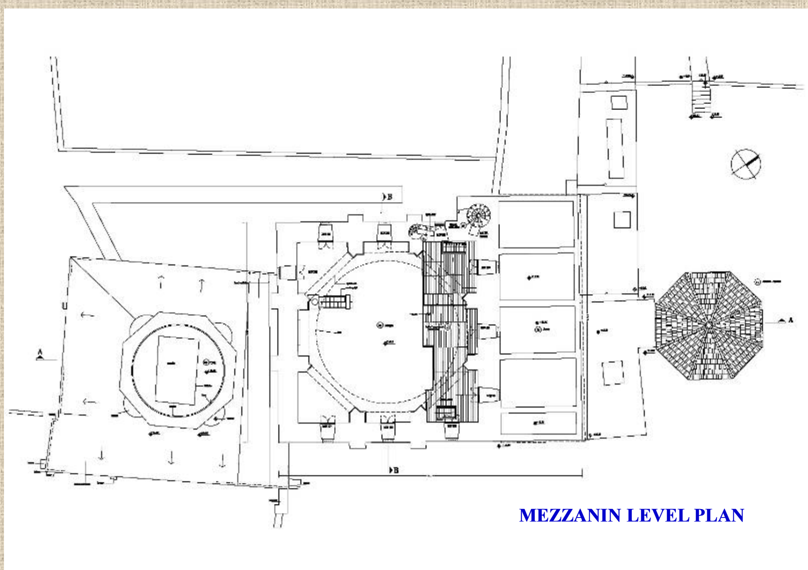

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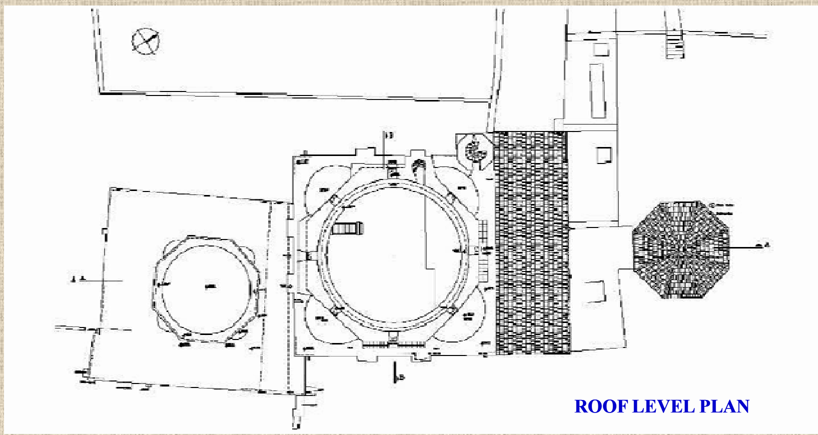

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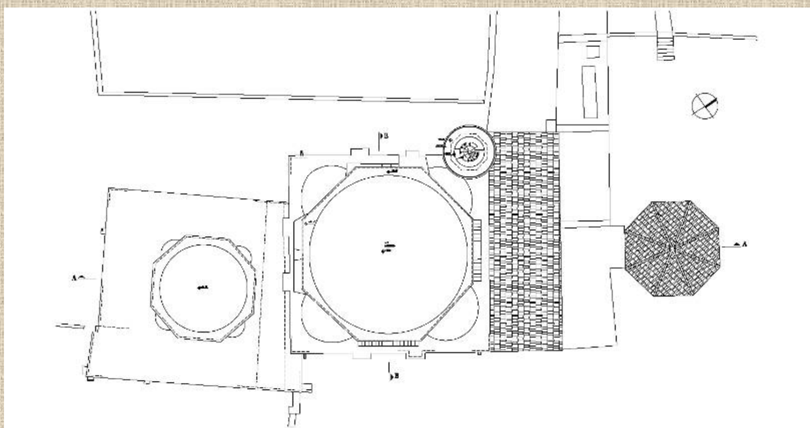

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SECTION A-A

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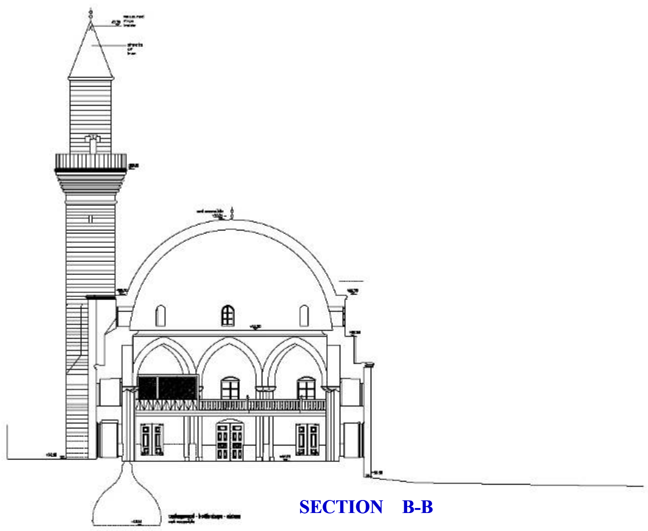

SECTION B-B

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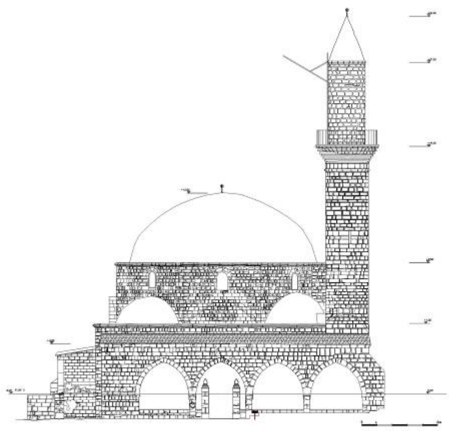

NORTH ELEVATION

- Photogrammetry drawings were carried out by Technocontrolli srl & CIAH .

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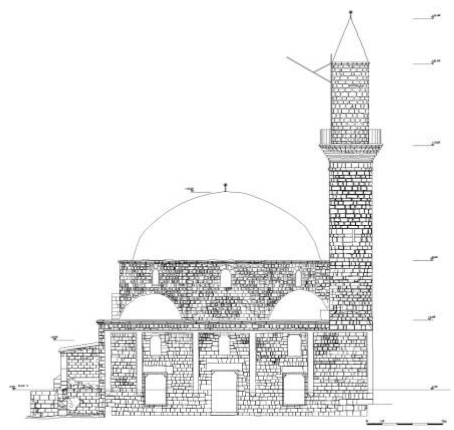

NORTH ELEVATION INSIDE THE PORCH

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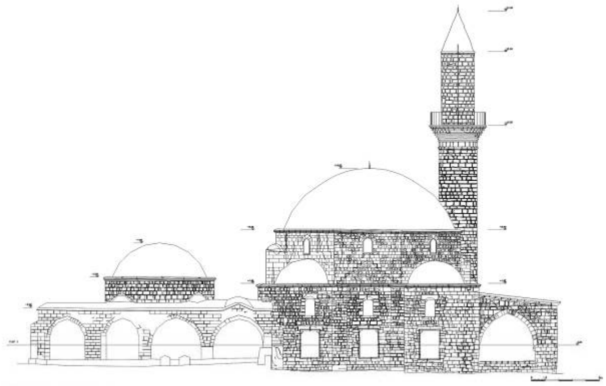

EAST ELEVATION

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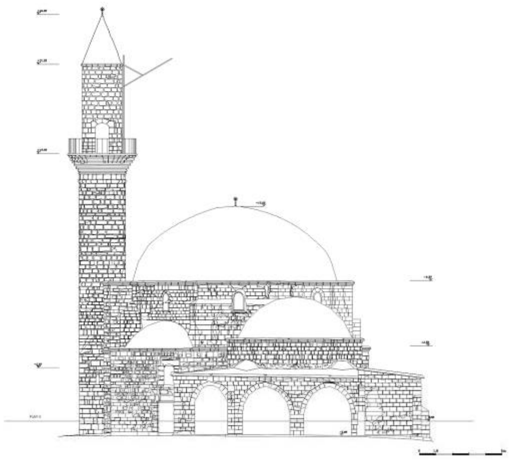

SOUTH ELEVATION

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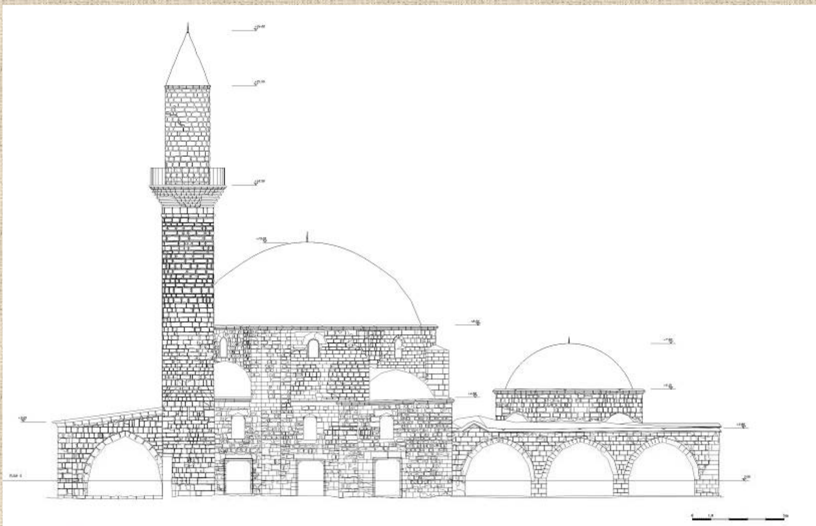

WEST ELEVATION

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II - Environmental Study for the mosque and site

Salt detection and chemical analysis :

- **Electronic salts detector was used to determine the presence of electrically conductive salt contamination on the surface of damped wall.**
- **On site chemical analysis of salts deposited on facades was carried out provided that the wall has not been disturbed for several years.**

Determination of salt percentage on walls

- **Tests were carried out on North and East façade, the tests show that is a substantial deposit of soluble salts is present. Normally certain nitrates and chlorides are deposited by evaporation of ground water (rising damp) on the surface of walls.**

On site chemical analysis:

Sample was collected from the eastern facade at 1.75m from ground level to the right of the middle window.

The chemical analysis has shown, that there was no traces of nitrates, but chlorides were present in medium concentration.

Detection of nitrate & chlorides

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Damp check:

- **Measurements had been recorded on the inner wall surfaces (piers) of the mosque at 0.50 m and 1.50 m from flooring level.**
- **Dampness identification color on the instrument was always red (e.g.; excess moisture, decay inevitable); which indicate the need of immediate intervention.**

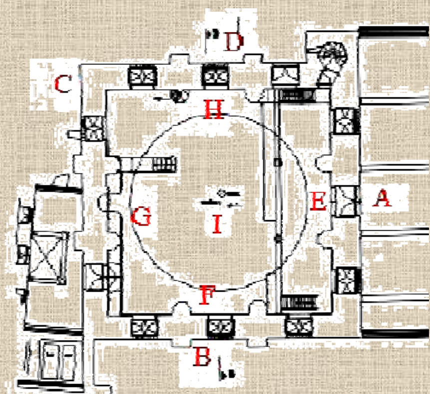
Temperature and relative humidity measurement:

- **Air temperature and relative humidity, measurement had been recorded on 29.1.2001 and 30.1.2001.**

Dampness measurement on wall surface

Measurement of air temperature .

Measurement of relative humidity,



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Measurements outside the mosque area:

Location	Air Temperature °C	Relative Humidity %	Wall Temperature °C
North portico	14.0	63.7	------
East	14.8	63.4	15.6
South	14.6	63.4	-----
West	14.5	63.3	16.4
Average	**14.5**	**63.5**	

Measurements inside the mosque area:

Location	Air Temperature °C	Relative Humidity %	Wall Temperature °C	Dew point
North	14. 9	59. 2	15. 4	
East	17. 3	51. 5	15. 9	
South	15. 7	54. 7	15. 3	
West	15. 2	57. 4	15. 9	
Middle	14. 5	61. 7	----	
Average	**15. 5**	**56. 9**	**15. 6**	**7. 0**

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Measurement of PH Value

Measurement of PH value, is important to determine acidity or alkalinity of a solution.

- PH indicator strips were used.
- PH value has been determined in comparison with colors scheme.
- PH of the solution prepared from east facade was 6 (light acidic)

Probably Sodium Chloride (salt lake)

- A very acid solution has a PH value of 1 - [H^+] > [OH^-]
  more hydrogen ions than hydroxyl ions.

- A neutral solution has a PH value of 7 - [H^+] = [OH^-]
  equal numbers of hydrogen and hydroxyl ions.

- A very basic solution has PH value of 14 - [OH^-] > [H^+]
  more hydroxyl ions than hydrogen ions.

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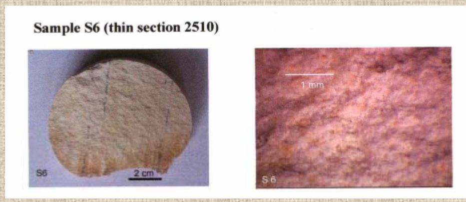
III - Mineralogical – Petrological study of Building Materials

- A diagnostic study for materials was essential. Physical and mechanical tests, as chemical and mineral analysis were carried out for stone and mortars.



Macro and stereo –microscope pictures

- The mineralogical-petrological study of building materials involved sampling and investigation for Eight (8) stone samples, Eight (8) mortar samples and one (1) pigment sample, were conducted by the Geological Survey Department of Cyprus **GSD**.

Stereo –microscope pictures

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- Core test locations were determined by CIAH, Cyprus Department of Antiquities and Geological Survey Department of Cyprus representatives.

Mosque East wall sample 3; 1.20 m from ground level

Mosque East façade sample 4; 3.00 m from ground level to the left of the third window

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ANALYTICAL TECHNIQUE:

- Chemical Analysis.
- Optical microscopy, using Polarizing Microscope.
- X-ray diffraction (XRD), using automatic X-ray Siemens Powder Diffractometer (D500).
- Scanning Electron Microscopy (SEM), using a JEOL JSM 5600 SEM compined with an energy depressive Spectrometer .
- Infrared (FT-IR), using Bruker 113v, Raman Spectrometry using Spectrometer Renishaw 1000
- Study for the pigment sample with Olympus microscope BH-2 and Laser Hene 40 mW.
- Pores Size and Pores Distribution by Mercury Pizometer.

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THE RESULTS OF THE LABORATORY TESTING

RESULTS OF PHYSICAL PROPERTY TESTING & UNIAXIAL COMPRESSIVE STRENGTH.

Sample No	Specific Gravity	Water Absorption (% of dry mass)	Bulk Density (Kg/cm³)	Porosity %	Uniaxial Compressive Strength UCS	
					ON dry sample (KN/ m²)	ON wet sample (KN/ m²)
1	2.72	9.29	1.4.91	32.90	9053.8	---------
2	2.74	28.43	1. 079	34.90	861.1	2225.5
3	2.76	13.10	1.716	33.40	6845.1	--------
5	2.70	15.17	test was not possible	42.63	--------	--------
6	2.69	14.01	1.442	39.10	6170.7	5698.6
7	2.67	3.05	--------	27.83	--------	--------
8	2.76	12.85	1.442	32.40	9188.7	-------
9	2.73	22.87	1.461	34.20	5648.1	2798.7
Avrge	2.72	14.84	1.438	30.62	4785.6	3574.3

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RESULTS OF POINT LOAD TEST RESULTS (SAMPLE DIA.78 mm)

Sample	Length cm	Force F daN	Index, Is F/ D2		Corrected Is (50 mm)		Failure Characteristics
			daN/cm^2	MPa	daN/cm^2	MPa	
S1	4	172	2.83	0.28	3.45	0.35	Rough
S2a	8	77	1.27	0.13	1.55	0.15	Edge angle, Rough
S2b	8	249	4.09	0.41	5.00	0.50	Trough out the axis, Rough
S3	11	303	4.98	0.50	6.08	0.61	Trough out the axis, Rough
S5	5	58	0.95	0.10	1.16	0.12	Edge angle, Rough
S8a	7	411	6.76	0.68	8.25	0.83	Edge angle, Rough
S8b	10	331	5.44	0.54	6.65	0.66	Rough (coarse with sand)
S9	8	529	8.69	0.87	10.62	1.06	Rough (Partly solidified)

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RESULTS OF BORES SIZE AND BORES DISTRIBUTION BY MERCURY

```
Pores Size and Pores Distribution by  Mercury

          Instrument name : Porosimeter 2000
          Method name     : BLANK
          Method filename : M6.PDR

                Sample informations
              Company name : NTUA
              Sample  name : M6 - HALA SULTAN TEKKE MORTAR 6
               Preparation : Basileiou
                      Date : 29/6/2001
                  Operator : Anonymous
           Sample mass (g) : 2.29
      Samp.dens. (g/cm3)   : 13.6
    Weight Dilatometer (g) : 44.51
  Weight Dil.+ Mercury (g) : 251.51
Weight Dil.+ Mer.+Sample (g) : 240.8

              Instrument parameters
         Porosimeter type : Po-2000
      Capillary radius (mm) : 1.5
      Dilatometer Vol (cm3) : 15.22
     Macropores connection : Manual
     Macropore Press. unit : (kPa)

             Acquisition parameters
        Step wise time (s) : 3
        Max pressure (bar) : 1800
                Pump speed : 2

              Analytical conditions
    Contact angle   (Deg) : 141.3
    Hg Surf.tens.(Dyn/cm) : 480
    Mercury height   (mm) : 101.5
    Hg density    (g/cm3) : 13.6

   Disk and filename of Blank measurement to subtract
        Filename :C:\POROSDIR\TYFLA\TYFL070

          Calculation & Report parameters
          Data report type : Extended
         Calculation model : Cylindrical

Total volume specific surface and pore radius average   (Ver 3.02)
   Total cumulative vol.(mm3/g) : 130.0437
   Specific surface area (m²/g) : .8
   Pore radius average (Micron) : 33.168
   Bulk density         (g/cm3) : 2.39
   Correc. Bulk density (g/cm3) : 3.467811
   Total sample porosity    (%) : 31.08
```

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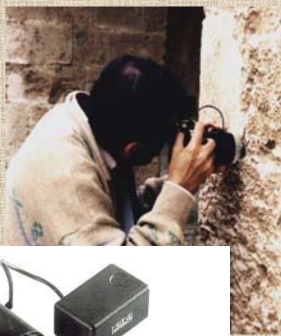
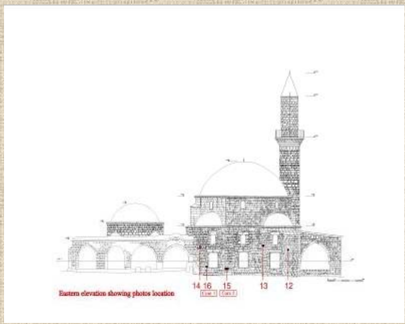
- **To cover most of the stone deterioration cases, surface contact photography for 21 stone samples at different locations of the mosque were conducted by CIAH team. Using HEINE DERMAPHOT compact camera supplied with special positioning light that gives a visual check of the object and contact plate (internally coated silica glass) with 1/10 mm scale.**





East Façade – Photo Locations

HEINE DERMAPHOT compact camera

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Stone surface after magnification 20X

Position of surface contact photograph # 9

Stone block at location number (9) show a sculpture at marble like stone (Cyprus marble). It has a bright white color. Dermaphot magnification of stone surface shows a heavy precipitation of salt layers. Dilation of salt layer due to high humidity produced mechanical cracks through the layer.

