

# ***Introduction***

**The safeguard of our archaeological heritage is based on conservation and management principles that take many aspects into account and require a wide range of professional skills. Site management is the process of planning and implementing measures to protect the site and its values, in order to achieve these objectives, the planning process must include the next 2 points:**

**Scientific Methods Used for studying the archaeological site**

***The study area***

**Examination of Stone Monuments Monumental Buildings  
*Characteristics and Properties***

**Scientific Methods Used in Examination and Investigation of Monumental Stone**  
**Characteristics and Properties**

***Examination of Stone Monuments Monumental Buildings***

- ***Ecological situation***
- ***Chemical Characteristics***
- ***Physical and Mechanical Properties***

# Scientific Methods Used for studying the archaeological site

*The study area*

## 1) Ecological situation

*A) Monumental registration*

*B) Zones description and environmental situation*

*C) Topographic feature of the area*

*D) Visual examination*

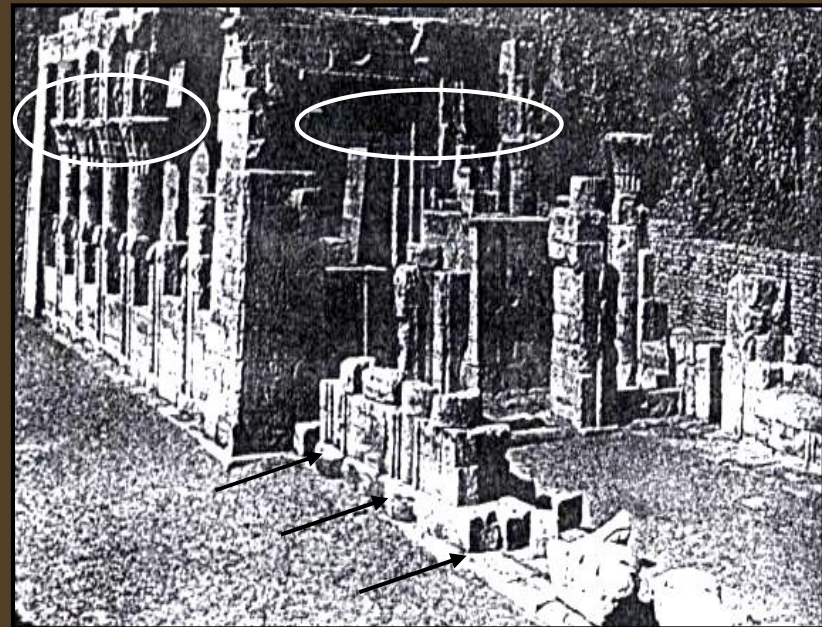
### **A) Monumental Registration**

In this part, we will study the *Historical*, *Monumental* and *Architectural* characteristics and different features of monuments under study through many ways such as:

- *Photographical and Phtogramerical registration*
- *Technical and Artistic registration*

## ***A-A) Photographical and Phtogramerical Registration***

In this part of study, we will use many types of ***classical, digital cameras*** with many scientific grade. Also, we can use other many types of mensuration instruments such as ***Total station*** for defining all historical, monumental and architectural features of any monuments or monumental sites such as (***size, relief*** and ***columns... etc.***).

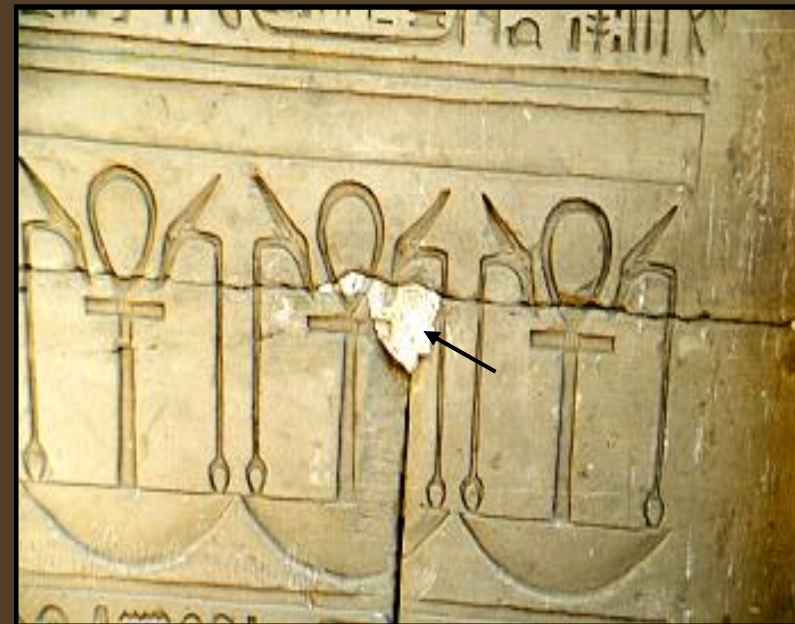




## **A-B) *Technical and Artistic Registration***

In this part, we will study the Technical and Artistic features of monument or monumental buildings for defining the *building methods*, *materials used*, *building styles* and *ages spirit of building* by using the next points:

