

# Modern Technology Applications in the Restoration of an Ancient Mud Brick Houses in Dakhla Oasis, Egypt

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## To cite this article:

Yasser Sayed Ali, Mahmoud Mohamed Massoud. Modern Technology Applications in the Restoration of an Ancient Mud Brick Houses in Dakhla Oasis, Egypt. *International Journal of Archaeology*. Vol. 4, No. 6, 2016, pp. 87-94. doi: 10.11648/j.ija.20160406.11

**Received:** September 13, 2016; **Accepted:** September 28, 2016; **Published:** October 25, 2016

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**Abstract:** Earthen architecture and ancient Mud Brick Houses come in a vast variety of Dakhla Oasis archaeological sites date back to Pharaonic, Coptic and Islamic periods and characterized by the construction materials compatible with the dry desert climates. Due to changes in the precipitation pattern of rainfall in the last three years in Dakhla Oasis, so it has been improved physics, mechanical properties of mud brick to become the best in the waterproofing of rain water without a change in properties or color by using modern technology applications in the production of modern building materials. Tests included the study of density, porosity, water absorption, Shrinkage, hardness and compressive strength, and color changes. Mineralogical composition and granulometric distribution of five ancient mud brick samples measuring, (2.5×2.5×2.5) from Dakhla Oasis were studied by using the analytical way X-ray diffraction to determine the main components and characteristics. In addition, using scanning electron microscope (SEM- EDAX) to study the results of the sample examination Synthetically treated. This paper studies includes scientific methods in the restoration of the architectural elements of an ancient mud brick house in Dakhla oasis, by using of modern technology applications, This can be utilized as evidence in Waterproofing mud brick buildings in Egypt and the earthen architecture worldwide in accordance with the priorities identified in each building.

**Keywords:** Dakhla Oasis, Mud Brick, Earthen Architecture, Silicon, Rainwater

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## 1. Introduction

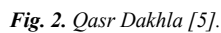
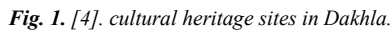
A mud brick is afire free brick, made of a mixture of clay, mud, sand, and water mixed with a binding material such as straw. They use a stiff mixture [1] and let them dry in the sun for two weeks at any rate.

Mud architecture is the first building areal and effective for humans on earth, if by any means, we can say that the emergence of construction mud back to ten thousand years or more, and that Egypt is one of the mud-brick first nation, which was guide to know the mud-brick and utilized since ancient times, Dynastic Period (around 3100-2613 b.c.), and the Old Kingdom (around 2613-2160 b.c.) [2].

Dakhla Oasis lies in the New Valley Governorate in Egypt. There are a several cultural heritage sites of mud-brick in Dakhla Oasis (Fig. 1), such as Qasr Dakhla (Fig. 2). In any case, the city goes back to the pre-Islamic period [3].

A mud-brick considered the principle building material in the greater part of the archeological sites in Dakhla Oasis, however, did not get the full consideration of scientists and researchers in restoration.

In spite of the excellence Dakhla Oasis with dry desert climates, However because of changing climatic conditions and precipitation amid the past three years, Dakhla ends up confronting a genuine fiasco may involve losing all the archeological sites of mud-brick inside the following ten years. Thus, the scope of our research to enhance the properties of the mud mortar for the assurance of the old structures of mud-brick from the harm brought about by the effect of down pour water.



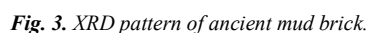
## 2. Materials and Methods

necessary number of bricks, Sift the soil through a mesh screen to eliminate any rocks that might weaken the strength of the bricks, Mix the soil with water and add a straw and mix it evenly by hand or with your feet after Adding insecticides to mud mortar. Determining the size of the wooden mold used in the preparation of bricks by taking the average three random samples from for each of old brick walls of the building and put the mud mixture into a wooden mold, then pack it tightly in to the mold to push out air bubbles and excess water, this ensures the bricks dry. Finally, lifted out the wooden mold of bricks and let them dry in the sun for two weeks at least.