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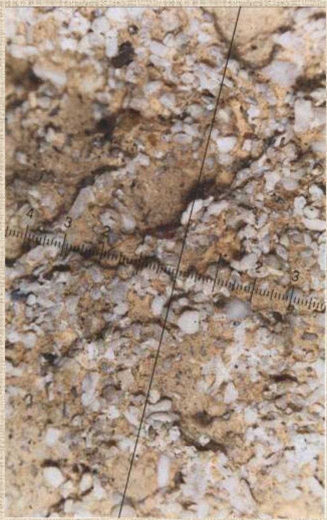

Stone surface after magnification 20X

Position of surface contact photograph # 15

Stone block at location number (15), is suffering from composite back weathering by alveolar and water washing. Leaving behind a deep holes inside the stone at a fresh stone surface. These holes are basically originated at natural weakness areas of the stone itself, but it may be developed and increased by physico-chemical stresses and acidic humidity as well as the decay of the binding material.

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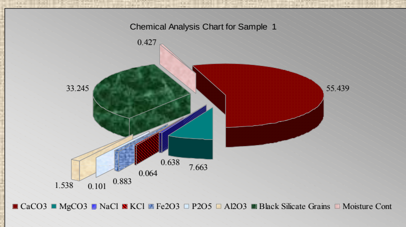
- **For further investigations; Two (2) screed samples, One (1) stone sample (paving tiles from the west side of the mosque) were obtained by CIAH team and chemical analysis were conducted by Geochemica Lab. in Cairo.**
- **The mortar composing the roof screed were found weak with high permeability.**



**Chemical composition of Sample # S1
(Screed Mortar over Mausoleum Dome)**

**Chemical composition of Sample # S2
(Original Screed Mortar over Secondary Dome supporting Mosque Dome)**

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- Chemical Composition for (Sample 1)

Code	% wt									
	$CaCO_3$	$Mg\ CO_3$	NaCl	KCl	Fe_2O_3	P_2O_5	Al_2O_3	Other black Silicate grains	Moisture Content	Total
S1	55.439	7.663	0.638	0.064	0.883	0.101	1. 538	33 .245	0. 427	99.998

- Hydraulic Index & Cementation Index for Lime (Sample 1)

$$\text{Hydraulic Index} = \frac{(33.24) + (1.538)}{(85)} = \frac{34.783}{85} = 0.41 \quad \textit{Moderate hydraulic lime}$$

$$\text{Cementation Index} = \frac{(2.8)(33.24) + (1.1)(1.54) + (0.7)(0.9)}{(85) + (1.4)\ 7.6} = \frac{93.07 + 1.69 + 0.54}{85 + 10.69}$$

$$= \frac{95.30}{95.69} = 1 \quad \textit{Eminently hydraulic lime}$$

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- Chemical Composition for (Sample 2)

Code	% wt									
	$CaCO_3$	$Mg\ CO_3$	NaCl	KCl	Fe_2O_3	P_2O_5	Al_2O_3	$Si\ O_2$	Moisture Content	Total
S2	83 .734	0.247	0.269	0.066	<0. 01	0. 051	0. 668	14 .787	0.177	99.999

- Hydraulic Index & Cementation Index for Lime (Sample 2)

$$\text{Hydraulic Index} = \frac{(14.787) + (0.668)}{(83.7)} = \frac{15.455}{83.7} = 0.18 \quad \text{Feebly hydraulic lime}$$

$$\text{Cementation Index} = \frac{(2.8)(14.8) + (1.1)(0.67) + (0.7)(0.001)}{(83.7) + (1.4)\ 0.24} = \frac{41.44 + 0.737 + 0.0007}{83.7 + 0.336}$$

$$= \frac{42.18}{84.03} = 0.5 \quad \text{Slightly hydraulic lime}$$

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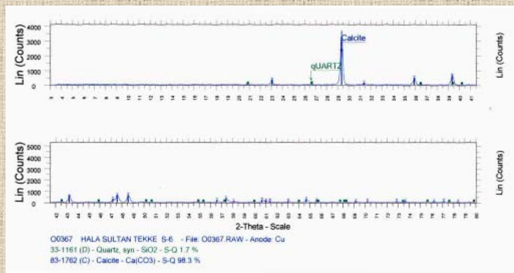
CONCLUSION :

Building Stones:

- All investigated stone samples consists of **organogenic fossiliferous micritic limestones**. The main constituent is the Calcite ($CaCo_3$) both in the fossils and the matrix – cementing material. Calcite content is generally higher than 97%, except one sample (S5) was less than 90 %. The rest of the material consist of Quartz, Feldspars and Mica.
- All samples are characterized as Beach rocks of Middle-Upper Eocene Age, except one sample (S6) probably of Neocene Age.
- According to chemical analysis a positive correlation is observed between Cl^- and Na. That indicates the presence of Halite (NaCl) in the pores of the building stones due to sea water.

The higher content of NaCl in the building stones explained by the higher porosity of the stones.



X-ray diffraction test for stone sample # S6

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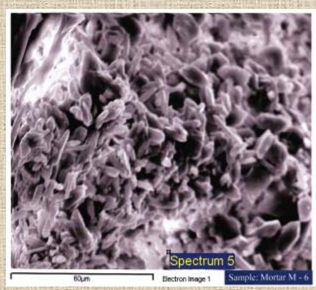
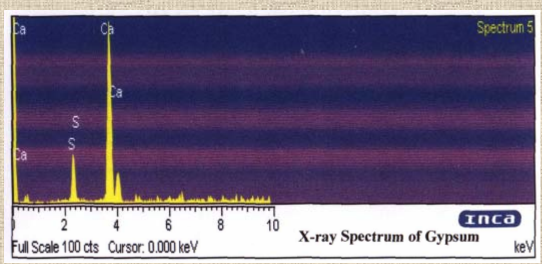
Mortar:

- All investigated mortar samples were similar and consist of Gypsum. Chemical analysis showed only traces (< 1%) of other constituents, mainly quartz.
- A small amount (up to 7%) of calcite was also identified. The grain size for gypsum is 3-5 micron width and 8-16 micron long with some rare prismatic crystals, partly dissolved.



Microscope scanning for mortar sample



X-ray Spectrum of Gypsum

X-ray diffraction for mortar sample

- **The analysis show no evidence of that Calcite was added on purpose to the gypsum mortar (this is a usual procedure) but we believe that Calcite content is related to or the geological environment of the raw material.**

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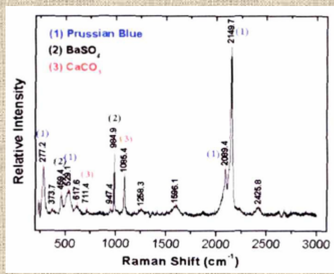
Pigments :

According to the analyzed pigment sample, Barite Ba SO_4 is used as white pigment and as pigment binder since the beginning of the 19 th century, and Rutile TiO_2 after the first world war.

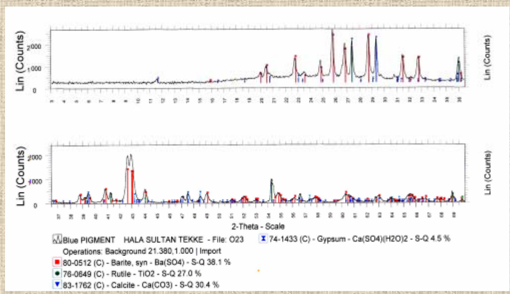
Russian blue is used as blue pigment since the year 1750.

In the analyzed pigment sample, Prussian blue was mixed with Barite and Rutile as pigment carrier.

According to the above observations the analyzed pigment could not be applied to the wood surface before the first world war.



Infrared (FT-IR) results for pigment samples

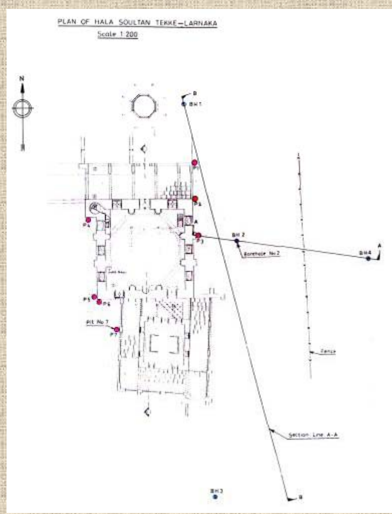


X-ray diffraction test for pigment sample

V - Geotechnical Investigation

- **Soil Investigations**

1. **Investigations of the soil and foundation were undertaken to determine the main structural problems. The subsurface stratigraphy at the Tekke location.**
2. **The geological investigation involved the drilling of 5 (five) boreholes and excavation of 7 (seven) test pits, in the locations proposed by CIAH, the mobile Auger was used for drilling. In all boreholes, Standard Penetration Tests (S.P.T) were preformed at 1-1.5 m intervals for the determination of density / consistency of the soils.**



Open Pits & Bore Holes Locations

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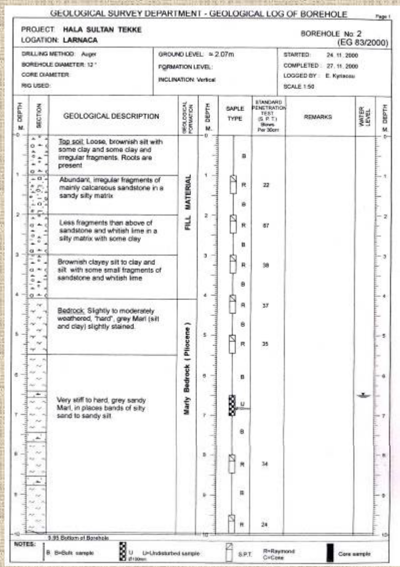
3. Beside the S.P.T's samples , disturbed bulk samples at 1 m intervals were obtained, undisturbed samples were also obtained from the the marly bedrock using U4 (100 mm) tube sampler of 50 cm length.

4. Laboratory tests on both, disturbed and undisturbed samples of the various lithological horizons were preformed for the determination of physical and mechanical parameters of the soils. A full chemical analysis on ground water samples were also done.

5. One plastic stand pipe (Pizometer) was installed for measuring ground water fluctuation.

6. Exploratory pits were excavated by hand, in order to evaluate the foundation conditions (i.e. type, size, materials, used mortar).



GEOLOGICAL SURVEY DEPARTMENT - GEOLOGICAL LOG OF BOREHOLE   Page 1

PROJECT: HALA SULTAN TEKKE
LOCATION: LARNACA
BOREHOLE No: 2 (EG 83/2000)

DRILLING METHOD: Auger
BOREHOLE DIAMETER: 12"
CORE DIAMETER:
RIG USED:
GROUND LEVEL: ≈ 2.07m
FORMATION LEVEL:
INCLINATION: Vertical
STARTED: 24. 11. 2000
COMPLETED: 27. 11. 2000
LOGGED BY: E. Kyriacou
SCALE 1:50

GEOLOGICAL DESCRIPTION	GEOLOGICAL FORMATION
Top soil: Loose, brownish silt with some clay and some clay and irregular fragments. Roots are present	FILL MATERIAL
Abundant, irregular fragments of mainly calcareous sandstone in a sandy silty matrix	FILL MATERIAL
Less fragments than above of sandstone and whitish lime in a silty matrix with some clay	FILL MATERIAL
Brownish clayey silt to clay and silt with some small fragments of sandstone and whitish lime	FILL MATERIAL
Bedrock: Slightly to moderately weathered, "hard", grey Marl (silt and clay) slightly stained.	Marly Bedrock (Pliocene)
Very stiff to hard, grey sandy Marl, in places bands of silty sand to sandy silt	Marly Bedrock (Pliocene)

SAMPLE TYPE	STANDARD PENETRATION TEST (S.P.T.) Blows Per 30cm
B	
R	22
B	
R	67
B	
R	38
B	
R	37
B	
R	35
B	
U	
B	
R	34
B	
R	24

9.95 Bottom of Borehole

NOTES: B B=Bulk sample; U Ø100mm U=Undisturbed sample; S.P.T. R=Raymond C=Cone; Core sample

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Geological Condition

The site is underlain by marly bedrock of possibly Pliocene age belonging to the Nicosia geological formation.

This bedrock is covered by fill material throughout the area, in which the mosque structure is built.

East to the mosque and in the vicinity of the Salt Lake, the bedrock is covered by lagoonal deposits.

West of the mosque and in vicinity of the existing restaurant, the bed rock is obscured by a marine terrace deposits.

Fill Material

Fill material was encountered in boreholes and open test pits around the mosque structure. It was placed artificially on the original ground surface which was most likely about 4 meter below present ground surface. The material is generally characterized by an inhomogenity both in terms of density and composition.

Fragments of variable size and origin, mainly of calcareous sandstone (calcarenite) are erratically dispersed in brownish, fine matrix. Pieces of bricks and whitish lime were also encountered in some places.

The density of the fill material varies from place to another, but usually it is loose to medium dense.

The maximum thickness of the fill material established at 4 meters.

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Marly Bedrock

The horizon incorporates a very stiff to hard, gray marl, which in terms of grain size distribution represents a mixture of clayey silt to silt and clay.

The upper part of the marl (1 to 1.5 m) is weathered and stained by Mn- and Fe- oxides.

Driven from the values of the liquid limit and Plasticity Index classify the marl as a high plastic cohesive soil. The marl due to the high clay content is also characterized by swelling and shrinkage potential when changes in the natural moisture content occur.

Hydrogeological Conditions

1. A study for ground water in the site and its chemical analysis was done. A chemical analysis of samples of the groundwater indicated high salinity and a significant sulphate content, i.e., highly aggressive.
2. The groundwater level was encountered at an elevation of – 4.4 meters, i.e., at a depth of around 6.5 meters below the existing ground surface at the location of the mosque.
3. Inspection of the rainfall records indicates that the measurements were taken during the rainy season, which lasts usually from October to April. The dry season on the other hand lasts for the remaining five months.

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Foundation Condition:

- Based on the findings of the exploratory pits; excavated at the contact with the mosque walls it is most likely that the mosque is founded in the marly bedrock, it was found that the mosque foundation level at depth of 3.6 –3.8 m from the existing ground surface. Down to this depth fill material previously described was encountered, covering the marl bedrock.
- The type of foundation of the walls, buttress and minaret are a combination of two main types:

Open Pit # 4

  - The first type comprises squared (dressed) blocks of calcareous sand stone (calcarenite), which are placed one on top of the other and bound by possibly lime mortar.
  - The second type represents a masonry composed of rubble stones of variable size, shape and origin(calcarenite, chert etc.) these stones are bound by brownish to white brownish lime and calcarenitic sand or silt.

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- The strength of the masonry is not uniform, it is rather erratic, depending on the degree of binding of the stones and the quality of the binding mortar and its distribution throughout the whole mass. Those revealed by the bits exhibited an overall good condition, except for some parts that appeared weaker, specially that it was noticed that masonry below 3 m depth was weaker than above, due to the less amount of stones present in the masonry.

Open Pit # 4

- An adverse factor for both types of foundation is the presence of roots of the existing trees close to the mosque walls. These roots gradually penetrate into the foundations, resulting in their deterioration and final weakening.

Open Pit # 5-6

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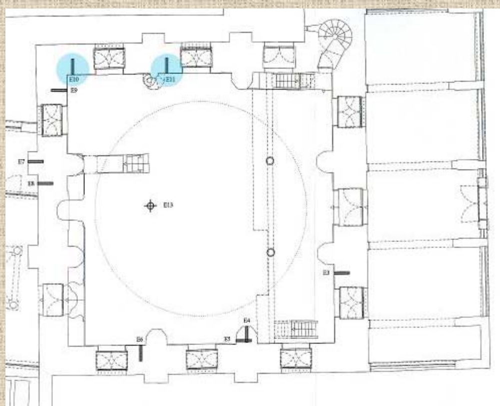
VI - Endoscopic Tests

- This examination reveal morphological variations in the masonry, thickness of mortar layers, cracks or internal cavities and the homogeneity of the masonry.



Endoscope investigation locations

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- It is introduced into a small diameter holes after the insertion of a metric tape to indicate its position.
- Tests can be repeated after consolidation to check the efficiency of the work carried out.

Realisation of the endoscopic investigation n. 11

Realization of Endoscope investigation

Nineteen (19) investigation test for walls, buttresses, domes and flooring of the mosque were carried out.