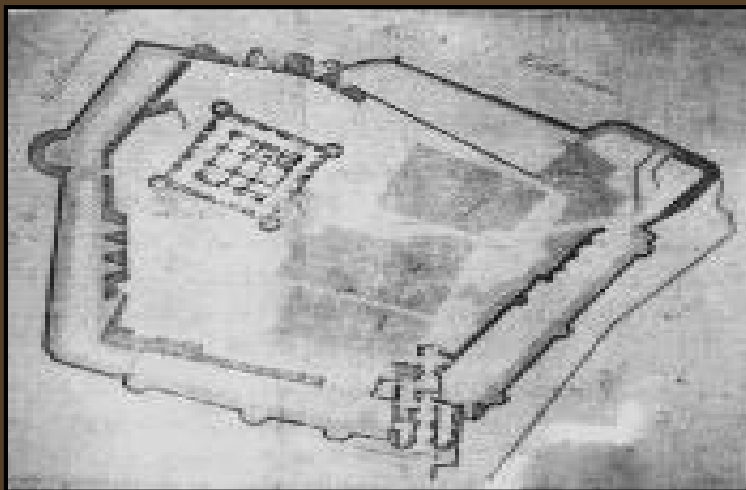
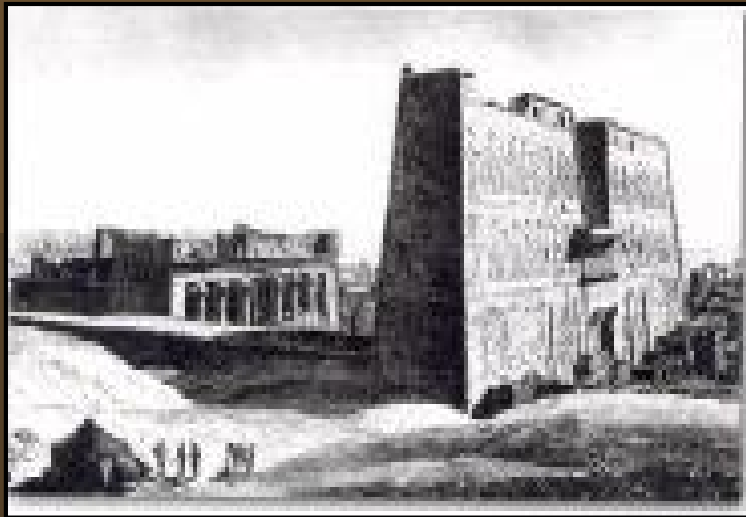
- *Drawing*
- *Coloring*
- *Computer programs... ect.*



## **B) Zones Description and Environmental Situation**

**In this part we must study the surrounded environment of archaeological locations, especially, when these locations represent different ecological situation and features description. In addition, we can see that These conditions vary between urban areas and regional ones. This variation is manifested in the ratio of carbon dioxide in rain, the rate of ice formation, the rates of heat and moisture change, salt-efflorescence and salt-sub efflorescence.**

**Also, we can decide that some of these conditions have been affected by natural environmental factors such as wind, rain, earthquakes, or human-caused environmental factors. All scientific data must be represented in different maps, graphs and figures as fallow:**



## **C) Topographic feature of the area**

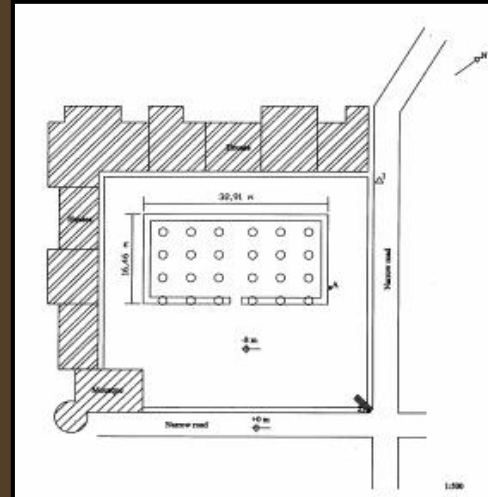
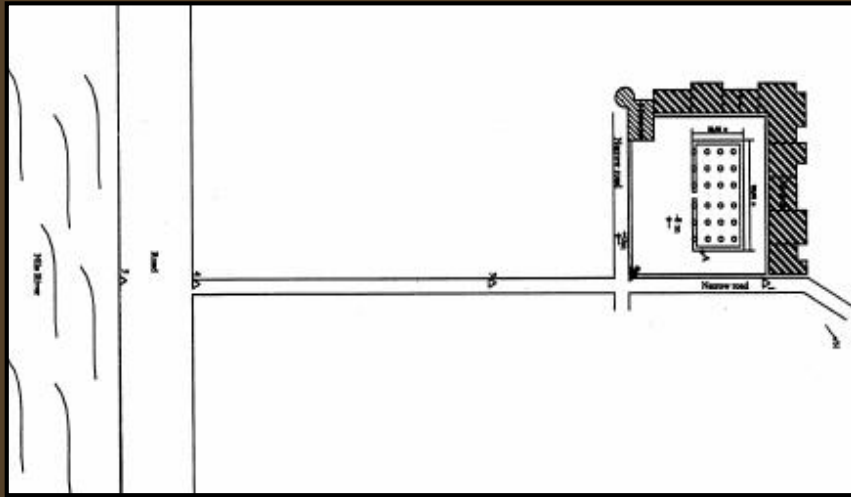
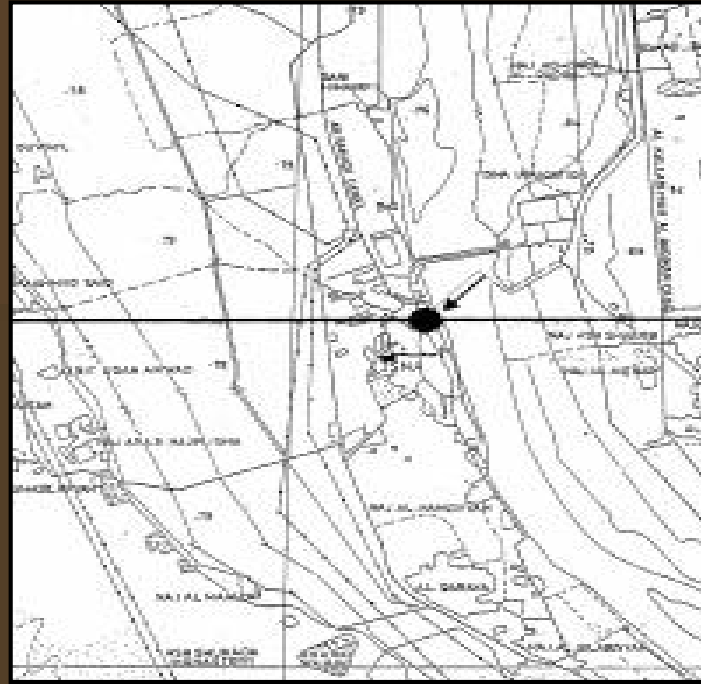
In this part of study, we must study all exogenous conditions in and around this area such as:

- *Site of the area and the monument*
- *Geological framework of the area*
- *Hydrogeological system of the area*
- *Metrological study of the area*