Random samples of an ancient mud brick were examined, in order to determine the mineralogical compositions, physical and chemical properties to make the same sort of mud brick to be utilized as a part of restoration and reconstruction (because of Article 9 in the Venice charter 1964 for restoration) [8].

The main clay minerals in ancient mud brick are illite Which is described with Lack of substitution of aluminum rather than silicon. Then kaolinite (the most widely recognized in the mud earthenware locally accessible) Which is portrayed as in active and slightest influenced by water.

Notwithstanding Halite (sodium chloride salts) the most common in the Dakhla Oasis soil. Mineral components as takes after: Quartz [ $\text{SiO}_2$ ], Calcite [ $\text{CaCO}_3$ ], Alpite [ $\text{NaAlSi}_3\text{O}_8$ ], Chlorite [ $\text{Mg}_2\text{Al}_3$ ], Illite [ $\text{k(AlFe)}_2$ ], Hematite [ $\text{Fe}_2\text{O}_3$ ], Halite [ $\text{NaCl}$ ] and the grains size distribution: Coarse sand [ $<2\text{mm}$ ] of 35.5%. Soft sand [ $<0.2\text{mm}$ ] of 31.5%. Silt [ $<0.02\text{mm}$ ] 8% Clay [ $<0.002\text{mm}$ ] of 25%.



**Table 1.** Results of Physical properties of ancient mud brick samples.

Physical properties of ancient mud brick samples					
Sample	Weight (g)	Volume (cm <sup>3</sup> )	Density (g/cm <sup>3</sup> )	Porosity (%)	Water Absorption (%)
1	15.6	14.20	1.09	39.08	37.8
2	25.2	16.55	1.50	53.70	25.4
3	13.2	12.8	1.03	31.34	24.12
4	11.5	10.6	1.08	26.15	22.36
5	17.4	15.8	1.10	43.24	42.26

## 2.2. Scientific Study to Shield the Mud- Brick Structures from Harm Brought on by the Impact of Rain Water

In spite of the excellence Dakhla Oasis dry climates, but over the three previous years, Dakhla has seen a change in the overall pattern of rain fall rates. As exposed to light winds and dust, in addition to the dense clouds. As a result, bumping the clouds led to the fall of the heavy rains that did not reach the limit floods, in addition, there is lightning and thunder, which is about 900 meters from the surface of the earth [9].

If this unusual circumstances as a result of climate change in the long-term, or they simply reflect fluctuations in unexpected, necessitated this improve the properties of the mud mortar in order to preserve mud brick buildings from damage caused by rain water effect.

Layers of plasters (mud mortar) on the mud wall, consider the first block against rain water (one more major source that causes defects and distortions of the components and construction elements in the mud-brick architecture) [10]. It is a building material used to cover the horizontal surfaces and the vertical walls of the mud-brick and fill in the blanks, are also used to cover the roofs and floors, and manufactured in the form of a dough becomes solid when dry and consisting of different materials such as mud or clay added to the sand. This is known as plastering [11] it is a pattern in the coverage of traditional architecture of mud-brick buildings such as in the Qasr Islamic city in Dakhla.

But the weakness of earth as a building material in resisting the influence of water, whether due to rain or rising from the floorings through the capillary action, where the Water penetrations in the mud buildings considered one the main reasons that lead to the damage.

So when the raining, which are often acidic, to arrive to surface vertically and horizontal, can generally say that rainwater is trying to wash and remove the surface crust and the drilling of the lattice channels in external layers of walls and soil bottom portions down to the mud brick, which change in structural elements and then pushing the walls and break down the balance and may lead to cracking and the collapse fully.

The main reason for this superior ability to minerals (the

main component of the mud mortar) to absorb water and lost, causing the complete dispersion of mineral sheets of these minerals, and with the repetition of expanding operations and deflation, especially with the high temperature leads to an erosion the mud and the weakness of the mud-brick molds and turned with time into little of resistance loads and pressures.