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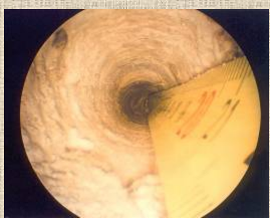

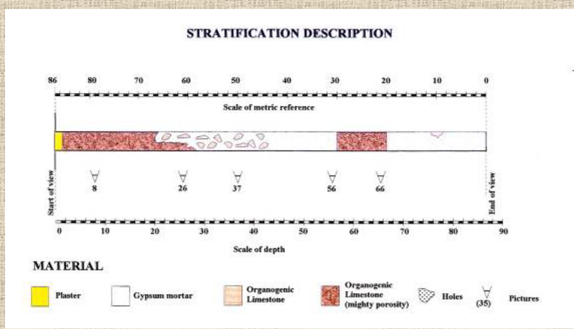

Description of Endoscope investigation # E 10

Endoscope photos for the wall strata

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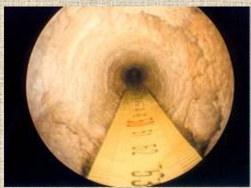
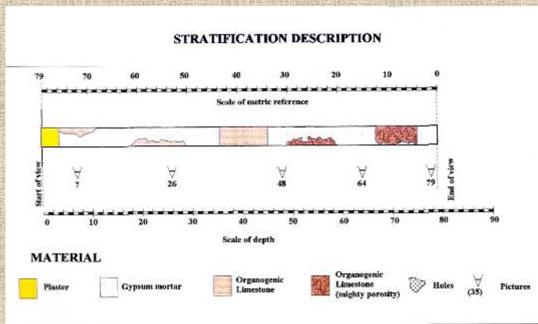
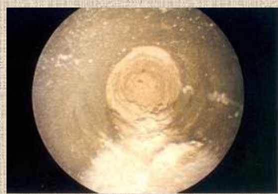




Description of Endoscope investigation # E 11

Endoscope photos for the wall strata



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VII - Sonic Tests

The sonic tests were carried out using the exciter gauge and the receiver on the opposite faces of the same wall. The tests included the South, North, East and West walls of the mosque. Also a pillar of the south side has been tested.

On the outside walls the results show a low speed transmission of the elastic waves (from 723 m/s to 835 m/s) and a quite high dispersion of data (15.9 % < standard dispersion < 24.0%) , due to the decay of the external surface of the walls.

On the pillar inside the south wall the masonry seems to be stronger and a little bit more homogeneous. The speed transmission of waves was (from 1007 m/s to 1820 m/s) and the p.s.d. is of 19.1 %.

Realization of sonic test # 2

Realization of sonic test # 4

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Plotting the speed of longitudinal sound-wave transmission through the wall. The velocity depends on stiffness, homogeneity and compactness of the masonry wall. These tests provide information concerning stone disintegration, micro-cracks and therefore the effectiveness of restoration procedures such as grouting of walls.

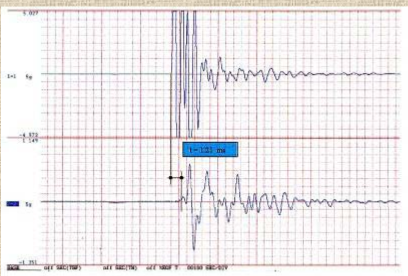


Chart of Sonic Impulse between points nn. 1 e 1
in direction "A"

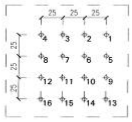
SONIC TEST S2

DATE:	29/07/01
YARD:	Hala Sultan Tekke Mosque - Larnaka
LOCALITY:	Cyprus
LOCATION:	Perimetrical wall East side, near the window

PLASTER	
INTERNAL FACE	SI
EXTERNAL FACE	SI

REINFORCED WALL	NO
WALL THICKNESS	142
GRID WHEELBASE	25x25

WAVE DIRECTION EXTERNAL > INTERNAL			
START n°	END n°	TIME (ms)	VELOCITY (m/s)
1	1	1.21	1174
2	2	2.29	619
3	3	2.13	666
4	4	1.62	878
5	5	1.72	827
6	6	1.43	991
7	7	1.67	852
8	8	1.69	838
9	9	1.83	775
10	10	1.77	801
11	11	1.86	765
12	12	2.04	696
13	13	1.54	919
14	14	1.75	811
15	15	1.86	763
16	16	1.43	993



Vm (m/s)	σ (m/s)	σ / Vm (%)
835	133	15.9

Recorded Values for Test # 2

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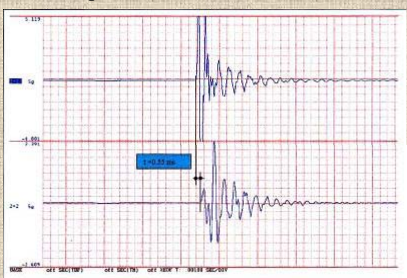
The tests is preformed by placing a piezoelectric receiver on one face of the wall and impulse generator on the other face of the wall, located in a symmetrical position.

Both instruments are connected to an oscilloscope, which then measure the time required for the second wave to travel from one side to the other.

Four (4) investigation test for walls and pillars of the mosque were carried out.



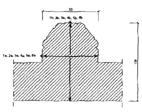
SONIC TEST S4

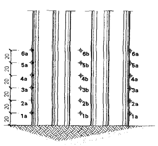
DATE:	29/07/01
YARD:	Hala Sultan Tekke Mosque - Larnaka
LOCALITY:	Cyprus
LOCATION:	Internal pillar south side

PLASTER	
INTERNAL FACE	NO
EXTERNAL FACE	NO

REINFORCED WALL	NO
WALL THICKNESS	93
GRID WHEELBASE	25x25

WAVE DIRECTION EXTERNAL > INTERNAL			
START n°	END n°	TIME (ms)	VELOCITY (m/s)
1a	1a	0.55	1691
2a	2a	0.62	1495
3a	3a	0.51	1820
4a	4a	0.63	1481
5a	5a	0.59	1576
6a	6a	0.67	1395
1b	1b	2.43	1081
2b	2b	2.30	1143
3b	3b	2.25	1169
4b	4b	2.37	1111
5b	5b	2.29	1146
6b	6b	2.61	1007





Vm (m/s)	σ (m/s)	σ / Vm (%)
1342	256	19.1

Recorded Values for Test # 4

Chart of Sonic Impulse between points nn. 1 e 1
in direction "A"

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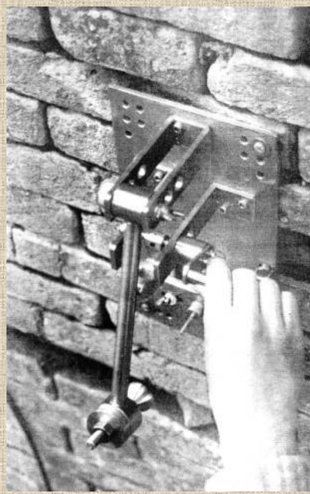
VIII - Penetration Tests

The test provides a way of measuring the hardness of materials. The strength of mortar can be calculated on basis of resistance offered to the penetration of nail: the number of blows is correlated with the degree of penetration of the nail (opposite figure) and the result is compared with others from previous laboratory tests on samples with known resistance characteristics.

The tests, consisting in the infliction into the mortar of standard dimension nail, have been carried out on vertical and horizontal joints of the walls, at the ground floor and at 3rd level. Many difficulties have affected the tests because of the small thickness of the mortar joints. On the external surface of the walls it was often impossible to perform the test being the joint filled by cement.
The best results of the compared resistance have been collected, in the joints of 10-15 mm at the ground floor, and were about 18 daN/cm².



Penetration Test on Mortar

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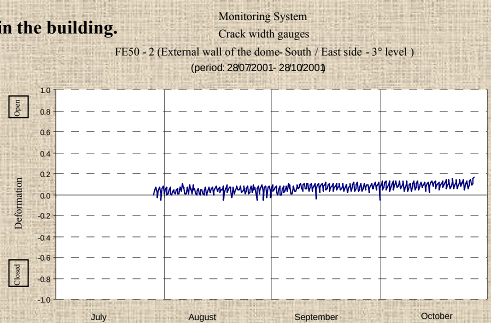
VIII- Structural & Environmental Monitoring

- As a part of this project, monitoring equipment were placed at various locations to perform the following tasks:
  - Monitoring the movement of the cracks that exist in the building walls.
  - Checking the slope variation and out of verticality for the minaret.
  - Assessing the direction and speed of wind.
  - Measuring the relative humidity within the building.



Results of one of Crack width gauges

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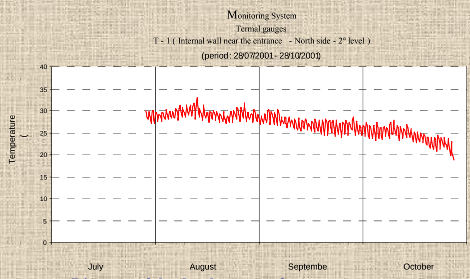

- During the period from 28 July 2001 to 28 October 2001, equipment were recording the data every 6 hours.

Diagram of the development of temperature: the phenomenon is fairly constant as a result of daily and seasonal temperature variations.

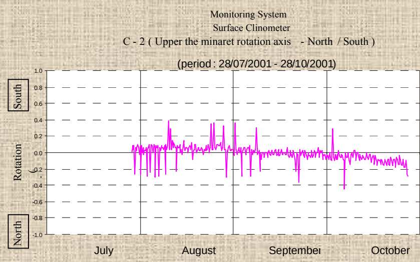

Diagram of the development of width of crack: the phenomenon is fairly constant as a result of daily and seasonal temperature variations.

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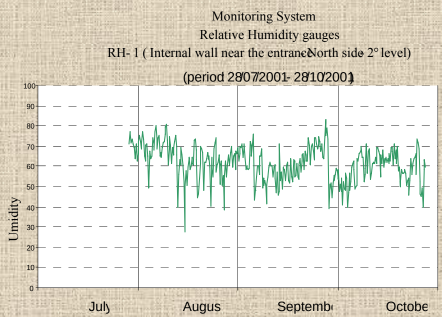

Results of one of Relative humidity gauges

- **Eight crack gauge meters were fixed to the building walls to measure the movement (progress) of eight cracks.**
- **Two surface clinometers, were placed to record minaret verticality.**
- **Two relative humidity gauges were fixed to record humidity.**
- **Two thermal sensors, were fixed to record temperature variation.**

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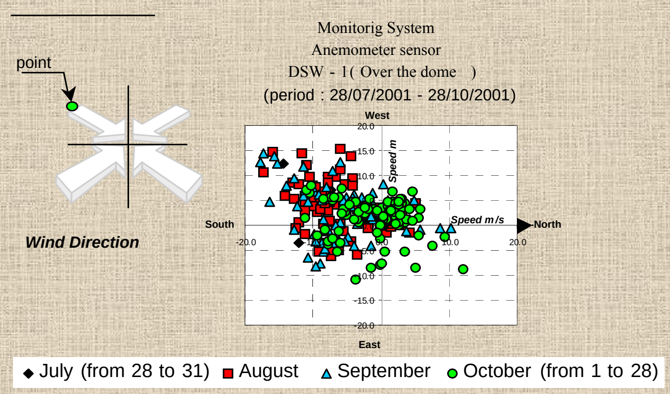

Results of Anemometer (speed and direction)

- **Data were recorded during last ten months, it was recommended to prolong recording during rehabilitation project and after project finalization.**

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Conclusions

- **Variation in crack width with time was fluctuating around a mean indicating that movements recorded are caused mainly by temperature or humidity variation.**
- **With regard to surface clinometer, recorded results indicated that rotation of the minaret was fluctuating around a mean value of 0.0 degree.**
- **Humidity measurements showed that during the measuring period humidity within the building reached 95%, which is considered a very high value.**
- **With regard to the maximum wind speed recorded during this period, it was 17 m/sec in the south west direction.**

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IX- Structure Assessment Study

A structural assessment study and a soil-structure interaction study were performed.

The main objective of the structural assessment study was:

- Determine the current structural conditions for the building.
- Developing mathematical model using the finite element technique, accurately containing all the building features such as openings, doors, arches, minarets ….etc.
- Studying the building behavior to various loading conditions and to assess the state of stresses within the building and the minaret walls under different loading conditions
- Evaluating the structural safety of the mosque and the minaret based on these calculations.
- To recommend, necessary measures and techniques for strengthening and retrofitting the mosque.

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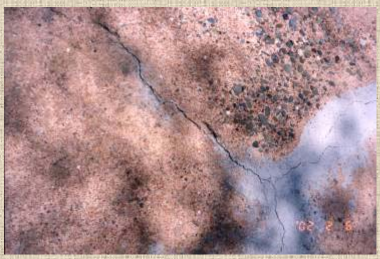
The study of static behavior of the building showed :



Variation in crack width with time was fluctuating around a mean indicating that any movements recorded are caused mainly by temperature or humidity variation and not due to structural reasons.

With regard to surface clinometer, recorded results indicated that rotation of the minaret was fluctuating around a mean value of 0.0 degree.

Humidity measurements showed that during the measuring period humidity within the building reached 95%, which is considered a very high value.

With regard to the maximum wind speed recorded during this period, it was 17 m/sec in the south west direction.

It can be concluded that :

The cracks existing at the building walls were stable and non-progressive

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Loading Conditions:

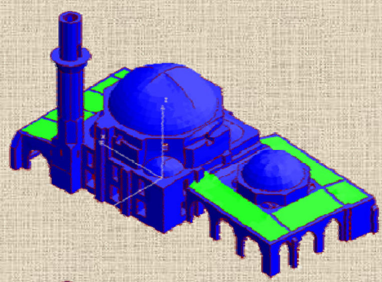
The building is exhibiting different loading conditions. These loads can be divided into two groups, vertical loads and lateral loads.

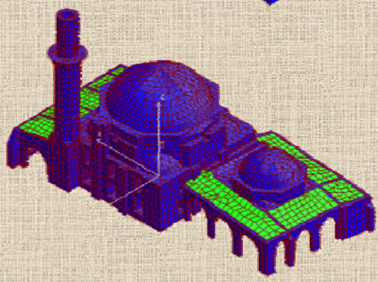
The main vertical loads are the self-weight of the construction materials which are composed of:

1. a) Weight of walls for Mosque, Main entrance and Mausoleum and are estimated according to walls thickness and based on assuming that the specific gravity of the stones equal to 22 KN/m^3 (2.2 t/m^3). This value represents the lumped specific gravity of exterior walls and interior filling.

2. b) Weights of minaret walls and domes at both mosque and mausoleum and were selected to be based on assuming specific gravity equal to 27 KN/m^3 (2.7 t/m^3) for stones comprising them.

3. c) Weight of wooden roofs covering the main entrance and the mausoleum and was estimated as 2.1 KN/ m^2 (210 kg/m^2) accounting for the weight of the wooden roof and the ceramic tiles or screed layers.





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Structural Modeling :

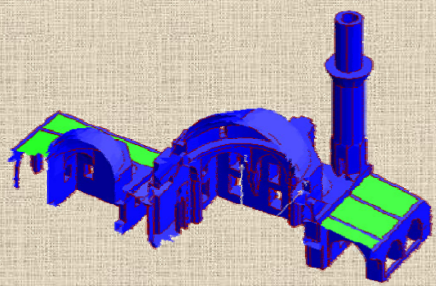
The multi-purposed finite element program,COSMOS/M is being used for the modeling all building elements.

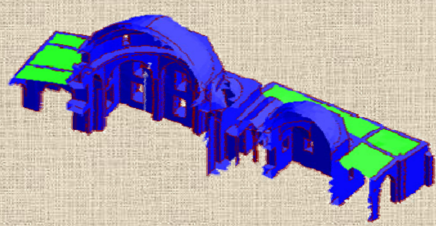
The building walls due to their low aspect ratio were modeled using the three dimensional tetra-hedral elements.

One dimensional frame elements were used to model all structural rods. Four node shell elements are also used to model the arcade roofs. The model was subjected to various loading conditions as appropriate to the local conditions of the site.

Figures produced show the external views of the model from the North-east and South-West sides, respectively. As well as internal views of the model for both East and West sides.

The building is exhibiting different loading conditions, vertical loads and lateral loads.





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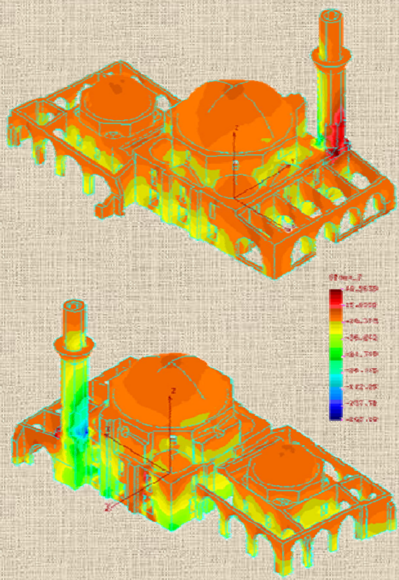
Levels of Stresses within the Building :

The model has been subjected to both gravity and to an equivalent lateral loading that represents the equivalent earthquake load as previously explained.

Five load cases were analyzed to study the effect of the gravity load (Z direction), and the combination of the gravity load with the lateral load in both horizontal directions (X and Y directions in both +ve and –ve orientation).

Figures were produced to show the stress distribution due to gravity loads in the Z, X, and Y directions, respectively. Maximum stress values were obtained from the finite element method. Generally, the maximum stresses obtained from the finite element analysis due to gravity loads were relatively small compared to the allowable stresses.

This indicates that the building is in good condition under the action of gravity loads.



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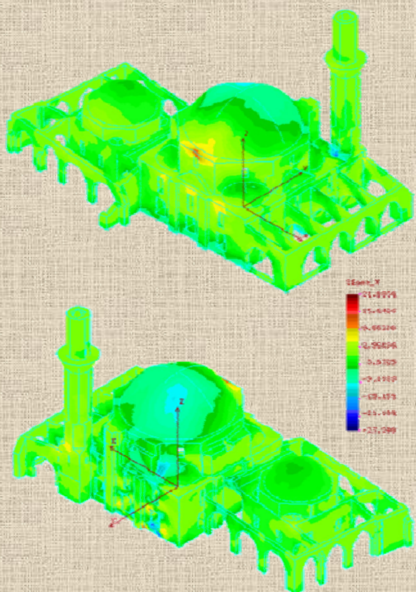
With respect to other loading conditions, higher stresses are encountered specially at the junction between the minaret body and the mosque walls.

