CHEMICAL STUDIES ON SOME ANCIENT EGYPTIAN MORTARS

A THESIS

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CHEMICAL STUDIES ON SOME ANCIENT EGYPTIAN MORTARS.

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NOTE
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The candidate has attended postgraduate course for one year in physical and inorgainic chemistry covering the following topics :-

Solvent extraction.

Inorganic reaction mechanisms.

Statistical thermodynamics.

Nuclear reactions.

Electrochemistry and corrosion.

Analytical and microanalysis.

Surface chemistry.

Symmetry element and grouptheory.

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SUMMARY

Chemical Studies on Some Ancient Egyptian Mortars.

The work on some Ancient Egyptian mortars deals with the surface characteristics, X-Ray Diffraction and infrared behaviours of three series of mortars extracted from the Great Giza Pyramid, the Second Giza Pyramid and from the Sphinx and its adjoining temple.

Behavioural studies are carried out after heat-treatment at 300°C, 400°C, 500°C 700°C, and 900°C respectively. For the adsorption studies, two reference materials (calcium sulfate dihydrate and calcium carbonate heated respectively at 400° C and 300°C) seem to provide adequate standard adsorption data.

X-Ray diffraction and infrared studies reveal the existence of gypsum, calcite and quartz phases in different proportions with a clearcut predominance of the gypsum phase in mortars extracted from the Sphinx.

Calcium silicate hydrate phases of different crystallographic modifications are also detected in a large percentage of the samples. In the case of the mortars

extracted from the Sphinx the tricalcium silicate hydrate phase of composition $Ca_3SiO_5 \cdot 1\ 1/2\ H_2O$ is probably present. No such phase is identified in the case of mortars extracted from the Pyramids.

An important feature observed is the prevalence of the hemihydrate or γ $CaSO_4$ modifications until a temperature as high as $400^{\circ}C$.

Ageing effects spanning through a long time of several millenia may be responsible for such a behaviour.

Surface activation of the samples through heat-treatment is mainly attributed to the loss of water through a change of $CaSO_4 \cdot 2H_2O$ to the anhydrite or hemihydrate forms.

1.1 INTRODUCTION

Alfred Lucas [1] in his pioneering work on Ancient Egyptian mortar, asserted that the mortar employed in ancient Egypt before Graeco-Roman times was of two kinds, namely "clay" for use with sun dried bricks and "gypsum" for use with stone. The clay mortar is simply the ordinary Nile alluvium, consisting of clay and sand mixed with sufficient water, with sometimes the addition of a little chopped straw.

J. P. Lauer [2] indicated that instances of the early use of clay mortar are found in the step pyramid complex at Saqqara. Analysis of this mortar showed a high percentage of powdered limestone ranging from 3 - 55 percent.

H. Junker (3) also referred to similar mortars found at Giza.

Lucas described the use of gypsum mortar as follows: "The mortar employed in Ancient Egypt for stone was of gypsum which necessarily was burnt and slaked before use ; in a few samples the gypsum had become dead-burnt, i.e. anhydrous. In much of the stone work, however, the individual blocks were so large and many, especially the facing stones, were dressed so truly that mortar as a binding material was not necessary and, although employed it was largely as a cushion between the stone to prevent the edges from being damaged while they were being placed in position and as a suitable material on which the large unwiedly blocks of stone could slide and by means of which they could be adjusted and placed accurately in position".

Some writers on Egypt have described Egyptian mortar as burnt lime (even when found in buildings as old as the Great pyramid), however chemical examination by A. Choisy [4] has shown that ancient Egyptians never used lime until the Roman period.

Lucas explained that gypsum was preferred over lime because of the scarcity of fuel, lime requiring a much higher temperature for burning, and hence more fuel than gypsum. Gypsum was quarried in a very impure state, it usually contained calcium carbonate. It was only with the advent of the Greeks and Romans, both who knew lime in Europe, where gypsum is useless for out door work on account of the wet climate, that lime - burning was practised in Egypt.

Lucas has also identified a mortar (in the enclosure wall of the unfinished pyramid of Sekhemkhet at Saqqara) which was made of fairly pure limestone and an unidentified organic adhesive.

In addition Lucas's [5] analysis of fifteen samples from the Sphinx, the Giza pyramids and Karnak indicated the presence of three major components namely, Gypsum (hydrated calcium sulfate), sand and calcium carbonate.

Gypsum in most instances was found to be the component present in the highest concentration followed by calcium carbonate and followed then by sand.

Magnesium carbonate and oxides of iron and aluminium were also found in minor quantities (1 - 4%).

This all to brief account on Ancient Egyptian mortar indicates that a limited amount of work has been carried out on such materials. Therefore, at this point, a perusal of the work carried out on other ancient mortars might give an over view on various constituents forming these binders at an early time in history and in appreciating the development [illegible] in such related studies on mortars.

Thus Malinowski et al [6] have made extensive studies of the properties of ancient mortars from Caesarea and Tiberias in an attempt to explain their durability. They concluded that the high strength and density of those mortars are due to:

a) The use of suitable materials

b) Correct mixture proportioning

c) Good mixing and excellent compacting.

They also concluded that in the preparation of high quality mortar, high grade lime, and in some cases special admixtures were used. They found that the binder consisted originally of lime but was subsequently completely calcinized by the action of water and air. Age, according to those authors, seemed to favour the formation of calcite as the stablest calcium containing minerals.

Teimurov et al [7] studied a mortar from Yusuf Ibn Kuseur mausoleum using x-ray spectrometry, differential thermal analysis and Infrared spectrometry. The mortar was found to contain gypsum, calcite, quartz and clay substances.

Jedrzejewska [8] examined over 1500 old polish mortars and attempted to group various specimens according to age, and method of manufacture. She found semiquantitative techniques accurate enough for specimen characterization which allowed the determination of the relative proportions of calcium carbonate, sand and complex soluble silicates. The results indicated that calcium hydroxide was present in all of the old mortars.

Mchedlov et al [9] discussed the reaction taking place at the contact zone between lime containing binders and aggregates in twelve samples which had been aged for extended time. These samples ranged in age from the first to twentieth centuries (A.D). The X-ray diffraction studies of those twelve ancient and old mortars showed the presence of:

1- Calcite as the main component increasing with the age of mortars

2- Calcium hydrosilicates in much lower concentration than that of calcite

3- Calcium Hydrosilicates of the tobermorite group in most of the specimens.

Wetter [10] analyzed mortars collected from 12 different ancient Roman constructions and attempted to date of ancient mortars by analyzing them.