### ***C-A) Site of the area and the monument***

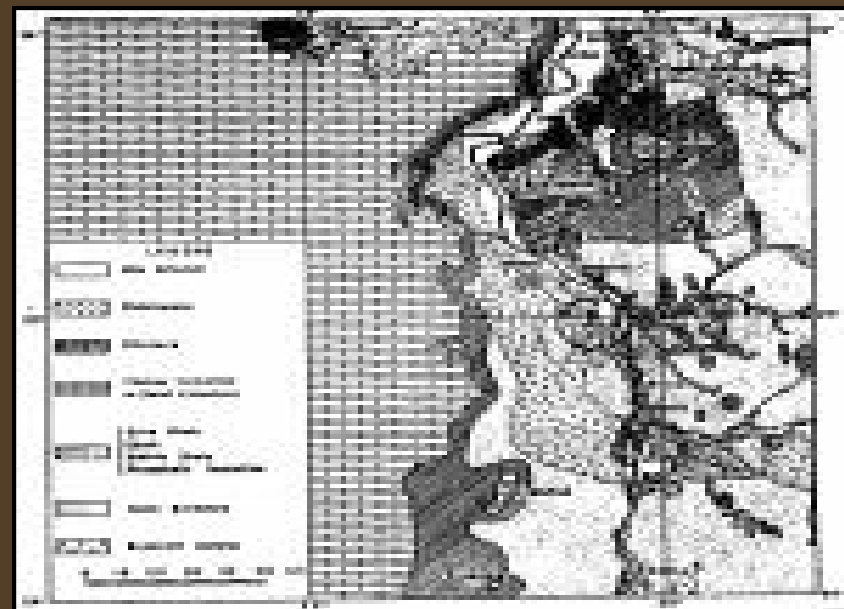
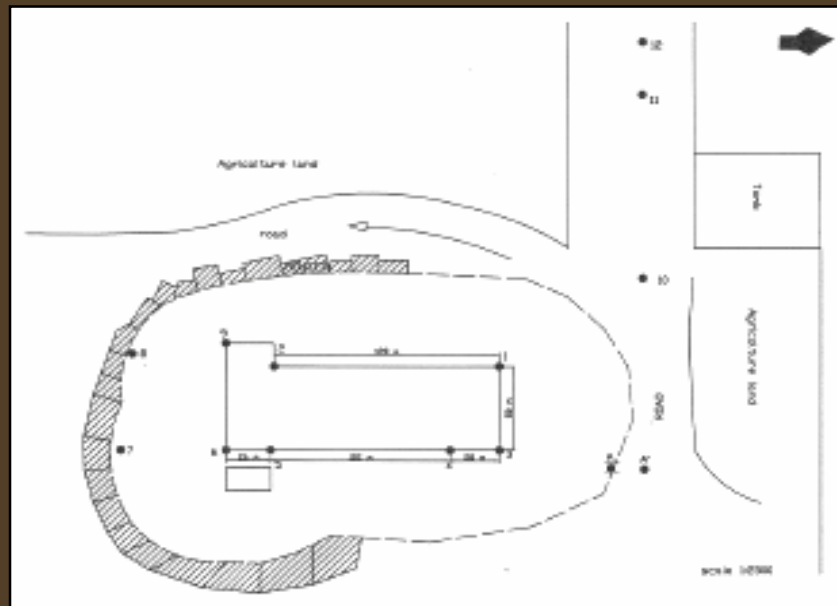
In this part, we will study the site of the area and its location on the general maps of the state and local maps of the towns, and we can study the border between the cultivated and deserted land the studied area, also, we must study the location of monuments itself, the distances which far from and surrounded areas from all directions

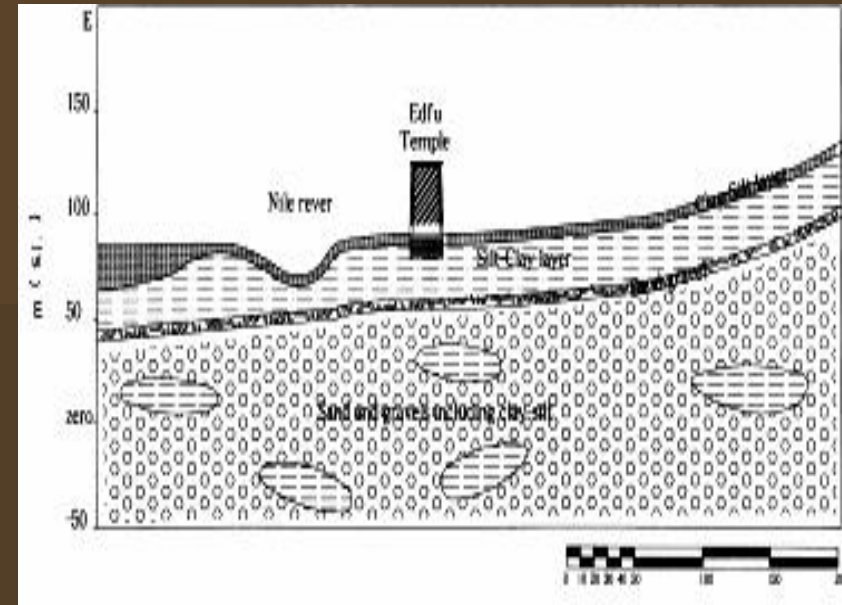
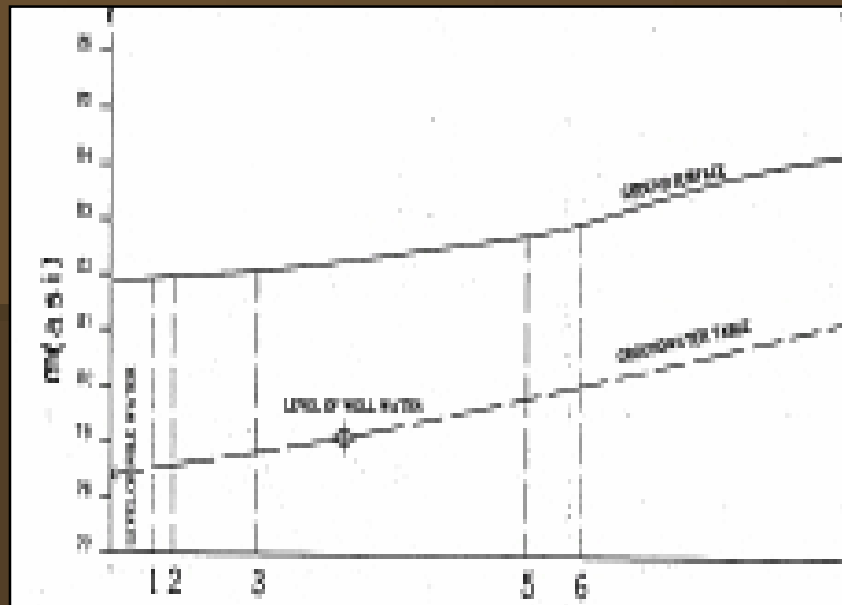