All recorded compressive stresses were noted to be less than the strength of the stones forming the building.

The tensile stresses reached within the building walls were high and may cause cracking in the case of large earthquakes. However, compared to stones tensile strength, the determined stresses were relatively low.

Based on the analysis, it can be clearly stated that the building is safe under the actions of gravity loads. It is expected that some cracks may develop at localized locations under the action of lateral loads. However, no collapse is expected.



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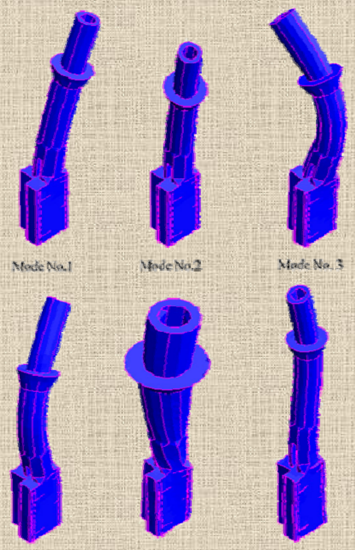
Model Analysis:

- To study the dynamic characteristics of the minaret, a frequency analysis has been conducted using the Cosmos/M finite element program.
- The minaret natural periods are relatively small indicating that the minaret is a stiff body with a relatively short height compared to its cross section.
- Figures were produced to show the mode shapes of the minaret structure for the first twelve modes.
- A modal spectrum analysis was also performed using the design response spectrum and including the first 50 modes.
- The maximum elastic response displacement value was found to be about 2.0 cm. This represents a drift ratio of about 0.12%.
- The maximum elastic stress in the vertical direction obtained from the spectrum analysis was found to be 3.24 Mpa.



Mode No.1 Mode No.2 Mode No. 3

Mode No. 4 Mode No. 5 Mode No. 6

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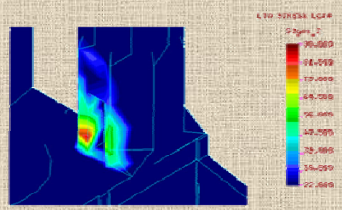
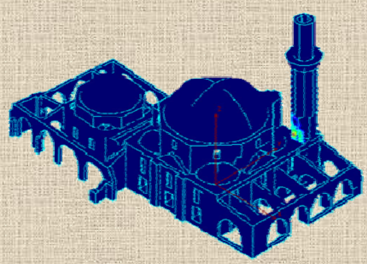
Conclusions and General Remedial Measures :

- From the finite element analysis results, slightly high stresses exceeding the acceptable allowable limits were noted at the connection of the minaret and the mosque roof.
- As a remedial measure, the internal wall should be grouted with a suitable mortar to ensure that it works as a one unit with the external leaf and the filling material for walls composed of two stone layers. The filling shall also insure that the walls act as one stone layer are connected without any gaps.
- It is recommended that carbon fiber reinforced polymer strips be added on the internal surface of the minaret wall at its connection with the mosque roof.
- The carbon fiber reinforced polymer strips shall be added in both vertical and radial directions to be able to carry the tensile stresses in both vertical and horizontal stresses.





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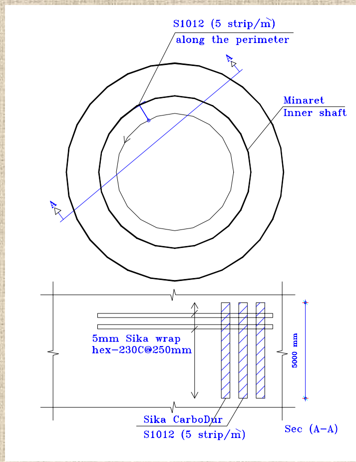
Structure Assessment for the Minaret

- The area to be strengthened by the carbon fiber method should include at least 0.5-m below the mosque roof to about 4.0-m above the mosque roof level.

The maximum tensile stresses expected in this region is about 0.9 Mpa.

- Carbon fibers are used in heavy duty bearing, in pressure vessels, deep sea submarines, aircrafts and spacecrafts. It has a high strength to weight ratio as well as high strength at temperatures, where other engineering materials suffer significant loss of strength.



- Providing Sika CarboDur strips in the vertical direction along the inner perimeter of the minaret for a length starting from 1.0 m below the roof level up 4.0 m above the roof (Total length is 5 m).
- Then, these strips will be fixed by a series of 5 cm (0.13 mm) horizontal strips made of Sika Wrap Hex-230 C each 25 cm.

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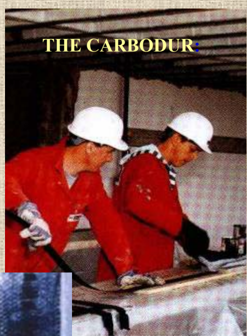

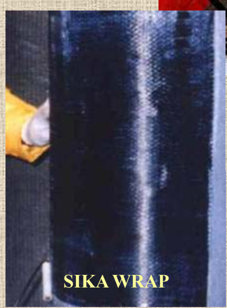

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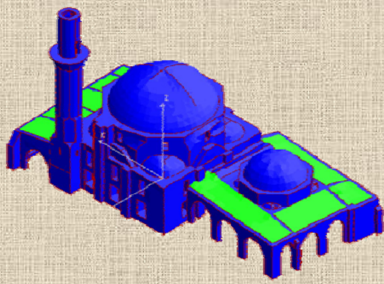
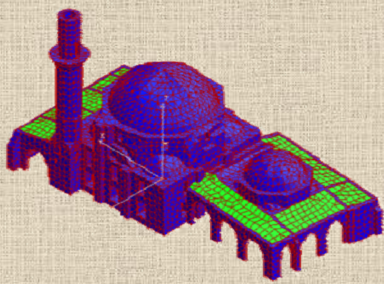
- According to the recommendation of CIAH (conservatoin consultant), two additional external wall elements located in the south and west sides of the mosque on top of the mosque roof are misplaced. To get the original architectural shape of the mosque, these walls need to be eliminated.

- The effect of removing these walls on the structural conditions of the Mosque were evaluated, it was concluded that the walls on top of the mosque roof on the south and west sides could be brought back to their original stair shapes without affecting the structural integrity of the building.





The stress levels in the modified model did not change considerably from those obtained in the original model. The maximum variation in stresses was found to be 0.07 Mpa.

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X- Soil Structure Interaction Study

The main objective of the soil-structure interaction study is to consider the effect of the soil stratification underneath the building foundation on its behavior. evaluating the loads acting on the building's various components and evaluating through visual inspection the structural integrity of the building and the points of weakness.

The scope of this study includes:

- **Identifying the soil parameters under dynamic and static loading conditions such as modulus of elasticity, angle of friction, and cohesion.**
- **Developing a three-dimensional finite element model that accounts for the superstructure and the soil stratification underneath the foundation. The model shall be used to depict the structural response under vertical and lateral loads.**
- **Evaluating the stresses and deformations of the superstructure taking into consideration the soil effect.**

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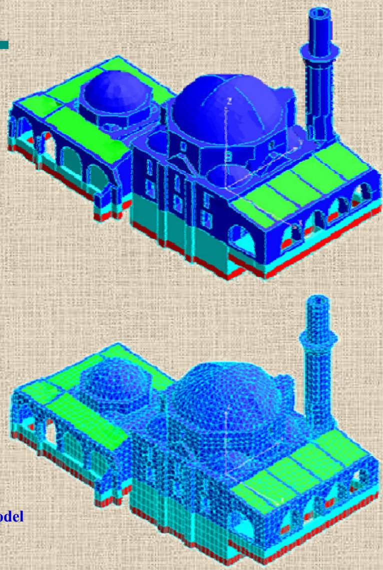
X- Soil Structure Interaction Study

ELASTO- PLASTIC MODELING FOR SOILS

Modeling of soil as a nonlinear elasto-plastic material is not an easy task. Soils exhibit large variety of behavior under different loading conditions. Some mathematical models such as Drucker-Prager yielding criteria are commonly used to represent the soil behavior.

The Drucker Prager model accounts for the increase the elastic zone domain with the increase of the hydrostatic pressure.



Three Dimensional Finite Element Model
North East View.

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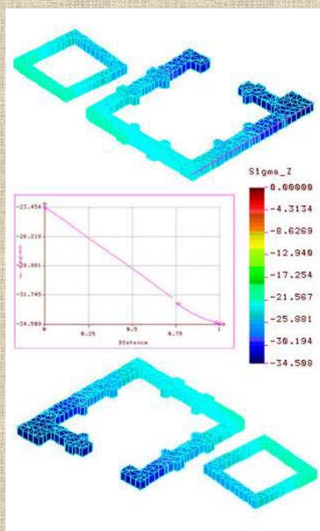
X- Soil Structure Interaction Study

SIMPLEFIED MODELING FOR SOILS

Using the three dimensional elastic model for the mosque established in the Structural Assessment Report, which shows a large number of elements and nodes. this three dimensional model was developed to include the foundations and the soil underneath using the elasto-plastic material behavior is rather difficult due to running time and space limitations of the computers.

In order to simplify the problem, a two dimensional nonlinear finite element model is constructed for the soil stratification. The objective of the model is to obtain a simplified spring element with nonlinear behavior in order to simulate the soil conditions underneath the foundation. This nonlinear spring can be used to simulate the soil in the three dimensional finite element model for the mosque.



Stress Distribution on Soil – Gravity Load.

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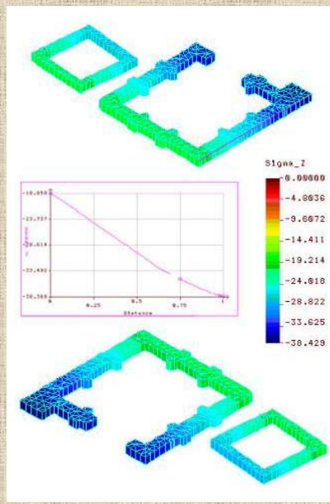
X- Soil Structure Interaction Study

In the two dimensional model, plane strain four node elements with two degrees of freedom per nodes were used. The elements are associated with nonlinear material using Drucker Prager yield criteria.

The model geometry represents the marl stiff (clay and silt) layer that starts from the foundation level to the end of the boreholes. Knowing that the influence of the stress bulb for the strip footings is around five times the foundation width, it is found that 40.0m depth of this layer can be accurately used in finite element modeling to represent the actual behavior of the soil.

The gravity loads, via applying a gravitational acceleration, is firstly applied in order to define the confining pressure for the clayey layer. Consequently, a line pressure at the top of the model is incrementally applied in order to obtain the force-displacement curve for the soil in the vertical direction. From this relation, an equivalent one dimensional spring nonlinear stiffness was depicted.



Stress Distribution on Soil – Gravity + Lateral Load.

X- Soil Structure Interaction Study

THREE DIMENTIONAL MODELING FOR SOILS STRUCTURE INTERACTION

The finite element model established in the Detailed Structural Assessment Report is developed to include the soil behavior by adding:

- 3-D Solid elements to represent the foundation of the structure.
- 3-D Solid elements to represent the soil nonlinear stiffness as depicted earlier.

The multi-purposed finite element program, COSMOS/M, was used for the modeling of all building elements. The nonlinear module was initiated using the Newton Raphson iterative technique.

A Von-Mises yielding criteria was used to implement the simplified modeling for the soil nonlinear behavior. In this case the soil shall act as a nonlinear spring with displacement force curve.

The model was subjected to two load cases.

The first; represents the gravitational loads .

The second; represents the lateral earthquake load in the positive Y-direction in addition to the gravitational loads. This case was selected since it gave the highest stress values in the linear analysis performed in the Structural Assessment Report.

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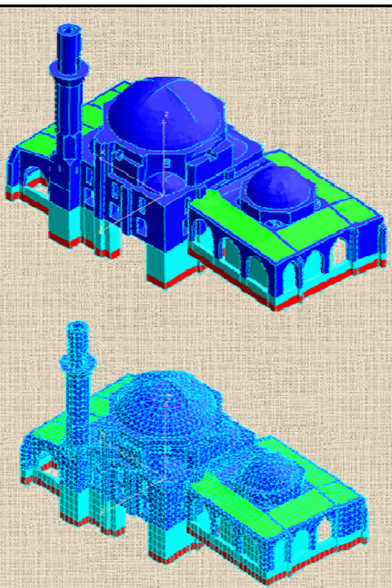
X- Soil Structure Interaction Study

RESULTS AND DISCUSSION

- The model demonstrate the stress distribution on the soil underneath the foundation of the main walls of the mosque and the mausoleum. It was shown that the maximum stress under vertical loading were noted under the west side wall (location of Mosque Minaret as well as discontinuity in wall foundation at the existing cistern).
- Although the maximum stresses slightly exceed the allowable value, the factor of safety in the current project against soil collapse under vertical load is about 2.76 which is considered acceptable.
- The value of the maximum stresses on the soil under the combined action of vertical and lateral loading was lower than the allowable value defined by the geotechnical report under secondary loads.



Three Dimensional Finite Element Model
South West View.

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X- Soil Structure Interaction Study

- The maximum vertical settlement obtained from the model was found to be about 53 mm. A large portion of this long term settlement is presumably have occurred over the building lifetime.
- Both models yield acceptable compressive stresses that are within the allowable values for the stone.
- The maximum tensile stresses obtained from both models yield approximately the same value.
- The maximum lateral displacement within the building obtained from the soil-structure interaction model was found to be about 45 mm.
- The maximum lateral displacement obtained from the modal analysis as outlined in the structural assessment report was found to be about 20 mm.
- The difference can be attributed to the nonlinear elasto-plastic behavior of the soil, which contributes in the total displacement of the structure as a rigid body motion.

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X- Soil Structure Interaction Study

CONCLUSIONS

The model gives comparable results with the linear models.

- **Higher lateral and vertical displacement were detected. This can be attributed to the nonlinear elasto-plastic behavior of the soil, which contributes in the total displacement of the structure.**
- **Higher stresses at the minaret connection with the mosque roof are also detected. This indicates that the mosque does not only have a rigid body motion relative to the soil but also the soil modeling contributes in changing the displacement gradient of the structure.**
- **The vertical stresses on the soil in both cases are still within the allowable bearing capacity given in the Geotechnical report as follows:**
  - **For vertical load, maximum bearing pressure is 3.4 kg / cm^2 which is marginally higher than the allowable given in the Geotechnical report (3.13 kg / cm^2 based on safety factor of 3.0). Consequently a safety factor of 2.76 can be acceptably adopted.**
  - **For earthquake equivalent static loads, maximum bearing pressure is 3.8 Kg / cm^2, which is lower than allowed by codes (1.33 x 3.13 = 4.2 kg / cm^2).**

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DETERIORATION FACTORS

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CAUSES OF DETERIORATION

In formulating an analysis of the contributory roles of various agents in the deterioration of the Tekke Mosque, it is our intent to use the tools of data collection and assessment, followed by interpretation, hypothesis formulation, and diagnosis.

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PHYSICAL AND CHEMICAL FACTORS

Environmental factors could be classified as natural or manmade.

The "natural" climate, is modified by man through :

- **Buildings.**
- **Heating.**
- **Industrial processes.**
- **Traffic.**

Some air pollutants have a "natural" concentration in addition to the man-made contributions.

Some climatic causes of decay, mainly natural ones:

- **Amount of Rainfall.**
- **Frequency of Heavy Rainfalls.**
- **Humidity.**
- **Daily and Seasonal Temperature Variations.**
- **Wind .**
- **Solar Radiation.**
- **Ground Moisture Conditions.**

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Water and Humidity

- **Water is one of the main factors in the decay of building materials. It reaches the surface of buildings and monuments in the form of rain, especially in combination with wind. If the rain water dissolves salts on its way, the damage caused after evaporation may be serious.**
- **Another effect that can lead to an increased water content in porous building materials is capillary rise. This can be still more pronounced if soluble salts are present. These may originate in the ground water but can also be a result of air pollution.**
- **Sulphates of Sodium, Potassium, Magnesium and Calcium can cause especially severe damage**

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Turbulence and temperature

- **Wind**
- **Solar radiation**

Particles, Aerosols and Gases

- **Air pollution is composed of particles, aerosols and gases.**
- **Air pollution components of natural origin:**

  Sand. Salt. Biological Material. Some Gases.

- **Most gases are mainly products of industrial activities:**

  Heating Traffic.

- **Most fuels, except natural gas, contain sulphur, sulphur dioxide SO_2 is one of the main gaseous by-products of combustion.**

- **Gaseous components of air pollution are:**

Oxides of Sulphur and Nitrogen Ozone Hydrocarbons Hydrogen Sulphide Organic and Inorganic Substances

- **Acid gases, SO_2, SO_3 and NO_x. Ozone and Electrolytes, such as sodium chloride can affect building stones indirectly through their corrosive action on metal parts.**

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Biological Factors

The bio-deterioration of stone materials in the open air depends on a number of prerequisites:

- Biological components distributed by aerial dispersal.
- The ability of biological components to adhere and attach to the stone surface.
- Water, temperature and nutrient conditions which permit their growth and colonization of the stone surface.
- The formation of mineral-dissolving growth products.

The biological components "air-spora“ include:

- Bacteria.
- Spores of Fungi and Mosses.
- Some Terrestrial and Epiphytic Algae.
- Fragments of Lichen. Pollen-Free or Associated with Non-Biological Particles.

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Surface

- The term "surface" is generally used to describe a solid/gas or solid/liquid interface.
- Particles and molecules that accumulate at the interface can serve as nutrients for the organisms.

Attachment

- The attachment, is irreversible, time-dependent and characterized by the appearance of polymeric adhesives. They may be preformed and/or the result of *de novo* synthesis, more pronounced with time. Produced in more substantial amounts they are described (in the case of bacteria) as networks of fibrils.

