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Preliminary observations on the building materials at the prehistoric settlement of Toumba Thessaloniki

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Abstract

From the excavations at Toumba Thessaloniki, large constructions built during the final Late Bronge Age and the Early Iron Age, were found.

The problem of the conservation of the mudbrick, the main building material of these structures, is severe and condition to select an effective preservation method is the knowledge of the composition and properties of the material, as well the processes contributing to the deterioration of the structures.

A study of the mineralogical and chemical composition and the physical and mechanical properties of the material was carried out and from the results it follows that it consists of a mixture of clay, silt and sand. It is mainly composed of quartz and natural aluminosilicates such as halloysite, feldspars (albite, anorthite), montmorillonite, trikalsilite, tosudite. It contains (in oxide, hydroxide or hydrate form) Al and Si, also Fe, K, Mg, Ca and minimal carbonate salts, Mn, Na, S.

The physical and mechanical properties and characteristics, related to the weathering resistance of mudbrick were determined: texture, hardness, strength, bulk density, porosity, physical moisture, water absorption, sonic velosity. The results of the above measurements showed that the material is unstable and soft, with a low strength, sensitive to deterioration caused mainly by water, rain and wind erosion. A suitable conservation treatment must be selected to protect the material.

Introduction

The excavations of the prehistoric settlement of Toumba started at 1983 and until these days large constructions including houses, roads and rooms of various uses were found, covering an area of 400 m^2. The constructions were built in six different phases during the final Late Bronze Age and the Early Iron Age, from the 11th century to the 6th century B.C.[1,2,3].

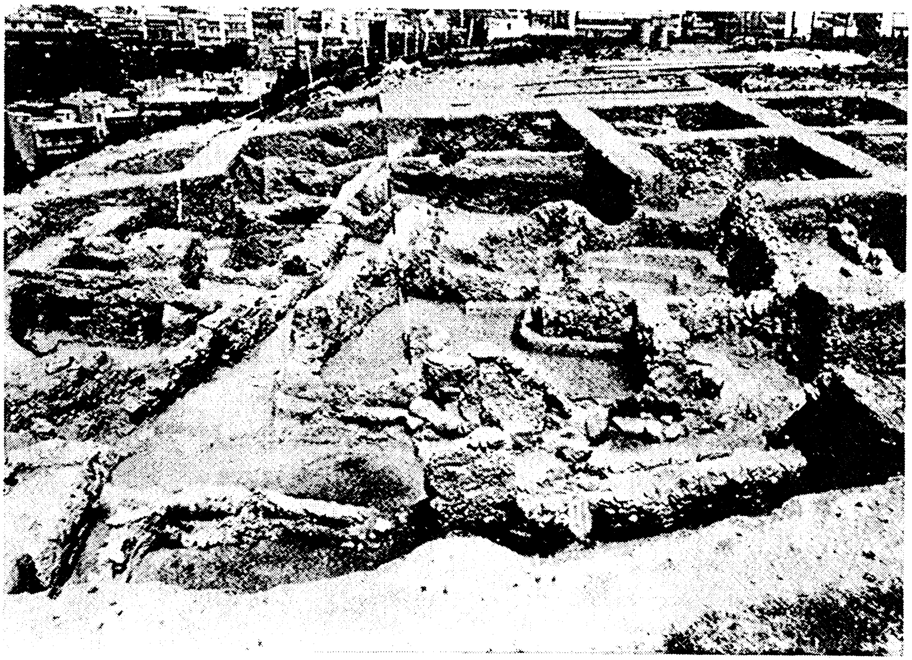

Figure 1: Part of the settlement-Main building and neighbouring constructions

The main building material of these structures is mudbrick, one of the earliest building materials used for thousands of years in many parts of the word.

It is known that the problems of the conservation of mudbrick structures is different and mush more difficult from these of other materials of historic monuments[4,5,6].

Mudbrick is a mixture of clay, silt and sand, mixed with water and shaped. The main causes of deterioration of mudbrick, arising from their nature, composition and properties, are the low stability of the material due to the repeated periods of absorption-adsorption of water and evaporation of moisture, the crystalization of soluble salts at or near the surface of the structure, the destructive action of rainwater and groundwater[6,7].

Condition to select an effective preservation method against the deterioration of these materials is the knowledge of theirs composition and properties, as well the processes contributing to the decay of the structures.

Aim of the present work is the study of the chemical and mineralogical composition and the determination of the physical and mechanical characteristics of the building materials of the prehistoric settlement of Toumba.