### 2.2.1. Chemicals Used to Enhance the Properties of Mud Mortar

In the earlier year's utilized a large number of chemicals as a part of the solidification of mud-brick to disconnect the downpour water, however the results were not satisfactory, even the utilization of micro-technology by mixing nano kaolin with polymer paraloid B-72 did not achieve the desired results in waterproofing and protect the mud engineering of harm [12]

In this research, resort to the utilization of silicones, one of the modern industrial resins for the accompanying reasons:

Mineral components to silicon comparative with mineral parts of the current mud mortar to contain both on the quartz. Silicones Characterized by high capacity to remove water (research theme) [13].

Silicones described by high capacity to oppose high temperatures that portray the air of Dakhla oasis in the summer.

### 2.2.2. Synthetic Treatment of the Samples

Cubic samples arranged for study and research. Sample weight (30g). measuring (3cm×3cm×3cm), presented the best result in waterproofing. A mixture of dough clay homogeneous, their components as takes after:

15 Gm of the old mortar layer; 5 Gm of clay contain a high extent of the mineral kaolinite. It has a low shrink–swell capacity and a low cation-exchange capacity and utilized as a part of the production of pottery in Dakhla; 4.5 Gm of Pottery powder.

Addition Watery silicon composite (Low-viscosity silicone straight forward, transparent Anti-dampness and water) Mix well dough clay previous down to the textures it has been suitable in the rate of 20% and decide the rate of silicon water content by the following equation:

$$\text{Silicon Water content of the sample} = \frac{\text{Sample weight} - \text{dry sample weight}}{\text{Dry sample weight} \times 100} = \%$$

Box Weight (g)	15	
Dry sample weight + box (g)	40	= dry sample weight and the box - Box Weight
Wet sample weight + box (g)	45	
Water weight (g)	5	= [wet weight of sample + box] - [dry sample weight + box]
Dry sample weight(g)	25	
Silicon Water content (%)	20	

### 2.2.3. Investigation by Scanning Electron Microscope (SEM)

Sample contains elements (CA, S, SI), as well as key elements (FE, AL, NA), secondary elements of the elements (CU, ZN). (Fig. 4)

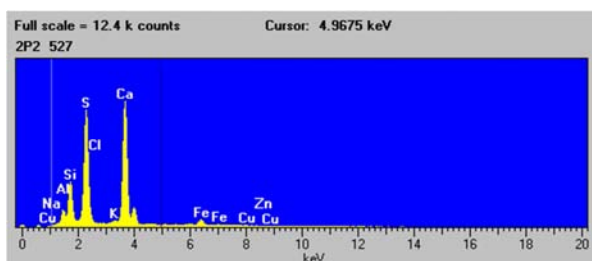
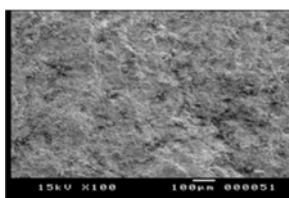


Fig. 4. EDAX analysis of the mud bricks' treated sample.

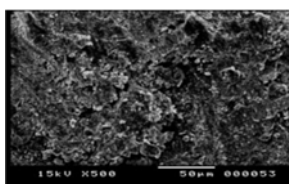
Table 2. The elements in the sample and rate relative to each other.

The elements in the sample and rate relative to each other			
NO	Element	Compound	Weight %
1	Na	Na <sub>2</sub> O	1.23
2	Al	Al <sub>2</sub> O <sub>3</sub>	3.73
3	Si	SiO <sub>2</sub>	13.21
4	S	SO <sub>3</sub>	13.21
5	K	K <sub>2</sub> O	0.72
6	Ca	CaO	35.35
7	Fe	Fe <sub>2</sub> O <sub>3</sub>	4.33
8	Cu	CuO	0.18
9	Zn	ZnO	0.17

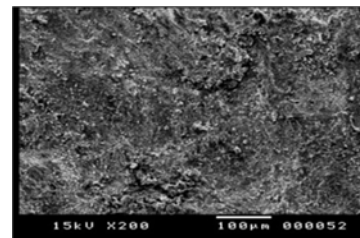
Delineates the granular piece of the sample mud mortar after treatment and seem homogeneous to a huge degree without any crevices or appearance of the material between the grains, where homogeneous with mud mortar material with not to fill the pores and the presence of precious crystals of salt (Fig. 5)