### ***C-B) Geological framework of the area***

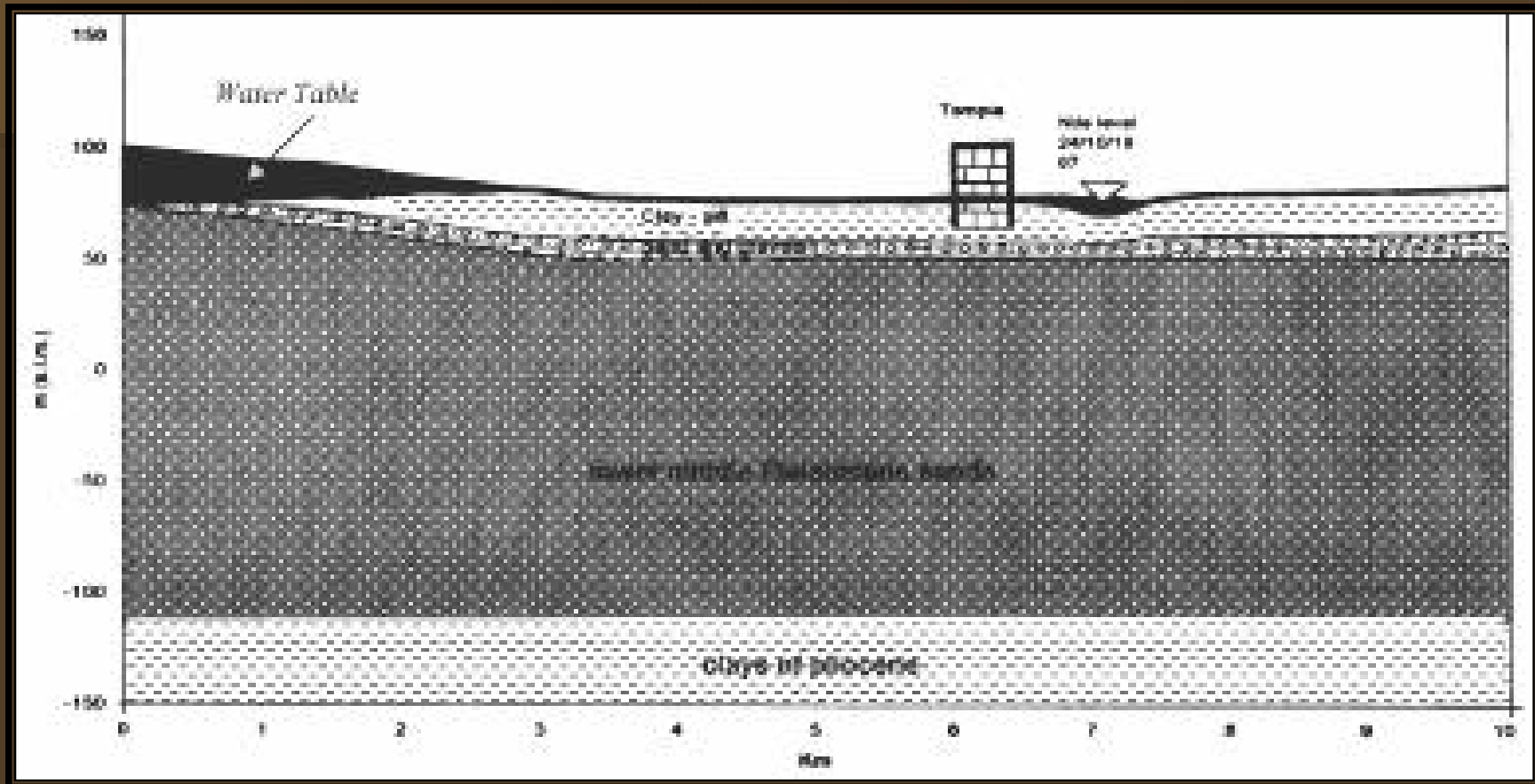
In this part, we must study the monumental site and the region which belongs on the geological map of the state, in addition, we have to study all geological characterization and different eras dominate in this area along time. Also, we can study The structural units to which the area under study belongs as stable and unstable formation, clay formations which covers the surrounded area and other mineralogical feature dominate in the area.



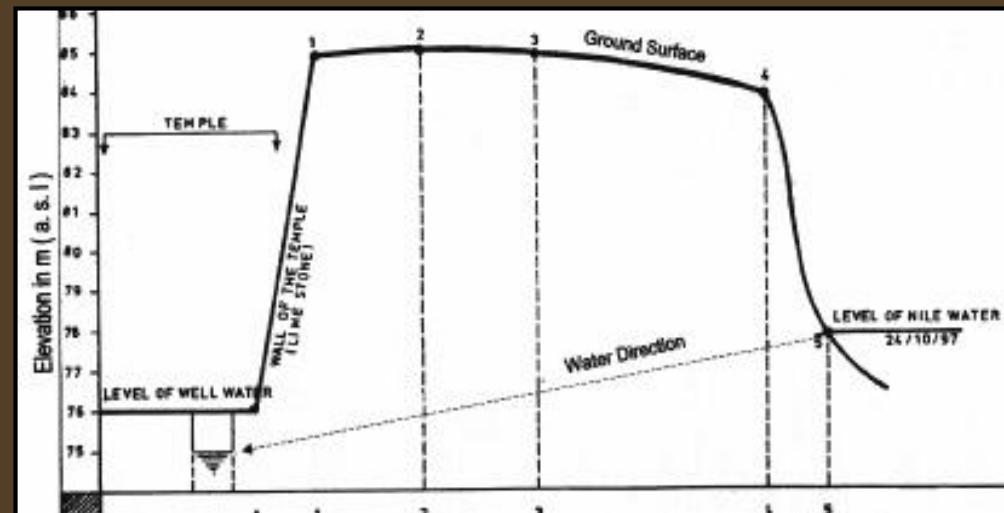
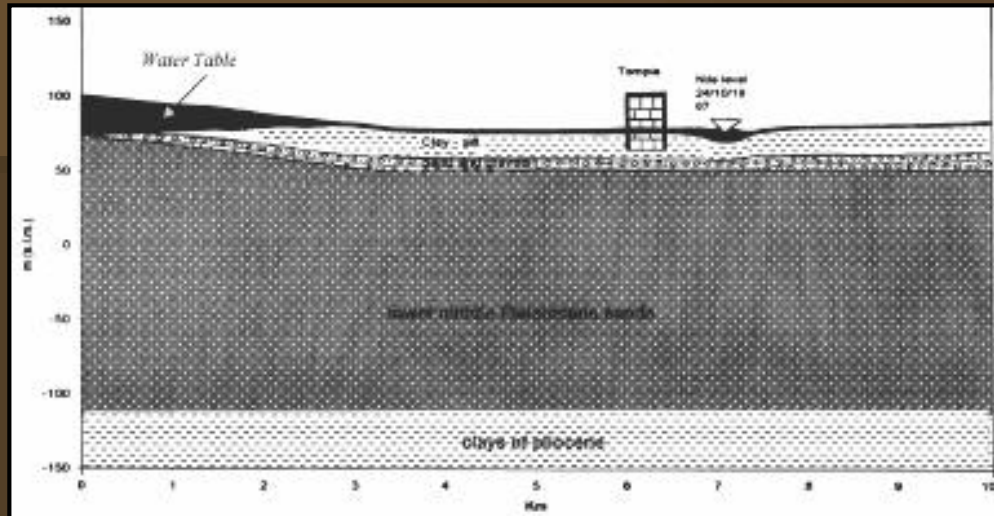