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- Contrary to the heterotrophs, the autotrophs do not require any supply of organic substances. They can all utilize CO_2 as a carbon source. Concerning the energy source, some of them are photo-autotrophs, utilizing sunlight. Others are chemo-autotrophs (chemo-litotrophs) deriving their energy from oxidation of inorganic substances.

- Cyanobacteria (blue-green algae) are photo-autotrophs and include the most self-sufficient organisms that now exist.

- They can build both CO_2 and N_2 into organic molecules. They are free-living or constitute the algal component which, in symbiosis with a fungal partner, composes a lichen.

- Mosses and true algae also are photo-autotrophs.

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The Air Pollutants

Aggressive pollutants
Sulphur dioxide (SO_2)
Nitrogen oxides (NO_x)
Carbon dioxide- (CO_2)
Ozone (O_3)
Aerosols
Rainwater

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In summary, the following components are assumed to have significant corrosive effects on building materials:

Gas phase:

SO_2 , SO_3 , NO_2 , HNO_3 , HCl , Organic Acids , O_3

Aerosols:

H_2SO_4 , NH_4HSO_4 , $(NH_4)_3H(SO_4)_2$, $(NH_4)_2SO_4$ NaCl

Rain Water Ions:

H^+, NH_4^+, HSO_3^-, SO_4^{2-}, NO_2^-, NO_3^-, HCO_3^-

Through dry deposition, NO_2 is adsorbed on the surface layers of the building materials:

(g = gaseous, l = liquid, ads = adsorbed)

$$NO_2\,(g) \rightarrow NO_2\,(ads)$$

On occasions with high ozone concentrations the following oxidation occurs:

$$2\,NO_2\,(ads) + O_3 \rightarrow N_2O_5\,(ads) + O_2$$

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SURVEY FOR CAUSES OF DETERIORATION

Condensation Processes

In daytime, fixation of pollutants on stone will be greatest on the coolest parts of the exposed surface. The presence of temperature (Thermophoresis) and humidity gradients near the surface can also promote or hinder the deposition of particles. When condensation is taking place at the stone surface, both particles and gas fluxes will be increased. The nearby air is cleaned as most pollutants pass into the liquid, including liquid and solid particles suspended in air (acid gases, aerosol dust and carbonaceous particles).

- The presence of moisture at the stone surface is very dangerous, mainly for two reasons:

1. The pollutant concentration is very high since the amount of water involved is small.
2. These highly concentrated pollutant solutions and their reaction products can remain for long time on the surface because they are not washed away.

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Dissolution by Rainwater

- Heavy rainstorms have been suggested as an important contributor to the deterioration of the because it was observed that during a severe storm, erosion channels on the surface of the monument guided water to faults and cracks and then into the body of the structure.
- Annular rainfall averaged about 326.9 millimetres a year.

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DETERIORATION OF MASONRY MATERIALS

Composition, Structure and Properties

- Chemical Composition

Stones are natural or artificial inorganic masonry materials. The main minerals of the masonry materials are silicates, carbonates, aluminates, ferrites, sulphates and others, their hydrates and hydroxides. They are more or less soluble in or reactive to the action of acids or alkalis and water.

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General Mechanisms of Deterioration

- **Changes in Structure and Damage**

Durability of masonry materials can be defined as:

The ability to preserve the original structure and properties without deterioration over a certain time of exposure.

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DIAGNOSIS

The case history for the Tekke Mosque had been determined. The symptoms and the cause of the deterioration was defined.
Following a routine scheme, a complete survey had been made for all damages found in the Mosque, through direct observation, by studying available documentation, and by means of laboratory investigations, collectively formed a well planned analysis.

The diagnosis also included documentation with different techniques of the present situation and results of laboratory analysis. Studies of records of earlier measures also were included.

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CONCLUSION

- Stone investigation had shown that the main building materials is:

  Organogenic (fossiliferous) Micritic Limestones
- The main constitutent is the Calcite ($CaCo_3$) both in the fossils and the matrix – cementing material.
- The rest of the material consist of Quartz, Feldspars and Mica. Most of the analyzed samples are characterized as Beach rocks of Middle-Upper Eocene Age.
- The stone is characterized with its higher porosity , low compressive strength, low bulk density and high water absorption .
- The analyzed samples show great amount of fossils with different sizes as well as weak cementation material between the grains of the building material. The binding material, which is in many cases not dense, combined with partial dissolution of the fossils, has created high porosity.
- East and West facades are under the influence of great physico-chemical stresses (wind, wetting, drying and temperature fluctuations).
- Surface disaggregation is causing widespread erosion and loss of surface material.

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- Large aggregation of white salt ($NaCl$) is observed on the facades causing damage to the stone; large pieces of limestone are flaking away.
- Weathering, washing, large aggregation of white salt and biological activity have caused serious damage to the stone. Stone become more porous, pitted, washed and weathered.
- All these reasons, beside the severe environmental conditions has characterized the types and degrees of the stone deterioration:

  Pitting Disaggregation Chipping Flaking Exfoliation

  Chromatic Changes (soiling caused by Fungi, Alega, Molds)

  in some cases Disintegration Erosion.

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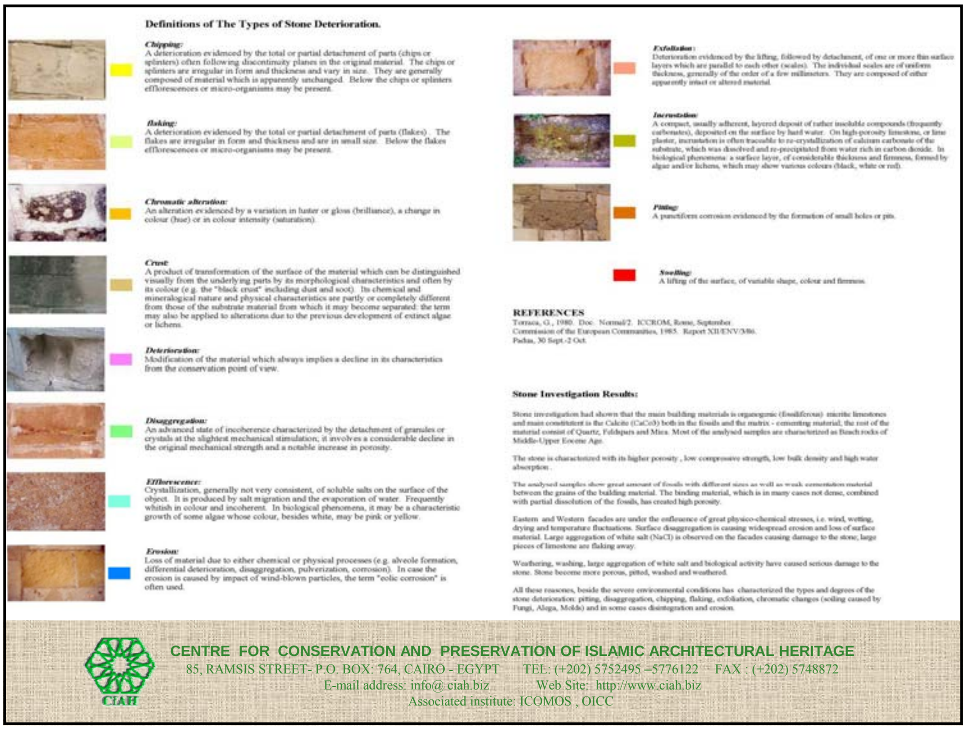
Definitions of The Types of Stone Deterioration.
Chipping:
A deterioration evidenced by the total or partial detachment of parts (chips or splinters) often following discontinuity planes in the original material. The chips or splinters are irregular in form and thickness and vary in size. They are generally composed of material which is apparently unchanged. Below the chips or splinters efflorescences or micro-organisms may be present.
flaking:
A deterioration evidenced by the total or partial detachment of parts (flakes). The flakes are irregular in form and thickness and are in small size. Below the flakes efflorescences or micro-organisms may be present.
Chromatic alteration:
An alteration evidenced by a variation in luster or gloss (brilliance), a change in colour (hue) or in colour intensity (saturation).
Crust:
A product of transformation of the surface of the material which can be distinguished visually from the underlying parts by its morphological characteristics and often by its colour (e.g. the "black crust" including dust and soot). Its chemical and mineralogical nature and physical characteristics are partly or completely different from those of the substrate material from which it may become separated: the term may also be applied to alterations due to the previous development of extinct algae or lichens.
Deterioration:
Modification of the material which always implies a decline in its characteristics from the conservation point of view.
Disaggregation:
An advanced state of incoherence characterized by the detachment of granules or crystals at the slightest mechanical stimulation; it involves a considerable decline in the original mechanical strength and a notable increase in porosity.
Efflorescence:
Crystallization, generally not very consistent, of soluble salts on the surface of the object. It is produced by salt migration and the evaporation of water. Frequently whitish in colour and incoherent. In biological phenomena, it may be a characteristic growth of some algae whose colour, besides white, may be pink or yellow.
Erosion:
Loss of material due to either chemical or physical processes (e.g. alveole formation, differential deterioration, disaggregation, pulverization, corrosion). In case the erosion is caused by impact of wind-blown particles, the term "eolic corrosion" is often used.
Exfoliation:
Deterioration evidenced by the lifting, followed by detachment, of one or more thin surface layers which are parallel to each other (scales). The individual scales are of uniform thickness, generally of the order of a few millimeters. They are composed of either apparently intact or altered material.
Incrustation:
A compact, usually adherent, layered deposit of rather insoluble compounds (frequently carbonates), deposited on the surface by hard water. On high-porosity limestone, or lime plaster, incrustation is often traceable to re-crystallization of calcium carbonate of the substrate, which was dissolved and re-precipitated from water rich in carbon dioxide. In biological phenomena: a surface layer, of considerable thickness and firmness, formed by algae and/or lichens, which may show various colours (black, white or red).
Pitting:
A punctiform corrosion evidenced by the formation of small holes or pits.
Swelling:
A lifting of the surface, of variable shape, colour and firmness.
REFERENCES
Torraca, G., 1980. Doc. Normal/2. ICCROM, Rome, September
Commission of the European Communities, 1985. Report XII/ENV/3/86.
Padua, 30 Sept.-2 Oct.
Stone Investigation Results:
Stone investigation had shown that the main building materials is organogenic (fossilferous) micritic limestones and main constitutent is the Calcite (CaCo3) both in the fossils and the matrix - cementing material, the rest of the material consist of Quartz, Feldspars and Mica. Most of the analysed samples are characterized as Beach rocks of Middle-Upper Eocene Age.
The stone is charactorized with its higher porosity , low compressive strength, low bulk density and high water absorption .
The analysed samples show great amount of fossils with different sizes as well as weak cementation material between the grains of the building material. The binding material, which is in many cases not dense, combined with partial dissolution of the fossils, has created high porosity.
Eastern and Western facades are under the enfleuence of great physico-chemical stresses, i.e. wind, wetting, drying and temperature fluctuations. Surface disaggregation is causing widespread erosion and loss of surface material. Large aggregation of white salt (NaCl) is observed on the facades causing damage to the stone; large pieces of limestone are flaking away.
Weathering, washing, large aggregation of white salt and biological activity have caused serious damage to the stone. Stone become more porous, pitted, washed and weathered.
All these reasones, beside the severe environmental conditions has characterized the types and degrees of the stone deterioration: pitting, disaggregation, chipping, flaking, exfoliation, chromatic changes (soiling caused by Fungi, Alega, Molds) and in some cases disintegration and erosion.
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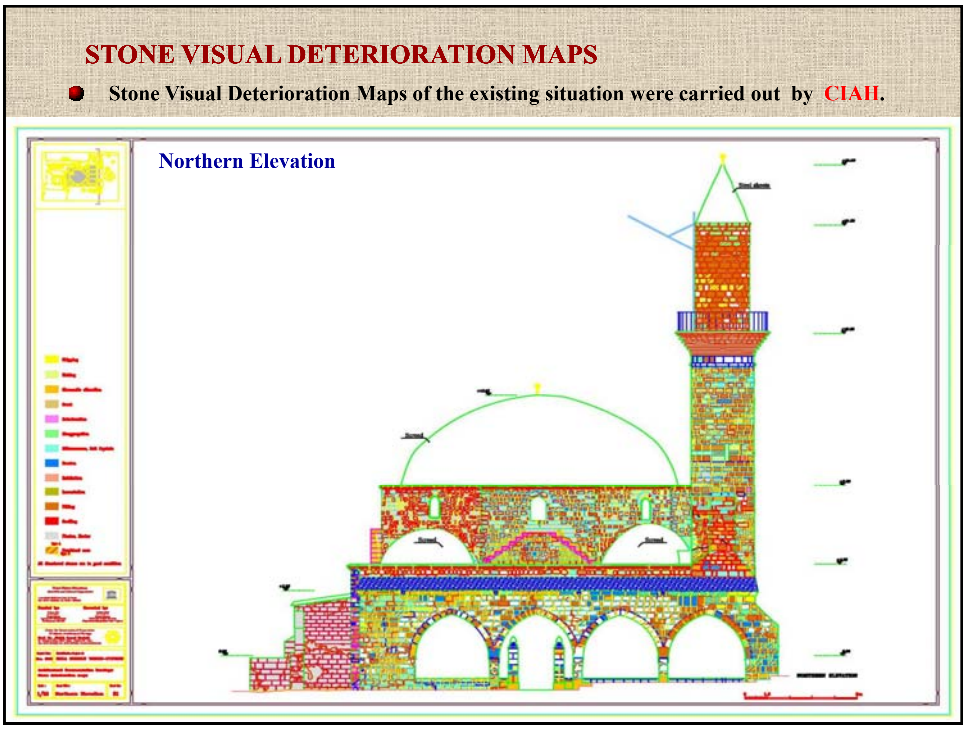
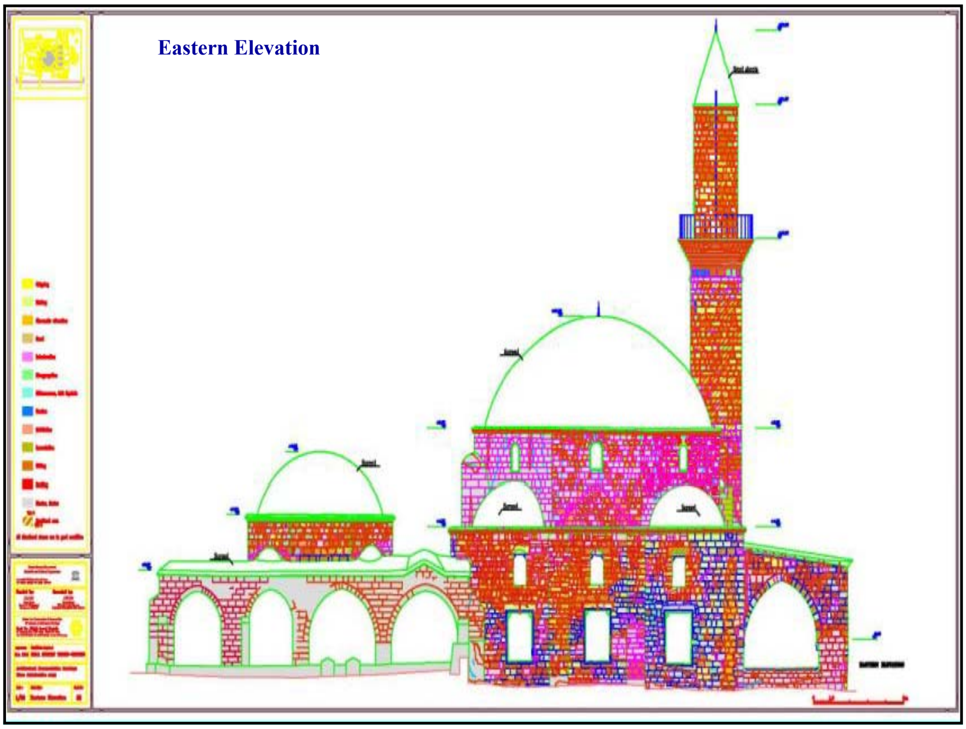
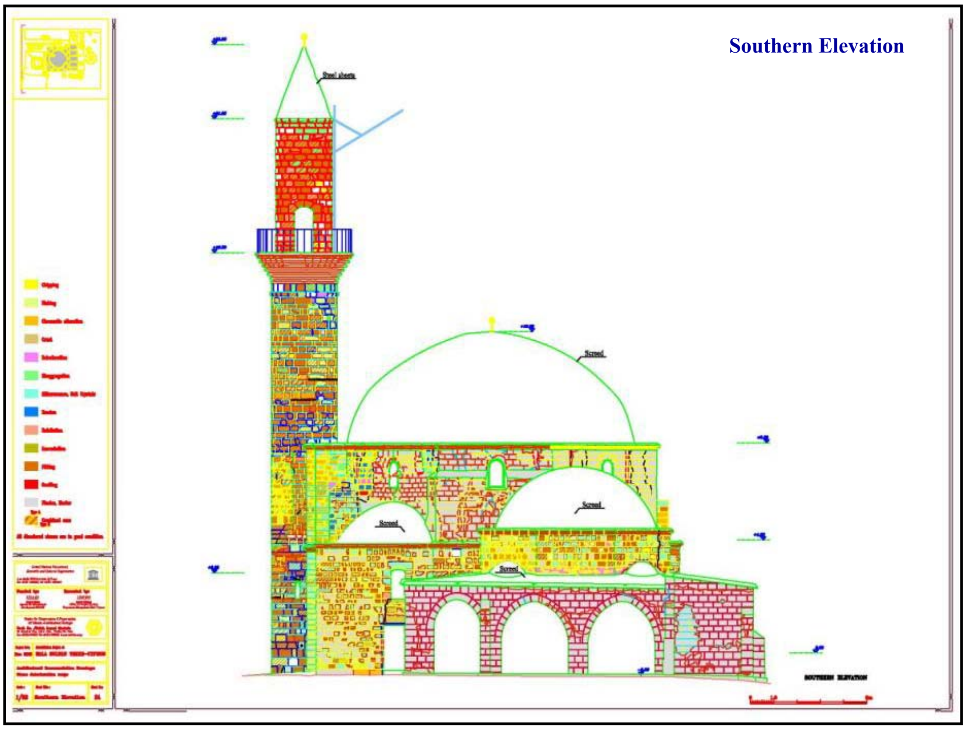
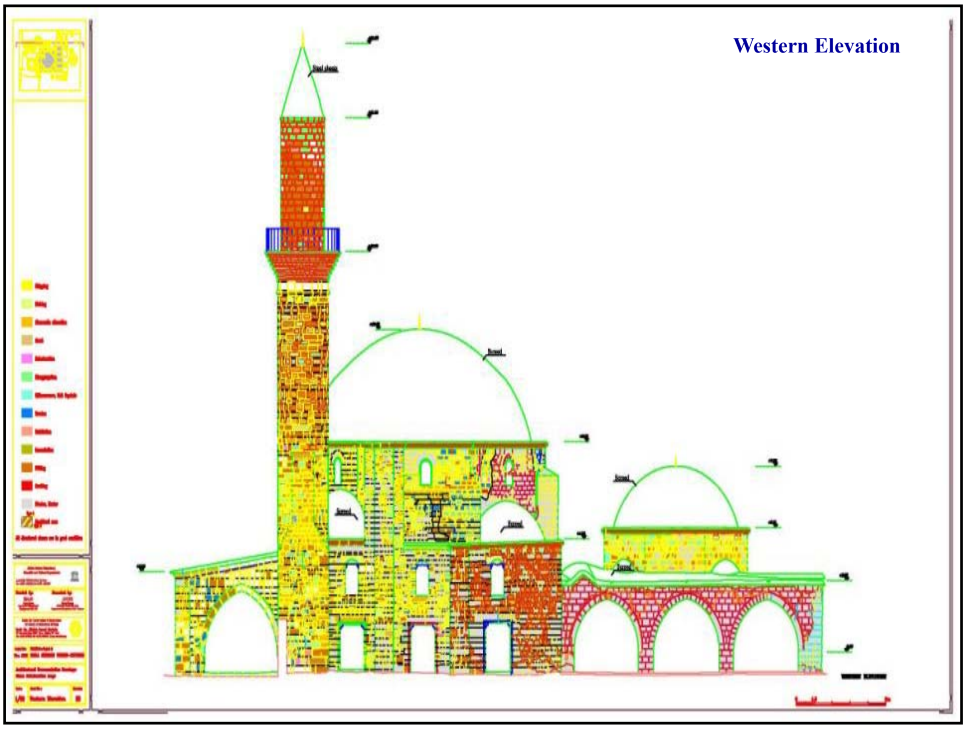
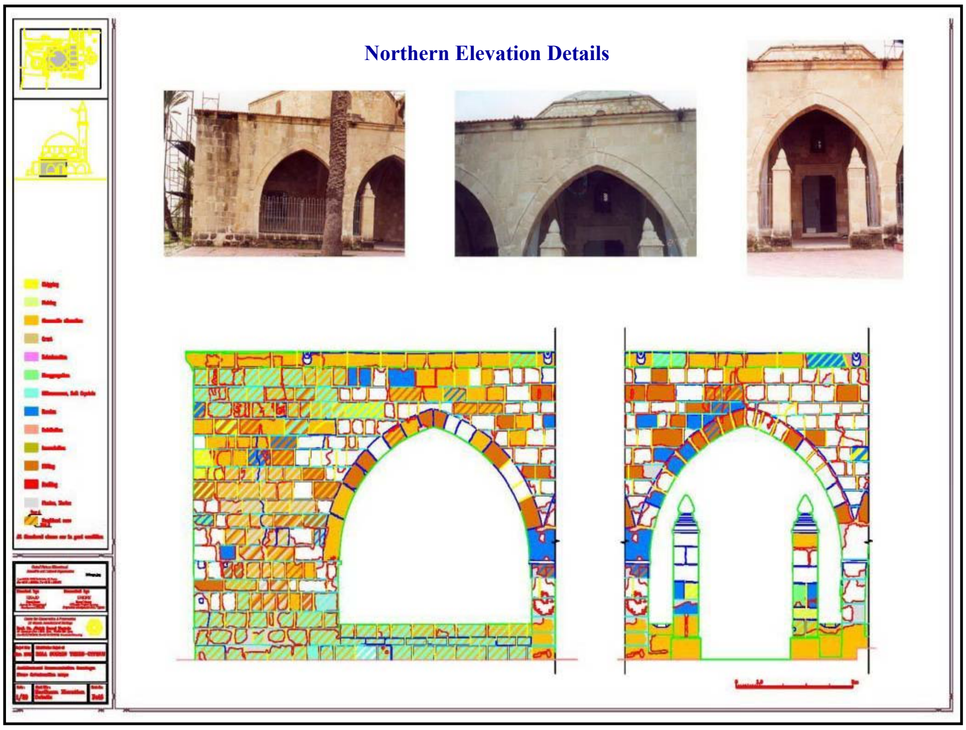