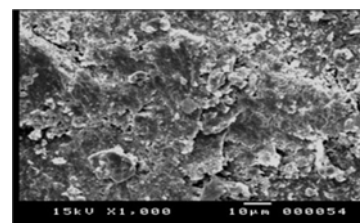
A



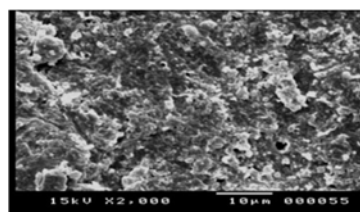
B



C

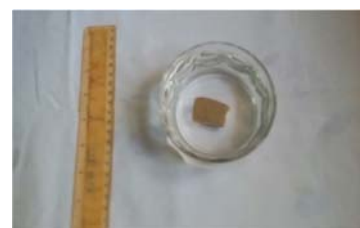


D



E

Fig. 5. (A,B,C,D,E) SEM photo micrographs of the treated sample with strongly magnification (100,200,500,1000,2000).



Submersion Test in water(Fig.6)

Fig. 6. The treated sample not disintegrate in water and does not collapse permanently.

### Investigation of the treated samples conduct under Accelerated Ageing Test:

#### Thermal Accelerated Ageing Test

Tests were subjected to a temperature of 120°C and left to cool at room temperature for a few back to back sessions has been appeared by the outcomes that the sum total of what tests have been easy to get in shape, running in weight reduction rate was between 0.21% to 0.84% with a slight



change in the shade of the sample surface.

#### ***Accelerated Ageing Test in saline solutions***

Tests overflowed with a saline solution of sodium chloride proportion grouping of 20, 25 and 30% for a few hours and after that, left at room temperature were then presented to high temperature and for a few successive sessions did tests did not influence by maturing with saline solutions for non appearance any appearance of testimony saline on the surface of the sample and The material is well with great imperviousness to sodium chloride most normal Dakhla oasis soil.

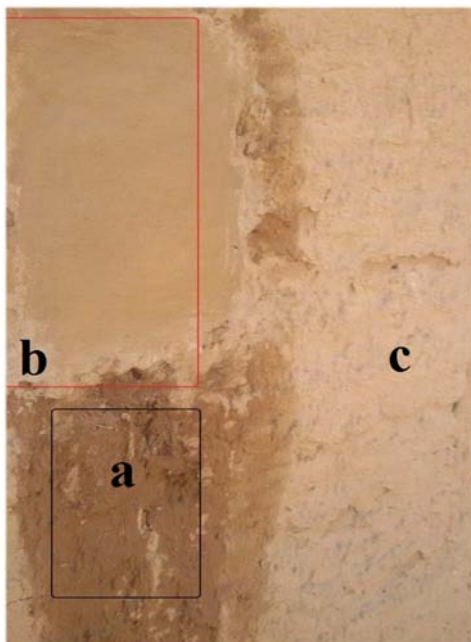
### ***2.3. Reasonable Application in Dakhla***

#### ***2.3.1. The Functional Application Part of a Wall of Mud-Brick in Dakhla***

Distinguished rectangular, measuring 20 cm ×30 cm with depth of 3-5 cm in the mud brick wall with good show to the mud brick in rectangular and Spraying brick with water. Collecting the old plasters of the rectangle with the expansion of Clay earthenware that contain kaolinite, Pottery powder and Low viscosity watery silicon.

Preparing mud mortar from the previous ingredients with the endorsed rate for the previous study sample and Settling mud mixture and apply it.

The accompanying figure demonstrates the quickly record for the specialized state of the rectangle processor and the lower parting moment of exposure to water (Fig. 7).



**Fig. 7.** (a,b,c) The functional application part of a wall of mud-brick in Dakhla. (a) The lower part of the rectangle moment exposed to water. (b) Rectangle processor moment exposed to water. (c) Instant dry rectangle processor after exposure to water directly. It is noted approaching for its color from the color of the Ancient dry mud mortar (plasters).