### ***C-C) Hydrogeological system of the area***

The aim of this study is to explore the influence that the groundwater flow, and its quality properties may have on the conservation problems found at any area, and study which kinds of salts can influence in the groundwater system in the area. Also, studying the water flow in the area under study and the way it interacts with the soil, which depends on the hydraulic conductivity and the outcropping present.



All of these purpose will realize through studying the relations between *Hydrogeological system, Stratigraphic scheme and Metrological conditions*



### ***C-D) Metrological study of the area***

The aim of this study is to explain the influences of different data of weathering factors dominate in the area such as:

- \* Air temperature***
- \* Relative humidity***
- \* rain quantity***
- \* Wind velocity***

Therefore, we can analyze these data by using some of computer programs to realize the relations between them and different mechanisms and forms affecting the stone surfaces, finally we can represented these data in suitable tables and figures.



## **D) Visual examination of colored crusts**

**In this Visual examination of colored crusts and bio-deterioration symptoms on the stone surfaces mostly deals with the deterioration grades of these surfaces. Also, it can shows the effect of any deterioration factors dominate at any area as microorganisms colonizes of some spices and their reactions with these surfaces “chemically or physically mechanisms”, all resulted data show on many pictures of deterioration forms.**



**Scientific Methods Used for studying the archaeological site**  
*Components and Compositions*

**2) Chemical characteristics of stone**

***A) X – Ray Analysis***

**\* X-Ray Florescence (XRF)**

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***B) Atomic Absorption (AAS)***

