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Clusters of plasters - An Experimental Analysis of Plaster Production in Prehistoric Cyprus

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Two distinct types of plaster were produced in prehistoric Cyprus: the lime plaster and the *havara* plaster. The latter was obtained by mixing the local secondary limestone (*havara*) with water, with no pyrotechnological process involved. Because lime plaster and havara plaster have very similar characteristics, archaeologists often struggle to distinguish them in the field. An experimental study was undertaken to produce new data that could aid in examining the manufacturing techniques of prehistoric plaster materials in Cyprus.

> The production of havara plaster should not be viewed as indicative of a lack of technical expertise. Rather, it reflects a culmination of experimentation and acquired knowledge, enabling prehistoric workers in Cyprus to manipulate available local resources and produce resistant materials without any pyrotechnological process involved.

Introduction

Two distinct types of plaster have been produced in Cyprus since Prehistory using calcium carbonate sources. Lime plaster is prepared by calcinating a local limestone at high temperatures; the resulting quicklime is then mixed with water and aggregates. Mud plaster, on the other hand, is more simply produced by combining calcareous soil, water, and aggregates without involving any pyrotechnological process. In the southern region of Cyprus, in particular, the calcareous soil deriving from the natural breaking down of the secondary limestone, locally named *havara* (Schirmer, 1998), appears to have been largely used in the production of mud plasters both in prehistoric (e.g. Le Brun, 1984, p.31) and vernacular architecture (Ionas, 1988, p.57). Because lime plasters and *havara* plasters have similar characteristics to the naked eye, including their colour and porosity, archaeologists often face challenges distinguishing them that may lead to potential misidentifications. Microscopic analyses of archaeological specimens may also prove insufficient without observations and comparisons based on experimental prototypes (Karkanas, 2007; Regev, et al., 2010; Amadio, 2018; 2021).

Given the limitations of macro and micro analyses in distinguishing between these two plaster types, an experimental study was undertaken to produce new data that could aid in examining the manufacturing techniques of prehistoric plasters in Cyprus.

Methods

Twenty experimental plasters were produced in August 2018 and June 2019 at Erimi (Limassol District), and preparation included both *havara* plasters and lime plasters.

1. *Havara* plasters were prepared by reducing the local *havara* into powder and mixing it with water and different aggregate types (See Table 1). *Havara* was collected in the middle valley of the River Kouris.

2. Lime plasters were prepared by burning fragments of soft and hard limestone types. Limestone was similarly collected in the middle valley of the River Kouris and pertains to the local Pachna formation (Eaton and Robertson, 1993). Quicklime was obtained by burning limestone fragments of 5-10 cm for 1 to 4 hours in an open hearth of 1.5 m in diameter. The use of an open hearth was dictated by the need to reproduce as much as possible prehistoric methods of firing. Local materials, including dry branches and trunks of carob trees and

straw, were used as fuel. The temperature was maintained at 700 degrees Celsius for the entire experiment, and controlled and recorded using an infrared thermometer (Extech EXT42545). Lime-plaster specimens were manufactured in a variety of ways. Pure lime plaster was prepared by adding small amounts of water to quicklime until no reaction was observed. For the impure lime plasters, different types and percentages of aggregates were used (See Table 1). The preparation of the lime plasters followed the hot mixing procedure (dry slaking): unslaked quicklime (not hydrated with water) was mixed directly with aggregates and enough water to work the material *in situ.* The amount of water in the mixture was calibrated according to the 1:2 ratio (1 part lime and 2 of water).

Bricks of approximately 8 × 5 × 3 cm were produced for each of the plaster types prepared. The mixtures were manually compacted into identical rectangular aluminum pans, which served as molds to ensure consistency in shape and size across all samples. Once molded, the specimens were left to dry and carbonate under sheltered but naturally ventilated conditions to simulate an open-air but protected environment similar to that of traditional construction drying settings. The drying occurred primarily from the top surface, though the aluminum pans were not sealed, allowing for some degree of lateral and bottom evaporation. All specimens were left undisturbed for two weeks to allow for carbonation under ambient temperature and humidity conditions, without the use of artificial heating or forced airflow.

Sample N.	Plaster Type	Firing Duration	Aggregate Type	Notes
1	*Havara* Plaster	-	None	
2	*Havara* Plaster	-	25% Straw	
3	*Havara* Plaster	-	15% Limestone fragments	
4	*Havara* Plaster	-	25% Sand	
5	*Havara* Plaster	-	25% Ash	
6	*Havara* Plaster	-	40% Ash	
7	*Havara* Plaster	-	25% Clay-rich soil	
8	*Havara* Plaster	-	30% Goat dung	
9	Lime Plaster	1h	None	Not calcinated
10	Lime Plaster	2h	None	Not calcinated

11	Lime Plaster	3h	None	Not calcinated
12	Lime Plaster	4h	None	Only the soft limestone calcinated completely
13	Lime Plaster	4h	25% Straw	
14	Lime Plaster	4h	15% Limestone fragments	
15	Lime Plaster	4h	25% Sand	
16	Lime Plaster	4h	25% Ash	
17	Lime Plaster	4h	40% Ash	
18	Lime Plaster	4h	25% Clay-rich Soil	
19	Lime Plaster	4h	30% Goat dung	
20	Lime Plaster	4h	40% Powdered *havara*	

TABLE 1. EXPERIMENTAL PLASTERS PRODUCED USING DIFFERENT BINDERS AND AGGREGATE TYPES.

