ARCHAEOMETRIC STUDIES ON HALEPLIBAHCE MOSAICS IN TURKEY

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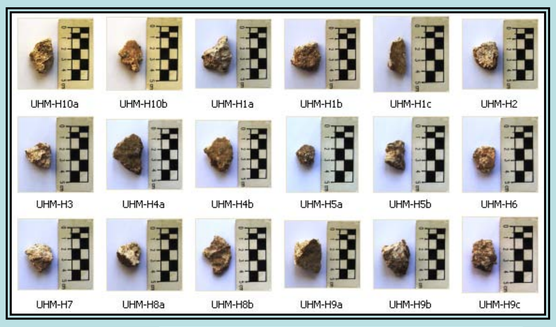
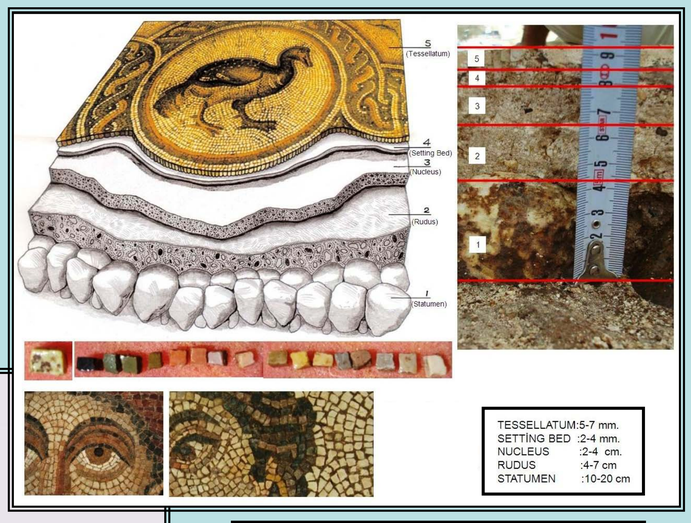
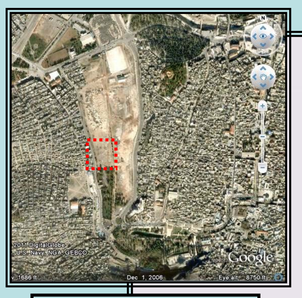


NUCLEUS / RUDUS MORTAR SAMPLES

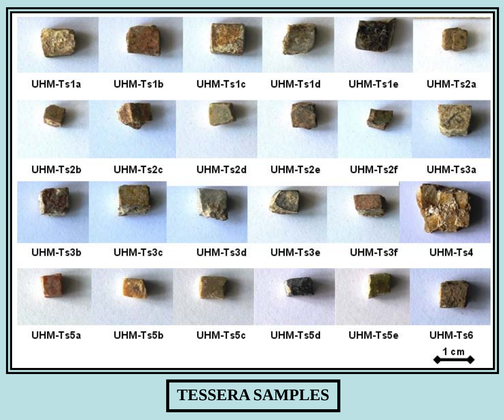


LAYERS OF THE HALEPLIBAHÇE MOSAICS



HALEPLIBAHÇE MOSAICS

LOCATION
EXCAVATION AREA
SAMPLES
CHARACTERISTICS



TESSERA SAMPLES

ABSTRACTS

Sanliurfa (ancient named Edessa) was located in the South-eastern part of the Anatolia. In the activity of urban infrastructure project in 2006, extra ordinary mosaics were discovered by chance in Haleplibahce region and the rescue excavations project directed by Sanliurfa Museum were started immediately in 2007 and then, in the year 2008 and 2009 primary and complementary conservation projects were also performed by Ankara University.

In the conservation periods in 2009, representative tessera and related mortars including setting bed, rudus and nucleus layers of the mortars of the mosaics from ten rooms of the building called Amazon Villa in Haleplibahce archaeological area were collected to characterise archaeometrically.