Experimental

Series of samples collected in three different locations, T1, T2, T3, were examined.

The chemical analysis of the samples was carried out by the Energy Dispersive Spectrometer (EDS-LINK AN 10/55S) of the Scanning Electron Microscopy (SEM) and the mineralogical analysis by X-R Diffraction.

The follow physical and mechanical characteristics have been studied[8,9,10]: particle size distribution, permeability, moisture content, the plastic characteristics by determining the Atterberg limits-liquid limit (LL), plastic limit (PL), plasticity index (PI), porosity, the point load index (Is) and the uniaxial compressive strength (UCS), the ultrasonic velocity (V).

Results and Discussion

The results of the chemical and mineralogical analysis of the samples are shown in Table 1 and Figure 2. The remainder percantage of the chemical analysis of the elements of Table 1 constists of oxygen and hydrogen.

Table 1

Chemical composition (%) of elements of samples

	T1	T2	T3
Al	5.67	5.84	3.33
Fe	4.31	3.98	2.21
Si	21.45	18.28	21.47
K	1.97	2.19	1.98
Mn	0.11	0.10	0.08
Mg	1.36	1.74	0.83
Na	0.10	0.06	0.02
P	0.77	0.32	0.86
Ti	0.37	0.31	0.32
Cu	0.51	0.57	0.63
Zn	0.11	0.51	0.48

Ca	6.54	11.28	4.25
S	0.06	0.02	0.15
Tot	43.33	45.20	36.61

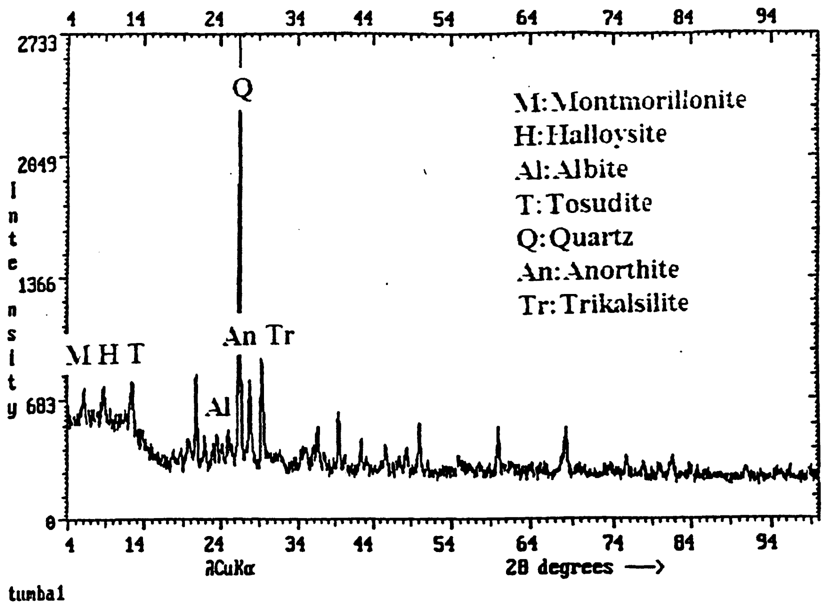

Figure 2. X-R diffractogram of the samples

The X-R diffractogram was the same for all the examined samples, indicating no mineralogical difference between them. The results of chemical analysis show slight only differences between the different samples, indicating also no significant difference in the composition of the mineral that contains (in oxide, hydroxide or hydrate form) Al and Si, also Fe, K, Mg, Ca and minimal carbonate salts, Mn, Na, S.

. From the results of Table 1 and Fifure 2 follows that the material is mainly composed of quartz (SiO_2) and natural aluminosilicates such as halloysite (aluminum silicate hydroxide hydrate-$Al_2Si_2O_5(OH)_4.2H_2O$), feldspars (albite-sodium aluminum silicate-$NaAlSi_3O_8$, anorthite-sodium calcium aluminum silicate-$(Ca,Na)(Al,Si)_2Si_2O_8$), montmorillonite (calcium magnesium aluminum silicate hydroxide hydrate-

$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2.4H_2O$), trikalsilite (potassium sodium aluminum silicate-$(K,Na)AlSiO_4$), tosudite (sodium aluminum silicate hydroxide hydrate-$Na_{0.3}Al_6(Si,Al)_8O_{20}(OH)_{10}.4H_2O$).