See also Figures 1 - 4.

Results

The resulting evidence indicates that the firing conditions in the open hearth were not optimal for obtaining complete calcination of the limestone samples. Only the limestone specimens which were fired for 4 hours were turned into quicklime, and among them, the hard limestone fragments did not calcinate completely. A substantial amount of fuel was used to stabilize the fire above 700°C over the 4-hour period, reflecting the demands of the open hearth setup.

The experiment also indicated that pure lime plaster was not the most resistant material among the lime plaster types prepared. This was indicated by the extended cracking of the material during setting. On the contrary, lime plasters mixed with organic aggregates, especially dung, and with clay-rich sediments, were more malleable and elastic and had better performances during carbonation.

The analysis further demonstrated that the *havara* powder mixed with 40% ashes deriving from the combustion of carob tree wood and straw resulted in a very homogenous and resistant end-product, with similar macro characteristics to the lime plaster tempered with ashes in the same proportion. Observations conducted by the naked eye indicate that *havara* plaster and lime plaster tempered with ashes are characterised by a microporosity deriving from the fine grain size of the raw materials and of the aggregate type used, which confers upon these plaster materials good elasticity and resistance to cracking.

Discussions

Experimental analyses conducted in this study confirm that *havara* plasters and lime plasters share similar attributes when they are tempered with the same aggregate type. From a broader perspective, the study conducted disclosed new data concerning the examination of prehistoric plaster production, particularly regarding the technical and environmental demands involved. Resource management emerged as a pivotal skill in the process of plaster-making. As demonstrated by experimental analysis, this is particularly evident in the preparation of lime plasters, which necessitated a substantial amount of fuel to reach the necessary temperatures for calcination. Our experiments, conducted in an open hearth with local wood and straw, maintained temperatures around 700°C. While this enabled partial transformation of limestone, it falls below the ~900°C threshold typically required for complete calcination into reactive quicklime. The controlled use of wood as a primary fuel source was essential to reach and sustain high temperatures. Dung was possibly used as a supplementary source of combustible material. However, ethnographic and experimental literature suggests that animal dung alone, particularly from caprines and ovines, has a lower calorific value and burns at lower temperatures than wood (e.g. Shahack-Gross, et al., 2005). Therefore, while dung may have been used as a supplementary fuel, readily available in the context of a pastoral economy, it would not have sufficed on its own to reach the high temperatures needed for lime production. In lime-burning, its use would have required careful combination with woods to ensure thermal efficiency. The production of lime plasters entailed multifaceted tasks, some of them requiring specialized expertise, such as firing and manipulation of binders and aggregates in correct proportions, while others were less specialized, like fuel and water collection. Hence, it appears that prehistoric lime plaster production in Cyprus involved different actors with varying work expertise and specialization (Amadio, 2021; 2024; Bombardieri, 2013). Observations conducted during the experiment indicated that a comprehensive understanding of the properties of local materials proved indispensable in obtaining plasters with optimal mechanical performance. The production of *havara* plaster should not be viewed as indicative of a lack of technical expertise. Rather, it reflects a culmination of experimentation and acquired knowledge, enabling prehistoric workers in Cyprus to manipulate available local resources and produce resistant materials without any pyrotechnological process involved. Further analyses will involve the study of these experimental materials utilizing thin sections under a polarized microscope and the conduct of mechanical tests to provide additional data about the properties of the plaster types produced.

Keywords limestone

Country Cyprus

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FIG 1A. PREPARATION OF THE STONE HEARTH. PHOTO BY AUTHORS.

FIG 1B. PREPARATION OF THE STONE HEARTH. PHOTO BY AUTHORS.

FIG 2A. COLLECTION OF THE LIMESTONE FRAGMENTS; SELECTION OF THE AGGREGATE TYPES. PHOTO BY AUTHORS.

FIG 2B. COLLECTION OF THE LIMESTONE FRAGMENTS; SELECTION OF THE AGGREGATE TYPES. PHOTO BY AUTHORS.

FIG 3. EXOTHERMIC REACTION OF THE LIMESTONE SAMPLES, WHICH WERE NOT FULLY CALCINATED. PHOTO BY AUTHORS.

FIG 4A. PREPARATION OF THE PLASTER SAMPLES. PHOTO BY AUTHORS.

FIG 4B. PREPARATION OF THE PLASTER SAMPLES. PHOTO BY AUTHORS.