***C) Infra Red (I R)***

***D) Microscopes Investigation***

**\* Optical light microscope (OM)**

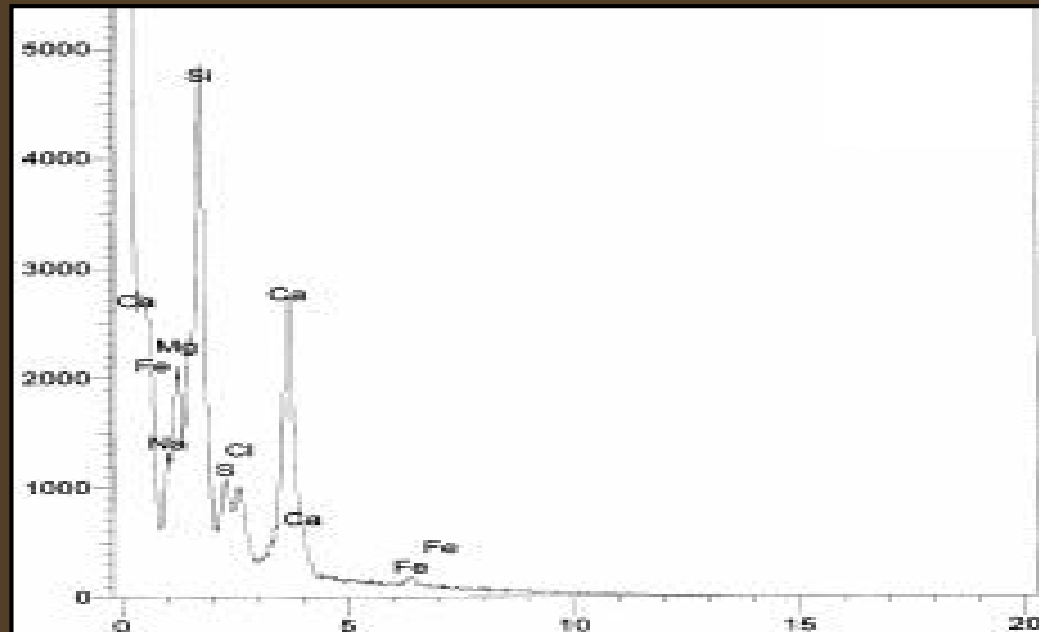
**\* Polarizing microscope (PM)**

**\* Scanning electronic microscope (SEM)**

***E) Other techniques***

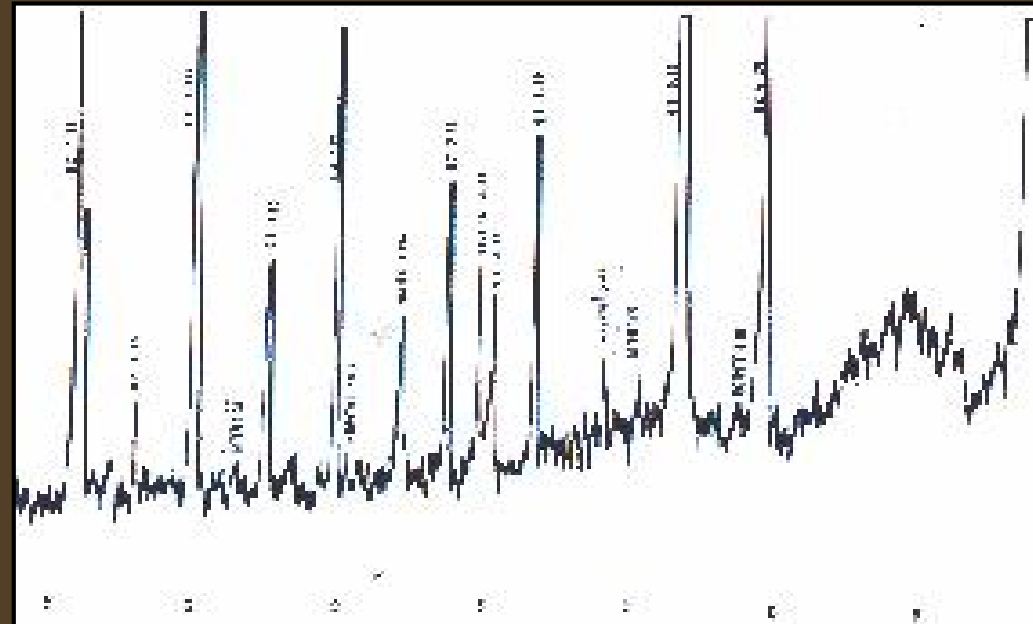
## A-A) X-Ray Florescence (XRF)

This technique is used for studying and investigating the **Chemical composition** of different components of any material “Solid or powder”, also, it is useful for studying and determining of some deteriorated and contaminated stone samples taken from different orientations and heights of the monuments. The different results are showed in next special charts.



## A-B) X-Ray Diffraction (XRD)

This technique is considered one of the most important techniques used to identify the **Mineralogical composition** of the materials; and their changeable appearances, it is used for studying and investigating the of different components of any material “Solid or powder The different data which indicate to the degradation mechanisms affecting stone and their symptoms on its surfaces are represented in next special charts



## B) Atomic Absorption (AAS)

Atomic absorption spectroscopy (AAS) is a spectro-analytical procedure for the **quantitative determination of chemical elements** using the absorption of optical radiation (light) by free atoms in the gaseous state. Atomic absorption spectroscopy is based on absorption of light by free metallic ions. In our field, is used for determining the concentration of a particular element in a sample to be analyzed. It can be used to determine over 70 different elements in solution, or directly in solid samples via electrothermal vaporization

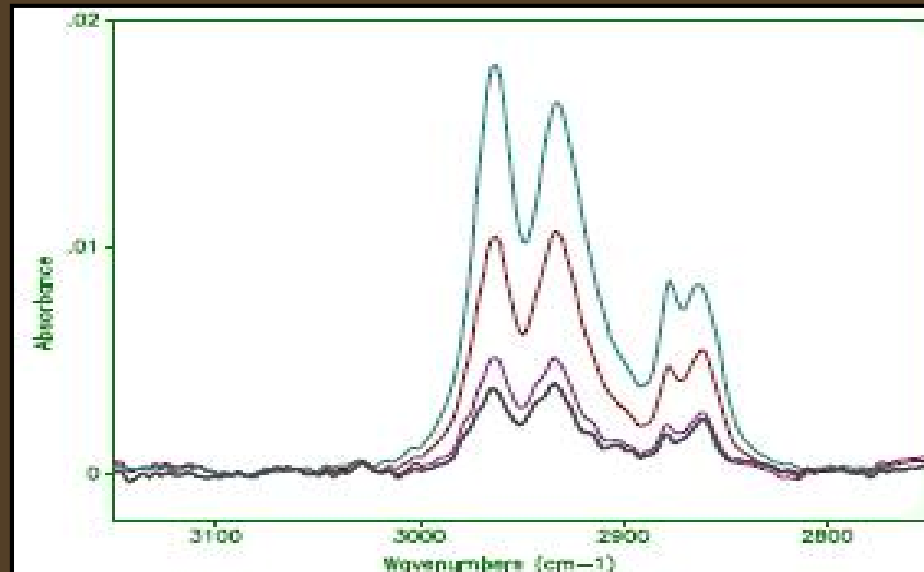


<i>Elements</i>		<i>Analytical results</i>	
		<i>Mg/l</i>	<i>%</i>
<i>Cation</i>	$\text{Ca}^{++}$	500	4.13
	$\text{Mg}^{++}$	1304	10.78
	$\text{Na}^+$	9898	81.84
	$\text{K}^+$	391	3.23
<i>Anion</i>	$\text{HC}_3\text{O}_3^-$	167	0.69
	$\text{Cl}^-$	21313	88.08
	$\text{So}_4^-$	2715	11.22



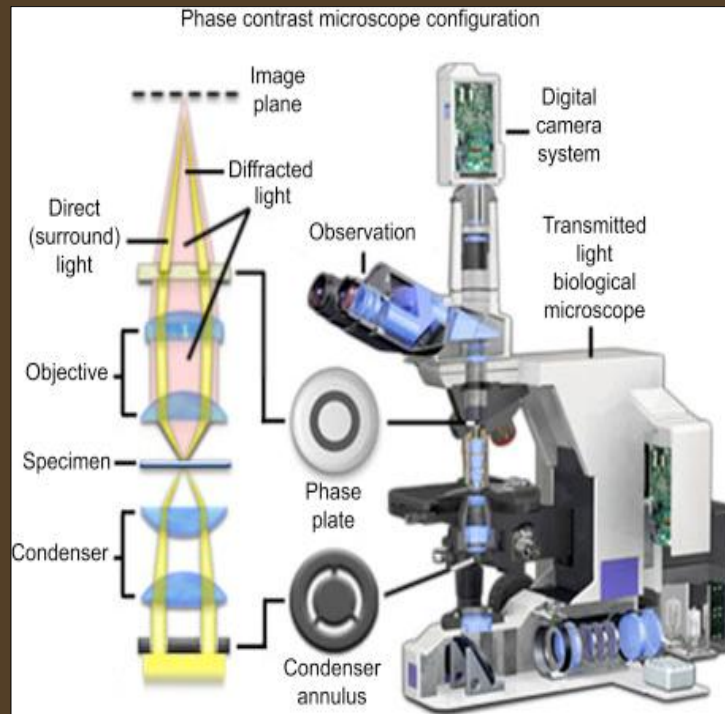
## C) Infra Red Examination (IR)