STONE VISUAL DETERIORATION MAPS
Stone Visual Deterioration Maps of the existing situation were carried out by CIAH.
Northern Elevation

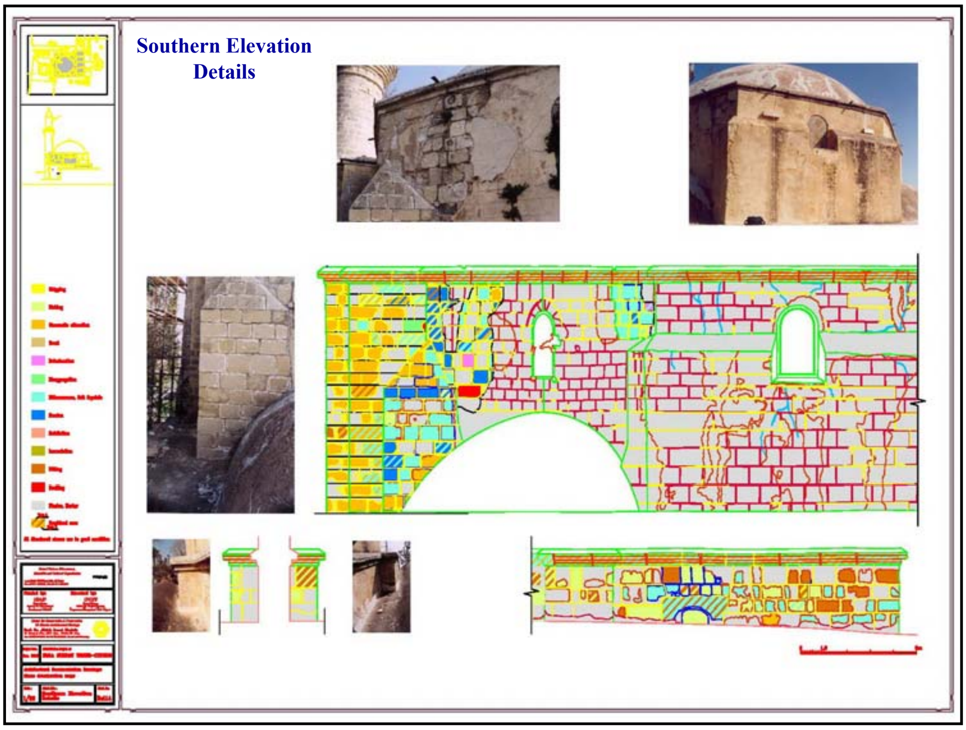

Eastern Elevation


Southern Elevation
Steel sheets
Screed


Western Elevation


Northern Elevation Details


Eastern Elevation
Details


Southern Elevation
Details

Western Elevation Details

REHABILITATION STANDARDS

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REHABILITATION STRATIGY

The rehabilitation project aspects, proposed interventions for repairing and improving the structural condition as well as safeguarding architectural values of *Hala Sultan Tekke Mosque*, are prepared in accordance with the strategies guidelines and recommendation of the following International Charters:

- The International Charter for the Conservation and Restoration of Monuments and Sites; *Venice charter* of 1964 which stresses on preserve and revail the atheistic and historic value of the monument .
- The *Amsterdam declaration* of 1975, which stresses the true interdisciplinary character of conservation.
- The Principles for the Conservation of Islamic Architectural Heritage; *Lahore Statement* (Pakistan 1980).
- *Burra charter* (Australia 1981) .
- *The Convention for the Protection of the Architectural Heritage of Europe* of Granada 1985.
- The United States, Secretary of the Interior's *Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings.* (USA 1978).
- *Recommendation of Nara Conference On Authenticity* (Japan 1994).

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REHABILITATION

It is defined as the act or process of returning a property to a state of utility through repair or alteration which makes possible an efficient contemporary use while preserving those portions or features of the property which are significant to its historical, architectural, and cultural values.

GENERAL STANDARDS FOR HISTORIC REHABILITATION PROJECTS

General standards apply to all treatments undertaken on historic prosperities :

1. Every reasonable effort shall be made to provide a compatible use for a property that requires minimal alteration of the building structure, or site and its environment, or to use a property for its original intended purpose.

2. The distinguishing original qualities or character of a building, structure, or site and its environment shall not be destroyed. The removal or alteration on any historic material or distinctive architectural features should be avoided when possible.

3. All buildings, structures and sites shall be recognized as products of their own time. Alterations which have no historical basis and which seek to create an earlier appearance shall be discouraged.

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GENERAL STANDARDS FOR HISTORIC REHABILITATION PROJECTS

4. Changes which may have taken place in the course of time are evidence of the history and development of a building, structure, or site and its environment. These changes may have acquired significance in their own right, and this significance shall be recognized and respected.

5. Distinctive stylistic features or examples of skilled craftsmanship which characterized a building, structure, or site, shall be treated with sensitivity.

6. Deteriorated architectural features shall be repaired rather than replaced, wherever possible. In the event replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual qualities. Repair or replacement of missing architectural features should be based on accurate duplications of features, substantiated by historical, physical, or pictorial evidence rather than on conjectural designs or the availability of different architectural elements from other buildings or structures.

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7. The surface cleaning of structures shall be undertaken with gentlest means possible. Sandblasting and other cleaning methods that will damage the historic building materials shall not be undertaken.

8. Every reasonable effort shall be made to protect and preserve archeological resources affected by, or adjacent to, any acquisition, protection, stabilization, preservation, rehabilitation, restoration, or reconstruction project.

9. Contemporary design for alterations and additions to existing properties shall not be discouraged when such alterations and additions do not destroy significant historic, architectural, or cultural material and such design is compatible with the size, scale, color, material, and character of the property, neighborhood, or environment.

10. Whenever possible, new additions or alterations to structures shall be done in such a manner that if such additions or alterations to structures were to be removed in the future, the essential form and integrity of the structure would be unimpaired.

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REHABILITATION RECOMMENDATIONS

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REHABILITATION RECOMMENDATIONS

It should be borne in mind that rehabilitation alone never can rescue a cultural object. The measures must be combined with preventive steps aimed at reducing the degradation factors in a larger context.

Through a review of the literature on the physical condition of Tekke Mosque, the most obvious mechanisms of deterioration have been outlined.

All the mechanisms can be assessed and their relative impact accurately weighted, a minimal intervention strategy to preserve the monument to its most pristine condition was designed.

This phase outlines the proposed treatment measures.

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1. STONE TREATMENTS

Stone Conservation works include:

- ***Cleaning***
- ***Desalination***
- ***Replacement.***
- ***Plastic Repairing***
- ***Consolidation***
- ***Maintenance***

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1.1 STONE CLEANING

- The aim of the cleaning is primarily to remove harmful or corroding substances. At the same time the object gets a more aesthetic appearance.
- Deposits of dirt and soot not only blemish the external surfaces of buildings, but they can also be harmful through chemical action, and they can hide decay.
- Both Mechanical and /or Chemical methods are proposed for cleaning.

CLEANING WITH DISTILLED WATER

- Cleaning methods based on water are recommended only for sensitive areas (e.g. Mihrab and internal inscriptions).
- After bristol soft brushes wisely used to remove dust, surface of chosen areas should be wiped with minimal amount of pressure using sponge damped with de-ionized distilled water, avoiding any damage to finishes, hidden timber or ferrous metals due to water penetration.

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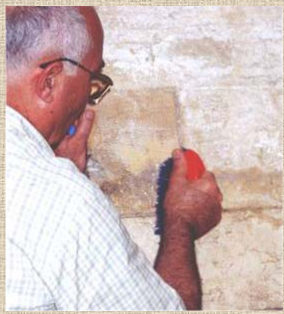
- A non-ionic detergent e.g. Triton X-100 (octiy –phenoxy-ethoxy-ethanol) 5%, could be used to accelerate cleaning or for final cleaning.
- Extra care should be taken to capture and remove all washing and rinse water before it is absorbed into the walls.

•Cleaning using de-ionized distilled water under normal pressure



•Cleaning using de-ionized distilled water and soft brushes

•Cleaning using Triton X-100 and Phosphoric brushes

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•Portico external wall after cleaning.

•Applying pads of Triton X-100 (octlyphenoxyethoxyethanol) on portico external wall.

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•Applying pads of Graffiti Gone- Step 2 on marble column, painted green in the mosque.

•Marble column after removing paint .

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•Marble plate after cleaning.

•Applying pads at the marble plate

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• Applying pads of Triton X-100
(octlyphenoxyethoxyethanol) on marble column
inside the mosque.

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MICROBLASTING

Historic Building, Germany
During cleaning using microplasting

- These methods could be successful when using soft abrasive powder applied by well trained technicians to gain full control of the cleaning and its depth, where the utmost caution is necessary. The method is also well suited for cleaning pre-consolidated stone .

Notre Dame De Paris
Recently cleaned using microplasting

Notre Dame De Paris, After 2 years,resulted
severe surface deterioration

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1.2 DESALINATION

TREATMENT FOR SALT-CONTAMINATED MASONRY WITH CLAY PACKS

- **Clays make very efficient poultices for reducing the amount of salts.**
- **A 50 micron attapulgite or sepiolite clay powder is added to enough clean water to produce a thick, sticky cream (the water should not be added to the clay, because a lumpy paste will be produced).**
- **The poultice may be effective within a few days, but it may need to be left for several weeks.**

Desalination using attapulgite poultices

The render should have open texture and rough finish to increase surface area.

Attabulgite: **Fibrous clay mineral; hydrous magnesium and aluminum silicate.**

Sepiolite: **Fibrous clay mineral ; hydrous aluminum silicates, principal ingredient of China clay (Kaolin)**

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TREATMENT FOR SALT-CONTAMINATED MASONRY WITH SACRIFICIAL RENDER

- **The surface should be scraped down after rendering with fine teethed edge of a hacksaw blade; this is carried out after surface has begun to stiffen.**
- **Treatment should be repeated as one render coat may be insufficient to reduce salt content to a safe level.**
- **Before applying the second coat, the first coat should be carefully removed and wall rewetted.**
- **Leave the coats for several months as sacrificial (lime: sand) renders are relatively slow method of masonry desalination .**

Removal of attapulgite poultices

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1.3 STONE REPLACEMENT

- Decaying stones which have a structural role and on which the stability and survival of the stones or other elements of the structure depend have a clear priority for replacement almost regardless of their intrinsic value.

Stone Cutting

Stone Dressing

Stone Replacement

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REPLACING WITH NEW STONES

Stone Replacement

Stone moulding

Stone Replacement

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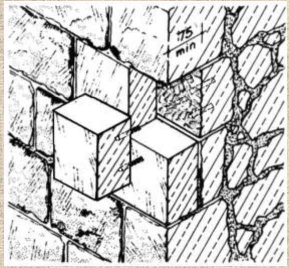
Adhesives and pinning

- Sometimes new stones, or new stone faces may be secured with epoxy adhesive.
- A typical example of this is the halving of decayed mullions, where the decayed stone is cut back and half mullions glued to the face of the surviving internal half.
- Excellent as modern resin adhesives may be it is always unwise to rely on the interface bond alone.
- The halving technique relies, on dowel pins of Titanium or Teflon bars*.
- Spalls and missing parts can be built up phosphor bronze wire and matching mortar.
- The use of pins and epoxy mortars has enabled valuable masonry features, shattered to be saved, which otherwise would have been lost.



Stone facing fixation,
using dowel pins of titanium or teflon bars and epoxy

* Teflon : Poly tetra flouro ethylene

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1.4 PLASTIC REPAIRING

- Plastic repairs are of a particular interest and importance to conservators because the technique frequently permits the retension of more original material with much less disturbance than would be possible for the execution of conventional masonry repairs.
- The repair must be prepared as samples on a piece of stone, not in a wooden mould, and judged on the dry and wet appearance.
- Plastic repairs should always be carried out by a stone mason or stone conservator,

Plastic Repairing
National Theater – Berlin - Germany

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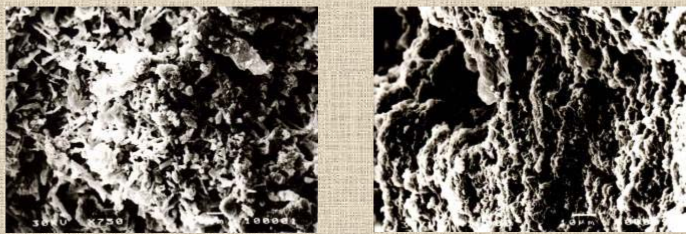
1.5 CONSOLIDATION

- Modern conservation techniques aim at consolidation of the stone, which in this connection mainly means replacing the binder that has been lost by weathering.
- A good consolidant for stone. It should penetrate, be strong enough to join the stone and must not react with acids.
- The consolidant should allow the stone to breathe in order to allow moisture to pass. No changes of the colour of the stone are allowed and it is even desirable that the consolidant should be invisible after treatment.

Stone sample before treatment



Stone sample after treatment with Wacker strengthener

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- As with all methods of conservation there is an ultimate requirement that the method used should comply with the demand of minimum intervention and be reversible.
- A variety of consolidants for stone have been tested both in laboratories and in practical treatment, Wacker silicones (Wacker OH 100 stone strengthener based on ethyl silicate) seem to give the best results hitherto, It has good penetration and give good mechanical strength to the stone as it forms a mineral binder (silica gel binder SiO_2) that is compatible with the stone material.