#### ***2.3.2. The Contrive of New Mud Brick Processor***

The scope of our examination is to waterproofing of structures mud archeological against down pour water, so was

utilized mortar mud treatment in the production of mud bricks utilizing Previous study sample components and in accordance with the established percentages. Submersion test has shown its ability in the water at high waterproofing (Fig. 8).



**A**



**B**



**C**

**Fig. 8.** (A,B,C) A, Manual Mud Brick processor mold. B, The treated mud-brick mold after let it dry in the sun for two weeks ,not disintegrate in water and does not collapse permanently. C, The final shape of the mud brick mold after 20 minutes of leaving the water and exposed to light to normal day light.

The samples of new brick processor were prepared in to cubic samples, measuring (2.5cm x 2.5cm x 2.5cm) which were dried in open air (45°C) for 48 hours and in electric oven (105°C) for 24 hours and, finally, they were subjected to the same experiments as the ancient bricks.

**Table 3.** Average of physical properties of the new mud brick processor samples.

Sample	Average of physical properties of the new mud brick processor samples					
	Weight	Volume	Density	Porosity	Water Absorption	Shrinkage
	(g)	(cm <sup>3</sup> )	(g/cm <sup>3</sup> )	(%)	(%)	(%)
1	17.6	16.23	1.08	23.98	8.98	1.31
2	24.1	17.58	1.37	25.02	8.33	2.12
3	15.2	14.81	1.02	22.37	9.86	1.14
4	12.5	10.65	1.17	20.19	11.24	0.59
5	20.4	17.82	1.14	23.21	10.13	1.69

There is increasing in the rate of Compression Strength on the compression machine of the type (ZwieFalter StraBe20.D-88499 Riedlingen) from 4.5 to 6.7 kg /cm<sup>3</sup> and no adjustment in the shading tests happens after treatment.

Final results of investigating samples of new brick processor confirm its good characteristics: "intermediate density, Low porosity, Low water absorption without disintegrate in water and very good surface morphological" (Table 4).

**Table4.** Final results of investigated samples of new brick processor.

properties						
Sample	Density	Porosity	Water Absorption	Shrinkage	SEM	Total
1	***	**	***	**	**	12
2	*	*	***	*	**	8
3	***	**	****	****	***	16
4	**	***	*	***	***	12
5	**	**	**	**	**	10

\*=1 point \*\*=2 points \*\*\*=3 points \*\*\*\*=4 points

## 2.4. Scientific Methods in the Restoration of the Architectural Elements of an Ancient Mud Brick House in Dakhla Oasis by Using of Modern Technology Applications

### 2.4.1. The Dynamic Substitution of Harm Mud Bricks

Substitution of brick that have been harmed and erosion part after one more of the wall (60 cm -120 cm) as indicated according to the case of the wall and replaces by utilizing dimpling strategy and the presentation of another mud brick with the same construction specification details with the utilization of the new mud mortar processor.

### 2.4.2. Unwinding and Reconstruction of the Walls

The way toward loosening up the wall precisely cautioned through and through hand keeping the old bricks to re-use it

again when re-construction, if true blue for use joined with the neighboring walls to hinder break down.

Adjusting the same old style amid the time of construction (brick and a half), dependent upon the courses of a mud brick wall to watch the direction of compaction templates and get on the right ligament.



Abu Qandil house. [14]-Qasr Dakhla

**Fig. 9.** Unwinding and Reconstruction of the walls.

### 2.4.3. Treatment of Cracks

Scientific and practical method to connect the cracks.

Clean the split of free soil and Insect homes. Digging a rectangular cross with the break and fit with the size and length of the break After deciding utilizing Ultra sonic Plus Velocity. Then, Spray the gap with fluid mud mortar and put a bit of acacia wood rectangular in this gap and fill in the spaces with bricks and mud mortar processor.