The particle size distribution shown in Figure 3 indicates that the mineral is composed from 10% clay, 50% silt and 40% sand.

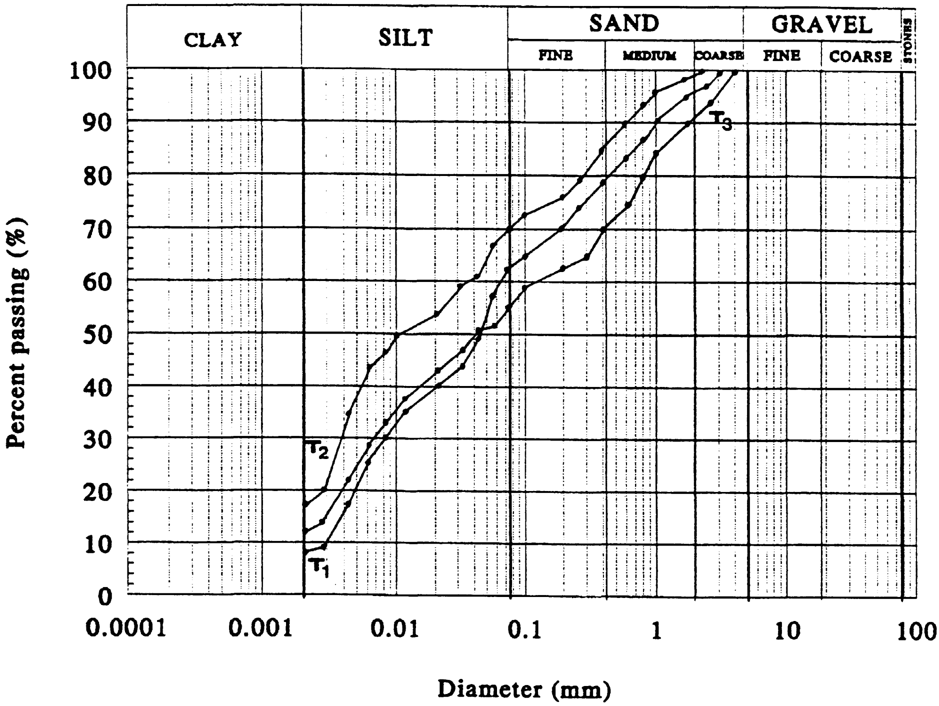

Figure 3. Particle size distribution of samples

The values of the physical and mechanical characteristics of the material are shown in Table 2.

Table 2
Physical and mechanical characteristics of samples.

	T1	T2	T3
Bulk density, ã (gr/cm^3)	1.61	1.61	1.66
Moisture content, m (%)	3.25	2.75	4.38
Permeability factor, k (cm/s)	3.24×10^{-4}	1.6×10^{-5}	8.1×10^{-5}

Liquid limid, LL (%)	32.0	36.1	41.0
Plastic limit, PL (%)	22.15	22.9	28.77
Porosity, n	0.43	0.42	0.41
Point load index, Is (MPa)	0.29	0.16	0.28
Uniaxial comprassive strength, UCS (MPa)	7.54	4.32	6.81
Ultrasonic velosity, V (m/s)	527.9	1035.9	524.4

The results of the chemical, mineralogical composition and the physical and mechanical characteristics of the material show a high content of silt and a presence of montmorillonite type of clay minerals that cause a dimensional instability of the structure[4,5,7], whereas the low presence of soluble salts does not influnce significantly its behaviour[11]. The observed great values of porosity and the values of Atterberg limits in combination with the low permeability and the above mentionned nature of the material indicate that the water can easy penetrate and remain into the material, resulting in a destructive influence of the rain water due to the absorption and evaporation of the moisture that causes changes in the volume and cracks in the bulk and the surface of the structure, leading to deterioration[12]. The effect of the ground water is low as the settlement is situated in the top of a hill, higher than the surrounding area. The values of Is, UCS and V show that the material is unstable and soft, with a low strength.

Conclusions

1. The building material of the settlement consists of a mixture of clay, silt and sand and it is mainly composed of quartz, hallosite, feldspars, montmorillonite, trikalsilite, tosudite.
2. The results of the study of the physical and mechanical properties of the material show great values of porosity, plastisity, low permeability, unstability and low strength.
3. The nature of the material and their determined properties show that it is sensitive to deterioration caused mainly by water, rain and wind erosion. A suitable conservation treatment must be selected to prevent effect of water and reinforce surface and structural stability.

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