Appsorbation measurement using Karsten Tube
before and after treatment with water repellant

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2. REPAIRS FOR WALLS AND FOUNDATIONS

2.1 GROUT MIXTURES

- One of the most useful grouting materials is undoubtedly low sulphate pulverized fuel ash ('PFA' or 'fly ash') which, over the last few decades has been used increasingly with cement, or lime, or both, and other additives which provide bulk or aid mobility and suspension.
- Non-hydraulic lime cannot be used without a setting aid. Combined PFA and lime can produce a mobile, low- to medium-strength grout which is frequently just what is required to fill voids in double-skin, rubble cored walls.
- Reactive PFA is a pozzolanic additive which, in addition, aids penetration. Avoiding 'settling out' during the grouting process.
- Unless the grouting operation is small or very specialized, it is recommended that pre-bagged grout mixtures are used as much as possible. These are available for a very wide range of functions and specialist suppliers will recommend grouts for particular situations.

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2.2 GROUTING OPERATIONS

- The use of liquid grout avoids dismantling and rebuilding defective masonry in many cases.
- In its simplest form grouting may be carried out by hand pouring into clay grout cups formed on the face of a wall. There is a choice of four basic methods which will be dictated by the nature and condition of the masonry.
- Gravity grouting is particularly suitable where the masonry is very vulnerable to movement under pressure and is the system most commonly used on ancient monument work.

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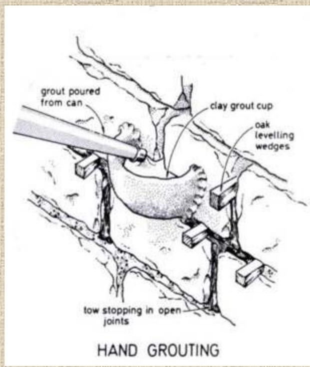
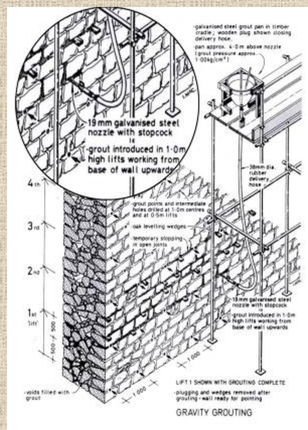
2.3 HAND GROUTING



- Local grouting can be carried out very efficiently by hand.
- This technique is suited to small, isolated voids or fine cracks and is frequently carried out in association with tamping and pointing.

2.4 GRAVITY GROUTING

- The grouting apparatus required for filling large voids



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3. JOINTS POINTING & REPOINTING

GENERAL

- As a general rule **joints should be cleaned out to a minimum depth of 25 mm** (1 in) and never to a depth less than their width; but wide joints, especially those liable to exposure to extreme weathering, should be cut out to a minimum 38 mm (1½ in) or even 50 mm (2 in).

- Sometimes the mortar has disintegrated to such an extent that the joints are largely empty, in which case they must first be deep tamped and, if necessary, hand grouted to fill the joint to the required depth for pointing. If tamped or grouted mortar comes closer to the face than 25 mm-38 mm it must be cut back to the proper depth and to a square face before pointing.

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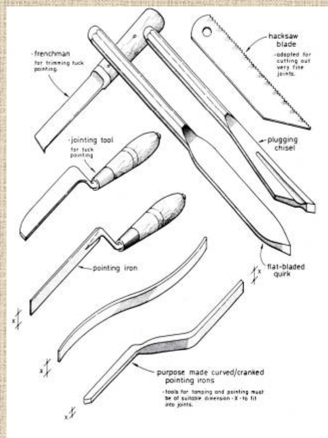
3.1 RAKING & CUTTING OUT THE JOINTS

- Raking out may be a simple operation without risk to the fabric where mortar is substantially decayed, but it is over-simplifying the situation to say that the joint does not need re-pointing if it requires cutting out.

- The empty joint at the face may be too much of a risk to leave alone, and additional cutting out may be necessary to achieve enough depth for pointing.

- More often, cutting out (as distinct from raking out with a knife blade or bent spike) is necessary to remove dense re-pointing of an earlier period, especially where this mortar -fortunately usually shallow in depth- is causing problems because of its high strength, impermeability and tendency to trap water behind it and accelerate the decay of stones.

- All Cutting out should leave a clean, square face at the back of the joint to provide optimum contact with the new mortar. Time for cutting out, which may be considerable, must be properly programmed.



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3.2 FILLING THE JOINT

- If the joints have dried out after cleaning they must be re-wetted before placing the new mortar. The mortar is pushed into the joint from a board and ironed in with the maximum possible pressure.

- Pointing trowels are in common use, but it is regrettably unusual to see pointing keys, which can be improvised to suit the particular work in hand. These may be cranked bronze or steel fleet, or beaten out rod or even wood. The mortar must subsequently be packed with a pointing key.

- The function of these keys is to push the mortar evenly into the joint for the full joint width; this they can do because they fit into the joint and do not try to achieve compaction from the surface alone.

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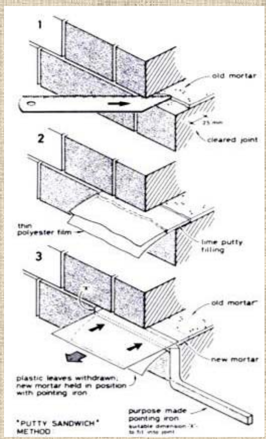
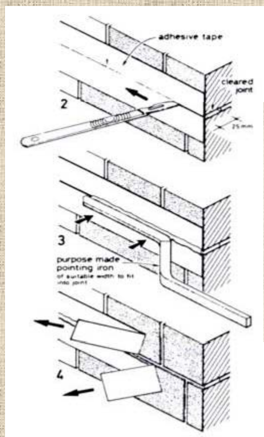
3.3 FILLING FINE JOINTS

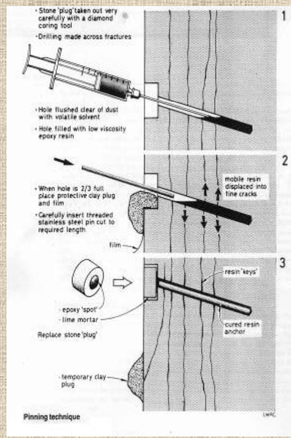
- Injection grouting of these joints is notoriously difficult, as the grout tends to disappear without any effect into the wide, open joints behind the face.



Method 1: Putty Sandwich



Method 2: Taping and Pointing



Method 3: Mortar Injection

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4. TREATMENT OF ALGAE, LICHENS AND MOSSES

- Sources of nutrition for organisms-such as dust, deposits of various organic substances, bird droppings, and unsuitable restoration materials must be removed from stone surface.
- Periodic cleaning as a preventive conservation measure is the principal and sometimes only way to prevent and control biological attack in outdoor environments.
- It has been found effective in controlling establishment of mosses, lichens, fungi, algae and higher plants by discouraging the accumulation of wind borne spores and seeds of plants and their subsequent germination.
- Partially removing of biological growth before applying biotical agents is usually recommended.
- Mechanical methods are favored for removing biological growth, as they eliminate the danger of leaving behind unwanted substances on the stone.

Biological growth
(Algae, mosses, lichens and fungi)

Biological growth
(mosses colonization)

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4.1 BIOCIDES

- Biocides refer collectively to bactericides, fungicides, algaecides and herbicides. They are normally used to eliminate and inhibit biological growth (lichens, algae and mosses).
- There are numerous ready-made chemical cleaners available on the market, but before using any of these it should be verified that there is no risk of damage to the actual stone object to which they are applied.
- Only well known products should be used as the damage caused by some substances might be detected only after a long time.
- Treatments have also been carried out using biological packs covered with polyethylene sheeting.
- These chemicals, however, are also potentially harmful to wildlife and humans.
- For this reason, there is a mandatory need to identify and disclose the toxicological properties of biocides. The most common indices for quantifying toxicity are LD_{50} (Lethal Dose 50 %) and LC_{50} (Lethal Concentration 50 %).
- Mechanical methods are favored for removing biological growth, as they eliminate the danger of leaving behind unwanted substances on the stone.

LD_{50}: Units of milligrams of the substance per kilogram body weight of the animal species concerned (rat).

•LC_{50}: Figures are reported as milligrams of the substance per cubic meter of the atmosphere to which the animal (rat) is exposed over a particular time period.

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Toxic values	Oral LD_{50}	Dermal LD_{50}	Inhalation LC_{50}
Very Toxic	0 - 50	0 - 200	0 - 2000
Moderate Toxic	50 -500	200 - 2000	2000 - 20000
Slightly Toxic	500 - 5000	Greater than 2000	Greater than 20000

* Normal **Asprin** has oral LD_{50} of 1375

- The biocides for treatment of masonry covered with algae, lichen, mosses and small plants is based on a quaternary ammonium compound effect the initial bill, and when combined with tributyl-tin oxide will have long term inhibiting effect on recolonization .

- By handling and mixing biocides, worker should wear rubber gloves; when spraying he should wear safety glasses, mask and goggles.

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5. TREATMENT OF SOIL AGAINST TERMITES

- Soil poisoning is only the first line of defense against termites attack.
- Chorpyrifos, Pyrethroids (permethrin and cyprenthrin) have been found suitable.
- Foundation should be exposed and the earth should be poisoned as it is replaced with the refill new soil mixed with the biocide material.
- The bottom of the trenchs should be poisoned by injection under pressure through drilled holes to the depth of 50 cm at least and distance between holes of 30-50 cm.

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6. REPAIRING OF METALS ELEMENTS

6.1 CAST IRON / WROUGHT IRON

- Corrosion of iron is the formation of Iron Oxide (rust) by the reaction of iron with oxygen and water.
- Application of paint is the most practical method of protecting iron.
- Cast iron and wrought iron is of intristic value and is preferable to repair than renew.

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Mechanical cleaning

- This process involve the power–driven tools such as grinders and rotary wire brushes. Needle guns can be used successfully to remove the rust and scale and can reach into awkward corners and angles inaccessible to other equipment.
- It is advisable to start at a pressure of 40 psi (6 kpa) with copper slag; satisfactory cleaning pressure should not exceed 60-70 psi (8-10 kpa).

Acid Pickling

- This process involve immersing items in a bath of warm diluted phosphoric acid to remove mill seal and rust.
- The reaction with iron results is a protective layer of phosphate on the surface (anodic inhibitors).

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Repairs

- Corroded ends can be tipped with stainless steel, delta bronze; for distance of housing at least 12 mm from masonry face.
- Embedded parts into pillars should be painted with epoxy resin. To replace loss of thickness, use a filler based on steel particles with an with epoxy resin.

Painting with protective paint

- Selection of the protective system should consider the historic and archaeological value of the existing coating, the method of preparation, difficulties of maintenance.
- Surface should be dry, to achieve satisfactory results in protecting internal and external iron work, a total film thickness of 125-250 microns, two coats of primer and 4 coats of air dry paint (alkyd resin paints) are recommended if they are applied to a rust and scale- free surface.

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7. REMOVING OLD (non historic) PAINTS FROM WOODEN SURFACE

- Using the brush, a thick layer of methylene chloride paint could be applied to the wooden surface.
- After five minuets, the old paint could be removed using scraping tool. For better results the previous step could be repeated for several times until the old paint is removed completely.
- To have a clean surface free from residue, fine sandpaper can be use parallel to wooden fibers.

8. CLEANING OF WOODEN ELEMENTS

- Stained or dirty wood work can be successfully cleaned by removing all dust and dry dirt by vacuum cleaner, scrubbing with natural PH soap and warm clean water.
- Old varnish can be removed using solvent made up from American turpentine (not substitute) and acetone. Surface should be washed down.
- When surface is dried, a thick protective coat made up from microcrystalline wax and preservative (natural turpentine) should be applied, to be rubbed down with clean soft cloth.

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9. TREATMENT OF WOOD AGAINST TERMITES

- All wooden elements to be treated against termites by brushing with proposed material to penetrate in soft wood 2- 4 mm.
- Wooden batten on wall plinth and ground (flooring), wood board for flooring and for timber in contact with the walls or the ground to be treated by Pressure Creosote in accordance with BS 913; 1972 or Dursban 4 TC.

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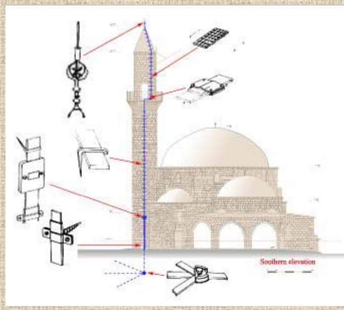
12. LIGHTNING PROTECTION



Proposed Lightning system for the Tekke mosque

- Lightning, an intensely bright spark or streak Of fight through the air to ground, has terrified and excited mankind for centuries.
- There are different types of lightning: cloud to ground, cloud to cloud and within a single cloud, not to mention such rare variations as ribbon and ball lightning. On average a cloud to ground strike would be in the order of 20,000 amperes with a duration of 0.2 seconds, and at its peak, the power released can be 100 megawatts per metre.
- The possibility of a Lighting strike to the structure of a building such as a small mosque or church is much greater, at around 1:500 per year. Electrical circuits may also be damaged by the electo-magnetic field generated. The effect of a lightning conductor placed appropriately on any building is to create an 'apparent earth' short circuiting the intense electric field below a thundercloud. This allows positive ions to be transferred through the conductor to the atmosphere, as an upward streamer.

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- The latest standard recommends that a series of down conductors is installed to protect the whole building, with towers and spires having a minimum of two down conductors placed diametrically opposite each other and horizontal conductors (coronas) vertically at 20m centres.
- The remainder of the building should be protected with a series of conductors interconnected to form a 20m x 10m ‘Air Termination’ grid, using where possible elements of the structure, such as metallic gutters, lead roofs, and so on.
- Also prominent features such as pinnacles, and crescents should have additional air terminals, as they will form upward streamers under the right conditions.
- The air termination must then be connected to ground with a series of down conductors spaced around the perimeter of the buildings. one for every 20m of perimeter (for structures more than 20m high this is decreased to 10m spaces).
- In order to provide adequate protection in accordance with BS 6651:1992 the bonding to electrical and other services is essential, to equalise the potential difference between those items and the lightning conductor during a strike. This is often ignored in the interest of expediency and cost.
- Once installed, down conductors and air terminations must be adequately earthed to ground with a series of electrodes, which may take the form of either driven rods, plates or mats made from copper.

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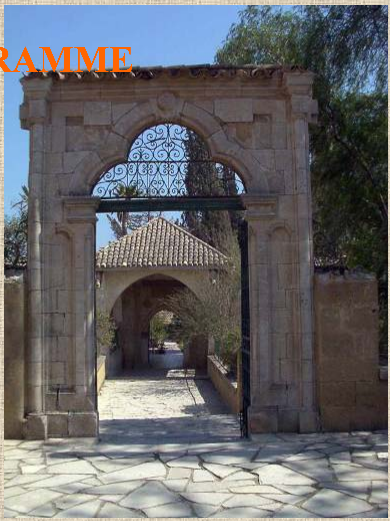
MAINTENANCE PROGRAMME



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MAINTENANCE PROGRAMME

1- INTRODUCTION

- The maintenance programme is aimed at keeping the cultural resources in a manner that will prevent the loss of any part of them.
- It concerns all practical and technical measures that should be taken to maintain the site in proper order. It is a continuous process, not a product.
- Maintenance should use natural forces to enhance the beauty of the cultural resource, but over-maintenance can destroy its beauty.
- Maintenance planning is an art which needs cultural and ecological sensitivity.
- Climate and the causes of decay control the appropriate degree of maintenance, together with the users' needs, but maintenance policies and programmes should also take into account the specific nature of every culture, aiming at a balance with natural forces.

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- A maintenance programme should follow well-established cycles describing who does what work, how this work is done, and how frequently. It should describe the actions in simple terms that can be implemented by cleaners, crafts persons, supervisors and all other individuals involved in the upkeep of the cultural resource.
- The implementation of the maintenance programme is followed by its re-evaluation based on results and time expended.
- Detailed descriptions of accurate hours worked and materials used are essential; traveling time should be kept entirely separate.
- Tasks should be clearly described so that outside workers can bring all the necessary tools and consumable supplies to the site, avoiding time wasted on abortive journeys.

A good maintenance strategy can prevent a great deal of damage and decay, and thus save money. Unfortunately, it is difficult to quantify these savings, and, as a result, those administering cultural heritage too often see only the cost of the professional service and are tempted to economize unwisely in this field.