***IR spectrometry*** has been used for studying and identification many of ***organic materials and function groups*** dominate in the archaeological field. Also, this technique was demonstrated as a viable technique for detection of materials in our field, as hydrocarbons extracted from the environmental waters and air pollution particles, through some comparative studies with stander diagrams or charts



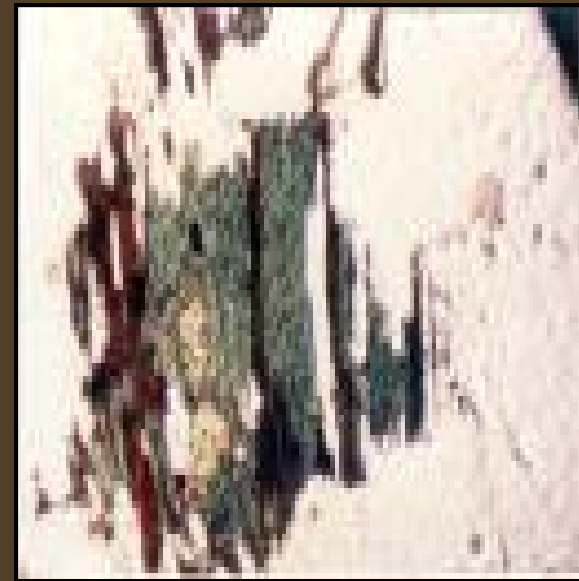
## D-A) Optical Microscope Investigation

The optical microscope is a type of microscope that uses visible light and a system of lenses to magnify images of small samples. It is the oldest design of microscope and were possibly designed in their present compound form in the 17<sup>th</sup> century. The image from an optical microscope can be captured by normal light-sensitive cameras to generate a micrograph. Originally, images were captured by photographic film or by modern digital cameras



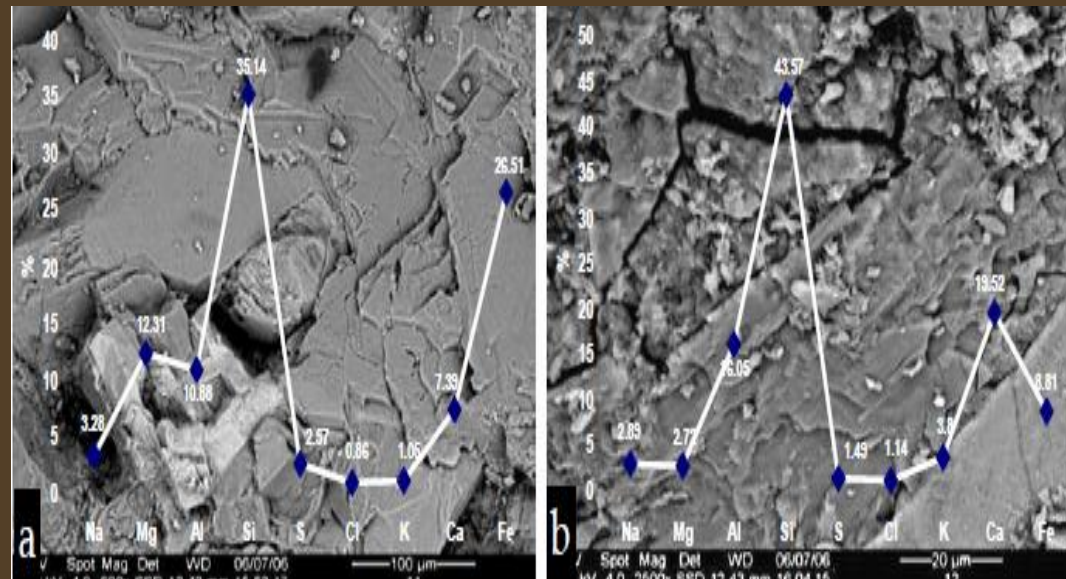
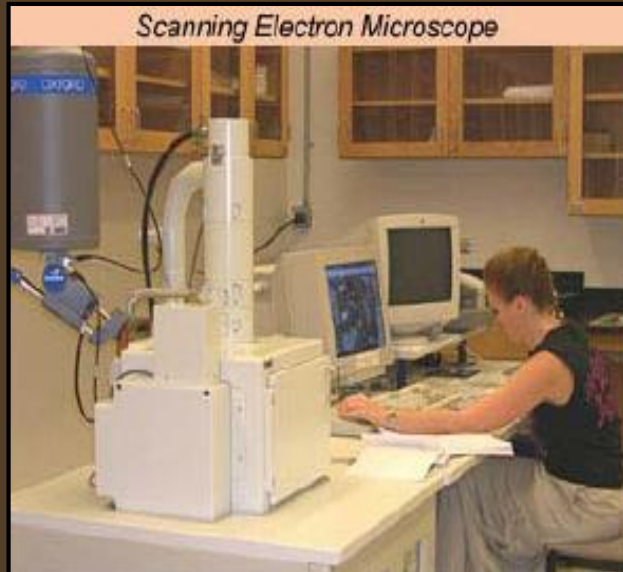
## D-B) Polarizing Microscope Investigation

**Polarized-light microscope (PL)** is one of the most famous techniques that used for studying the different optical characteristics of building materials “*Colors, Transparency, Texture, Grain size, Grain shape, Twinning and Pores*”. by observing of thin sections of these materials under normal or polarized light. The different results are shown in some special pictures as fallow:



## D-C) Scanning Electronic Microscope Investigation

**Scanning Electronic Microscope (SEM)** is very important tool in archaeological material research; SEM also has been applied in numerous studies of the deterioration of historical monuments. We used one of other techniques of **SEM** for studying and investigating the wet stone and highly contaminated hard crust surfaces samples this technique is Environmental scanning electron microscope **ESEM**.



## **E) Other techniques**

Also, we can see that there are other techniques may be used in the field of investigation of the archaeological materials as *UV rays, Ion chromatography and Intra oral camera....* ect...

## Scientific Methods Used for studying the archaeological site *Properties and Characteristics*

### 2) Physical Properties of Stone

In the field of restoration and conservation of monuments, in particularly the field of stone and monumental buildings, **physical** and **mechanical** properties play an important role either in definition of deterioration factors, its mechanisms and its forms or in choosing the suitable raw materials, which will be used in restoration and conservation works. From this point of view, we can divide these characters into:

**A) Physical properties**, which include “***Density, Specific Gravity, Porosity, Elasticity Modules, Water Absorption***”

**B) Mechanical Strength**, which include “***Uni-axial compressive strength, Tri - axial compressive strength and Tensile strength***”.