Qasr Dakhla – Bayt Al - Qadi

**Fig. 10.** Treatment of cracks.

### 2.4.4. Plastering Earth Walls

Blend the clay with a suitable amount of water. Afterward, left to mature and add the mixture mud to measure of water and unpredictable well into fluid mortar. Each additional eight parts of the mortar added to one part of sand with a dilute solution of primal Ac33 by 5% with no adjustment in their properties or their Shading. Mortar put on the walls and splashed with water and settles well.

### 2.4.5. Restoration of Roofs

Cleaning of old wood and supplant the harmed ones and Installation the palm stem on the walls legitimately, Put palm fronds on the palms tem crossly with the utilization of sinewy strings to weave. A layer of palm leaves is set on the roof top and spread with a layer of mud mortar and brick. Sterilization of wood sorts are utilized as a part of the restoration work and reconstruction against termites by utilizing Dursban 6 cm<sup>3</sup>/ liter in the kerosene.

#### 2.4.6. Restoration of the House Floor Materials (Fig. 10)

Get ready mud mortar (8 clay parts added to one part of sand), were given back that on the ground and settled in the same old style in flooring manufacturing in the Qasr Islamic city.

The improvement of the properties of the mud mortar utilized as a part of flooring is made utilizing a dilute solution of (SBR) 65 with no adjustment in their properties or their shading.



Qasr Dakhla –Bayt Al – Qurashi

Fig. 11. [15] Restoration of the house floor materials.

### 3. Results

We can say that this research is a new revelation in the field of waterproofing of earthen architecture, away from traditional solutions such as total coverage based archaeologist and that are difficult to apply as they change shape archaeologist. Also because in this way we can produce mud bricks anti-water, used in modern houses, enjoy with the advantages of mud brick houses in terms of the lack of financial cost and low temperature in the inner perimeter of the house.

Mud brick in Dakhla oasis contains the highest rate of quartz (sand) as essential component in the mud layers. Rate of lime and the nearness of mineral calcite and the nearness of the extent of iron oxides (hematite) as shading decide the shade of putting It likewise contains a high rate of sodium chloride and sodium sulfate, while the main clay minerals in old mud brick is illite. Then kaolinite.

Now, earthen architecture in areas with colder climates, may play the dominant role it already plays in warmer regions by using high standards of Waterproofing without any change in properties or color according to the previously mentioned studies as far as being:

Waterproofing does not close the pores. To demonstrate the best results in infiltration, it doesn't bring about the formation of a different layer at first glance, or change the shade of mud and increases the mechanical strength of the mud mortar and resistance to heat and UV. There is no chemical reaction between the polymer and the clay particles.

Improve the properties of the clay mortar (plaster layer) by adding (clay pottery) and expanded change by adding (mud Pottery + Pottery powder). In addition, keep mud mortar treated with all the mud mortar untreated from the physical and synthetic properties aside from not disintegrate in water and does not collapse permanently while allowing the normal

for the movement of water vapor.

### 4. Discussion

We did not find any previously published study using previous ingredients to improve the properties of mud mortar and insulation mud bricks in Dakhla against rain water, so we cannot compare our results with previous works.

Accessibility of materials utilized locally likewise the Watery silicon composite, as indicated by the rates previously mentioned studies is inexpensive particularly when contrasted with the artistic and historical value of cultural heritage.

On account of kidney application, secured just rooftops (with the establishment of Gutters) and the most elevated walls in the level heading (the highest points of the walls non - secured rooftop), additionally emerge mortar layer by 2:3cm from the side of the wall to keep the flow of rain water.

### 5. Conclusions

We want to warn the researchers that results of chemical and physical properties of mud brick in Dakhla Oasis is not applying it to other archaeological sites, as regards isolating the old buildings of mud-brick. This scientific study can be used as evidence in isolation of mud-brick after studying the physical and chemical characteristics of the mud-bricks, in accordance with the priorities identified in each building without any changes in properties or color.

### Acknowledgments

We want to thank the protectors of civilization in the Dakhla Oasis. A Tribute to these men who are working in silence.

Thanks for Prof. dr. Fred Leemhuis, field director QDP.

Thanks for the United Nations Development Program and the Japanese government.

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