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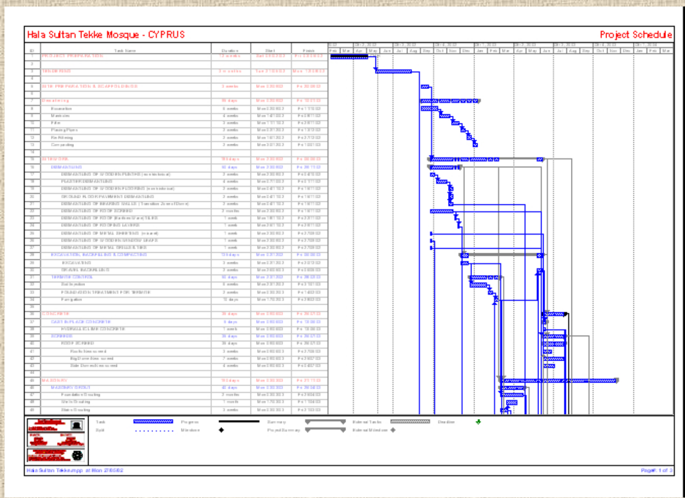
PROJECT EXECUTION PROGRAMME



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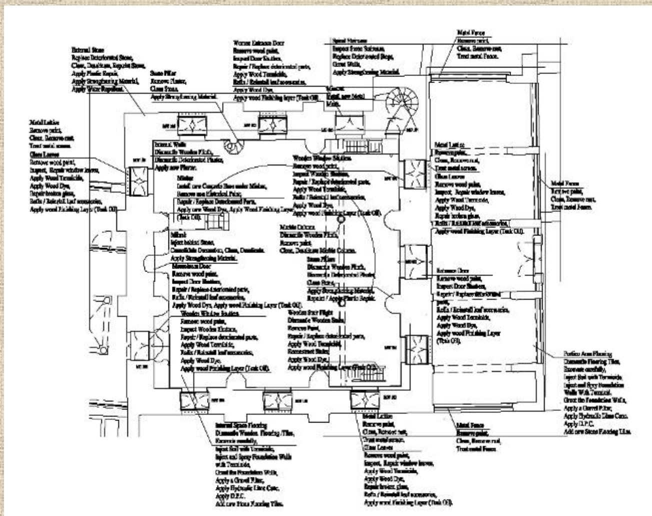
PROJECT EXECUTION DRAWINGS



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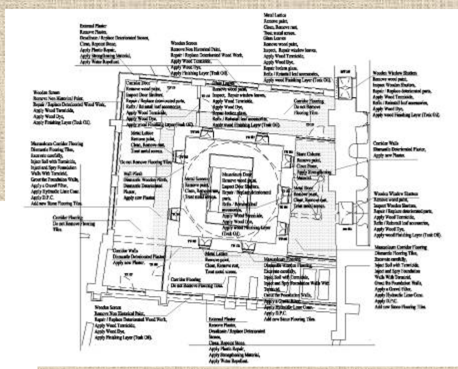

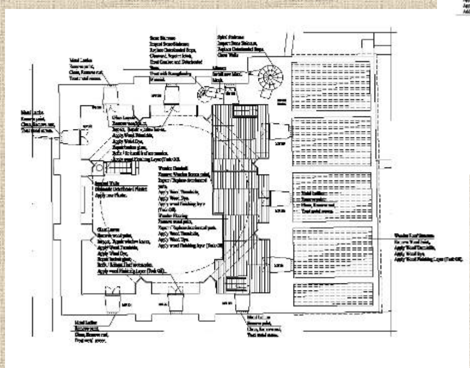

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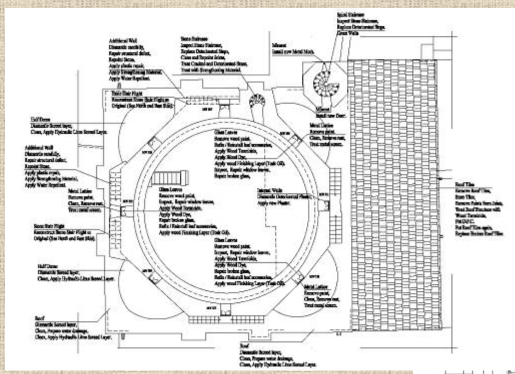

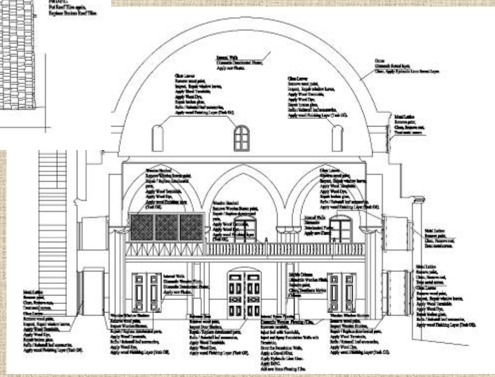

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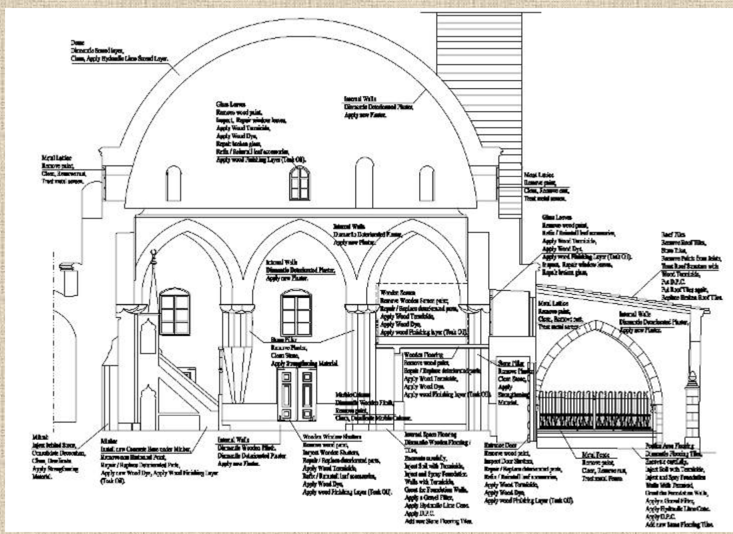

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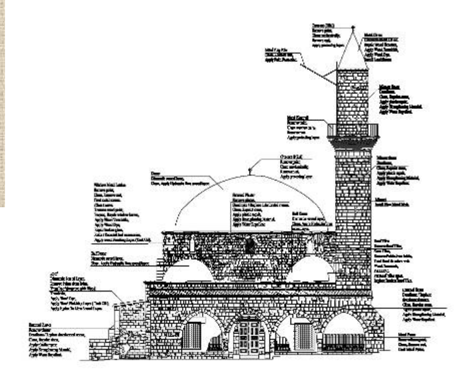

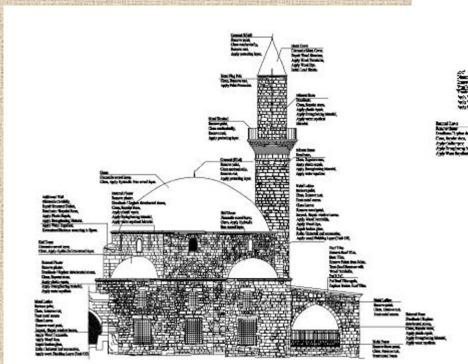

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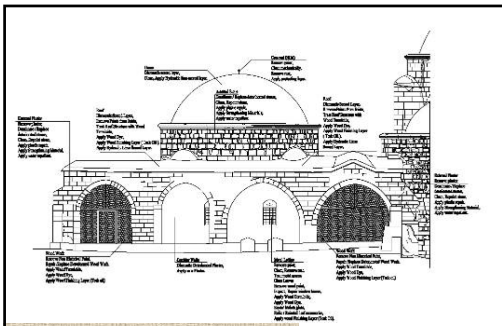

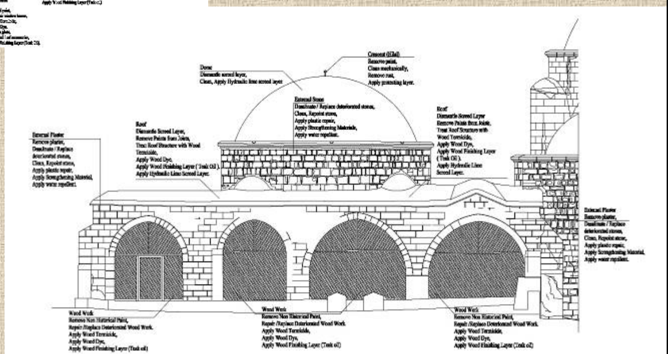

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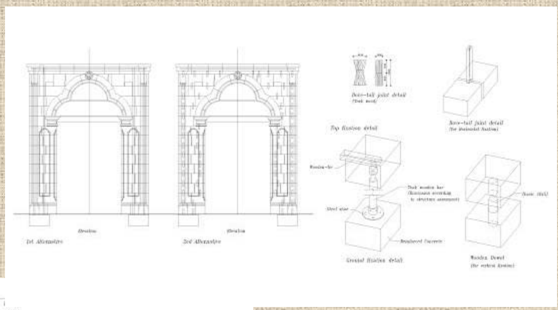

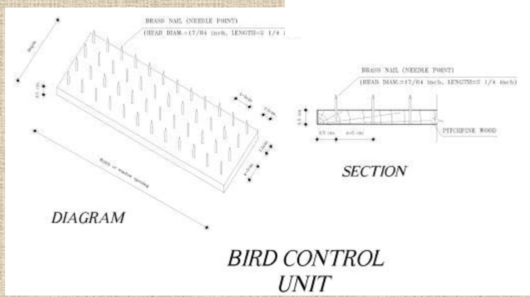

Main gate Structure Assessment

Bird Control Unit

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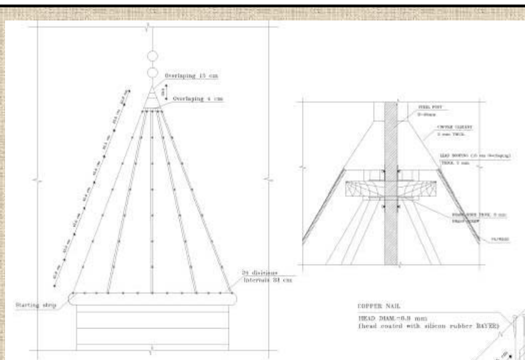
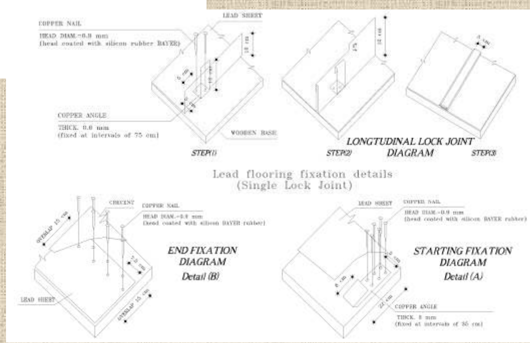


Minaret hood Lead Details



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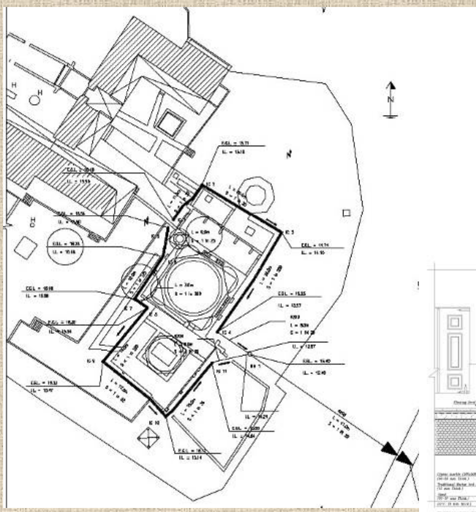

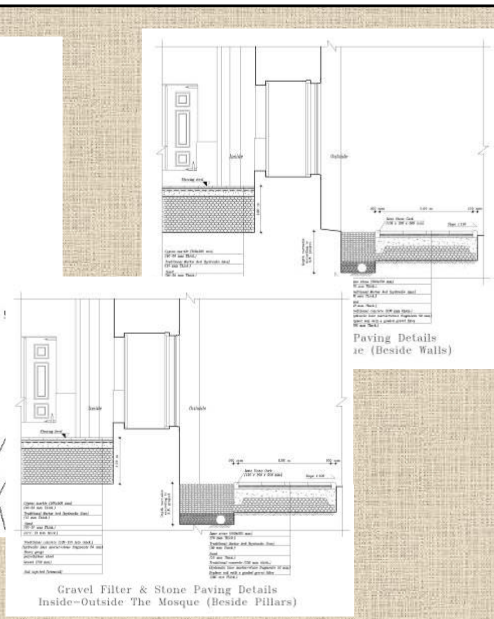

Storm Rain Drainage System for the Tekke

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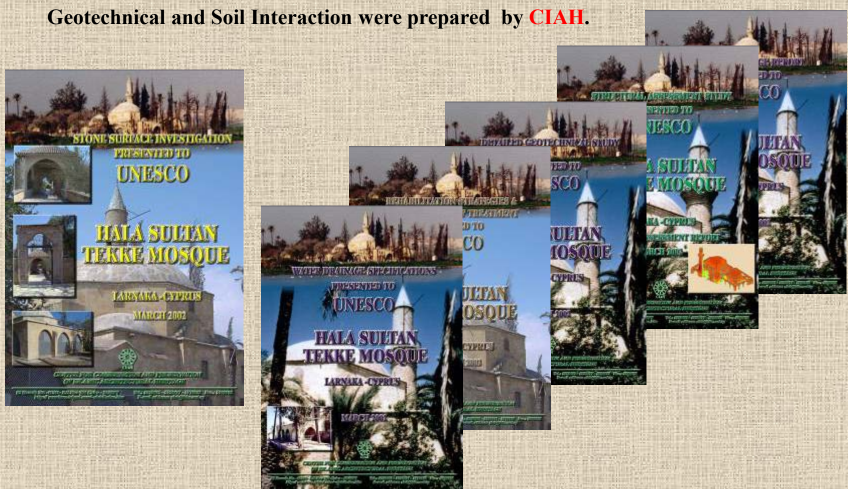
PROJECT FINAL STUDIES

- A complete set of studies covering Structure Assessment, Water Drainage, Geotechnical and Soil Interaction were prepared by CIAH.



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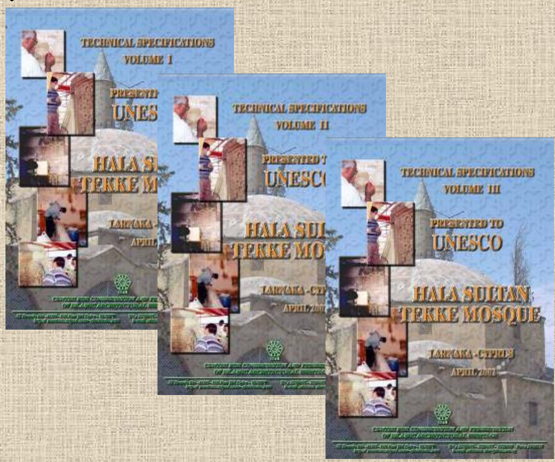
PROJECT SPECIFICATIONS & TENDER DOCUMENTS

- A complete set of Specifications and Tender documents according to ASTM were prepared by CIAH.



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Hala Sultan Tekke
After Rehabilitation

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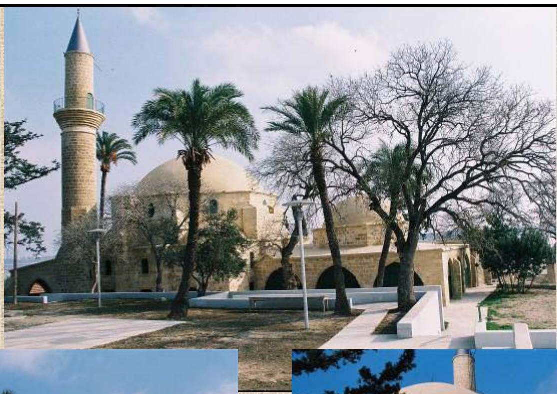

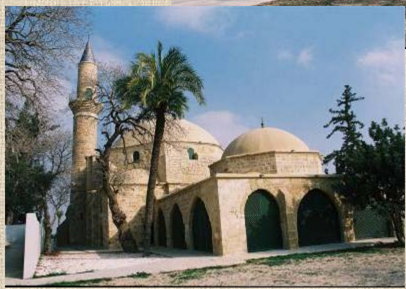

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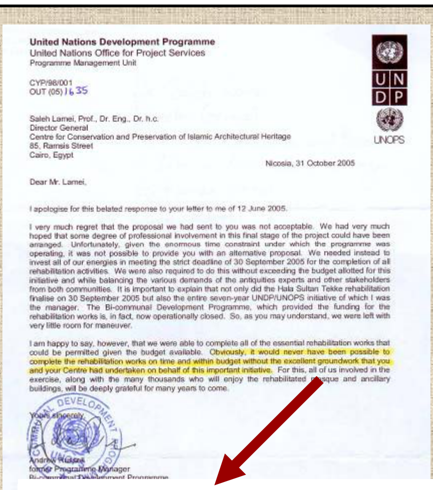

United Nations Development Programme
United Nations Office for Project Services
Programme Management Unit

CYP/98/001
OUT (05) 1635

Saleh Lamei, Prof., Dr. Eng., Dr. h.c.
Director General
Centre for Conservation and Preservation of Islamic Architectural Heritage
85, Ramsis Street
Cairo, Egypt

Nicosia, 31 October 2005

Dear Mr. Lamei,

I apologise for this belated response to your letter to me of 12 June 2005.

I very much regret that the proposal we had sent to you was not acceptable. We had very much hoped that some degree of professional involvement in this final stage of the project could have been arranged. Unfortunately, given the enormous time constraint under which the programme was operating, it was not possible to provide you with an alternative proposal. We needed instead to invest all of our energies in meeting the strict deadline of 30 September 2005 for the completion of all rehabilitation activities. We were also required to do this without exceeding the budget allotted for this initiative and while balancing the various demands of the antiquities experts and other stakeholders from both communities. It is important to explain that not only did the Hala Sultan Tekke rehabilitation finalise on 30 September 2005 but also the entire seven-year UNDP/UNOPS initiative of which I was the manager. The Bi-communal Development Programme, which provided the funding for the rehabilitation works is, in fact, now operationally closed. So, as you may understand, we were left with very little room for maneuver.

I am happy to say, however, that we were able to complete all of the essential rehabilitation works that could be permitted given the budget available. Obviously, it would never have been possible to complete the rehabilitation works on time and within budget without the excellent groundwork that you and your Centre had undertaken on behalf of this important initiative. For this, all of us involved in the exercise, along with the many thousands who will enjoy the rehabilitated mosque and ancillary buildings, will be deeply grateful for many years to come.

Yours sincerely,

Andrew [illegible]
former Programme Manager
Bi-communal Development Programme

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In the mentioned projects, the strategies and Guidelines for conservation and preservation were in accordance to the standards and principals of UNESCO Recommendations and ICOMOS Charters to preserve the unique historical, aesthetic values, authenticity of the material, the craftsmanship, the design and the setting.

The objectives of conservation of Historic Buildings should not only to concentrate on preserving and conserving the monuments, but also to upgrade the urban surrounding as well as to train the local architects and craftsmen to work on a proper way according to the universal standards and prepare the historic buildings for an adaptable reuse for the social, cultural, economical benefits of the local communities.

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