## A-A) Density ( $\gamma_d$ )

**Density**, one of the most important physical properties used in the archaeological field, especially when we need to contrive anew materials for restoring and conserving destroyed parts at anywhere. It is a relationship between weight and volume of a sample and we can define it as follow:

1. Cutting the sample  $? \times ? \times ?$  cm.
2. Drying in electric oven at **55o C** for **24 h**.
3. Weighting the dried sample (g).
4. Measuring the length of the sample (**XYZ**).
5. Calculating the ( $\alpha_d$ ) according to the next equation.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}} = \text{g / cm}^3$$

## A-B) Specific Gravity ( $\gamma_s$ )

**Specific Gravity**, one of the important physical properties used for defining the density of material grains', we can define it by using the Pycnometer instrument as follow:

Crushing the sample tell to be more finest.

1. Sifting a sample carefully through sieve "74  $\mu$ ".
2. Mixing the sample and drying in electric oven at **110 °C** for **24 h.**
3. Putting the sample in special container then in the Pycnometer.
4. Calculating the ( $\alpha_s$ ) according to the next equation

$$\text{Specific Gravity} = \frac{\text{Pressure}}{\text{Volume}} = \text{g / cm}^3$$



**Pycnometer**

## A-C) Porosity ( $\eta$ )

**Porosity**, considered the most important one of physical properties of any archaeological materials especially stonework's Mud brick and Mortars, also, it play an important role in definition of the solubility index of any consolidant materials during consolidation steps. From this scientific of view, we can define the porosity of stone materials according to the next equation.

$$\eta = \frac{e}{1+e} = \%$$

Where  $\eta$  = Porosity of material

$$e = \frac{\gamma_s - 1}{d} = \%$$

## **A-D) Elasticity Modules ( $V_p$ )**

**Wave Velocity propagation**, considered one of three methods from ultra sonic techniques which were used in examination of materials , they are:

- 1. Transmission method**
- 2. Echo method**
- 3. Surface transmission method**

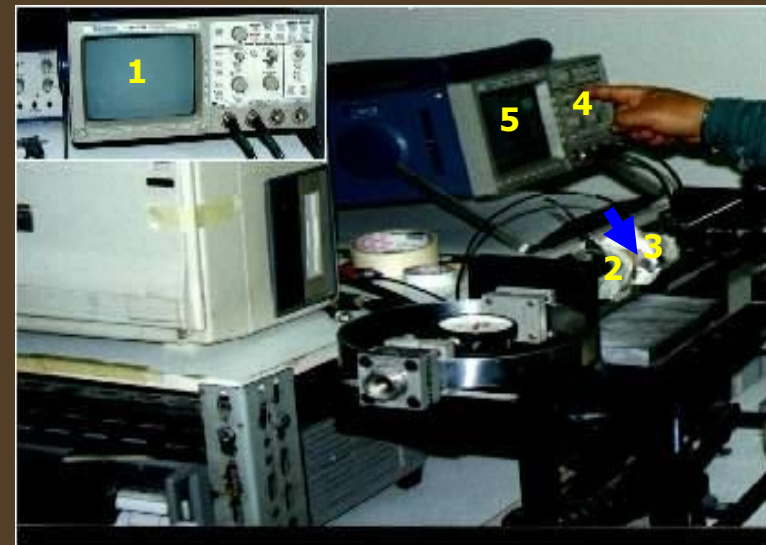
The ultrasonic waves as a Transmission method , are micromechanical oscillations which are spreading in solid , liquid and gaseous media and the frequency which can be used for natural stones diagnosis from 20 KHz to approx. 1 MHz. This technique is used to determine the elasticity modules of investigated materials through measuring the passing time of ultrasonic waves through different material. From this point of view, we can fallow the next steps for defining this method:

- 1. Measuring the dimensions of samples in directions (XYZ) by venire.**

2. Standardizing the instrument by using a glass column with known value ( $V_p$ ).
3. Putting the samples between two transducers (*Sender – Receiver*) and passing the wave through them .
4. Counting the time through the samples and calculating the wave velocity according to following equation.

$$V_p = \frac{D (\text{mm})}{T (\mu_s)} = \text{Km / Sc}$$

Where  $V_p$  = wave velocity  
 $D$  = dimension of sample  
 $T$  = time form sender to receiver



## A-E) Water Absorption (WA)

**Water Absorption**, considered one of the most important physiochemical properties of stone materials in particular in the restoration field where it control in other properties and we can define it as fallow:

Preparing a water jar contains about 3 rows of filter papers all of them consists of about 20 layer.

1. Adding distilled water till the edge of the filter papers and putting the drying stone samples.
2. Weighting the sample after 1/, 2/, 3/, 4/, 5/, 6/, 7/, 8/, 9/, 10/, 15/, 30/, 45/, 60/, and finally after full immersion for 48 h.
3. Recording the final results according to following equation

$$WA = \frac{\text{Sat. w} - \text{Dry. w}}{\text{Dry. w}} \times 100 = \%$$

Where **WA** = Average of water absorption  
**Sat. w** = Saturated weight of sample  
**Dry. w** = Dry weight of sample





## Scientific Methods Used for studying the archaeological site *Properties and Characteristics*

### 3) Mechanical Properties of Stone

**Mechanical strength**, considered one of the destructive methods used as general for defining the mechanical properties of building materials these methods are:

*Uniaxial compressive strength (UCS).*

*triaxial compressive strength*

*Tensile strength*

*Share strength*

Here, we will use the most important of them used in the field of restoration and conservation of monumental buildings *Uniaxial compressive strength*, Where, we can see that the resistant of any solid materials against any stress or deformation is due to the *kind of this stress* and *the kind of the tests used*. Finally, we can define it as fallow:

1. Cutting and polishing the sample and putting it between the 2 parts of the machine.

2. Reading resulted deformation at the beginning point(0 degree) before loading.
3. Switched on the machine to increase the load on the sample with controlling the pointer immediately at (0 degree).
4. Reading and the resulted deformation at any degree, then switching off the instrument immediately when decreasing the deformation degree, finally recording the results and calculating the strength value according the following equation:

$$\text{Strength} = \frac{\text{Stress}}{\text{Area}} = \text{kg/cm}^3$$