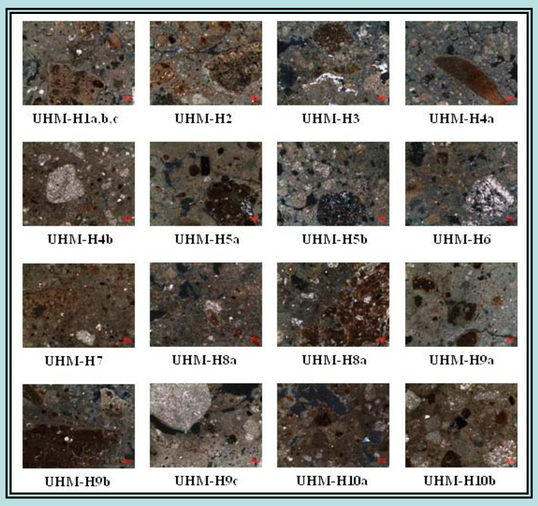
The samples first were visually examined, photographed and coded. For the analysis, the aggregate and binder part of the mortars were determined separately by the analyses agregate granulometry. The thin sections of each samples were prepared in the way to cross over all parts of it to be examined petrographically under optical microscope. The elemental composition of the samples have been determined using PED-XRF technique.

The results of archaeometric studies showed that the tessera as rock fragments are mainly limestone. The combined elemental and petrographical examination of the mortars also showed that the original high hydrolic character of the binder material of the mortars are mainly lime and mixture of lime and clay. In general, the agregate parts of the mortars reflects the local rock formation. The brick particles are also observed in the aggregate part of the all layers of the mosaic mortars.

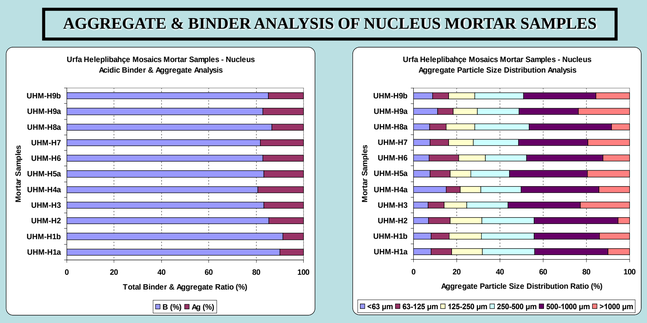
LOCATIONS OF MORTAR SAMPLES

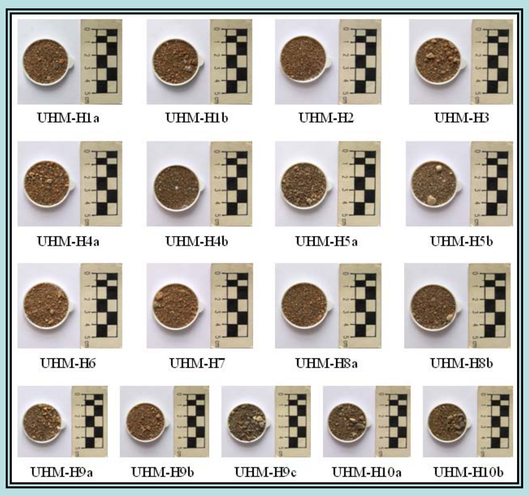
Samples	Locations (Mortar Type)
UHM-H1a	Mosaic Mortar from Room 1 (Nucleus – Upper)
UHM-H1b	Mosaic Mortar from Room 2 (Nucleus – Mid)
UHM-H1c	Mosaic Mortar from Room 3 (Nucleus – Down)
UHM-H2	Mosaic Mortar from Room 2 (Nucleus)
UHM-H3	Mosaic Mortar from Room 3 (Nucleus)
UHM-H4a	Mosaic Mortar from Room 5 (Nucleus)
UHM-H4b	Mosaic Mortar from Room 5 (Rudus)
UHM-H5a	Mosaic Mortar from Room 8 (Nucleus)
UHM-H5b	Mosaic Mortar from Room 8 (Rudus)
UHM-H6	Mosaic Mortar from Room 9 (Nucleus)
UHM-H7	Mosaic Mortar from Room 10 (Nucleus)
UHM-H8a	Mosaic Mortar from Room 11 (Nucleus)
UHM-H8b	Mosaic Mortar from Room 11 (Rudus)
UHM-H9a	Mosaic Mortar from Room 12 (Nucleus – Upper)
UHM-H9b	Mosaic Mortar from Room 12 (Nucleus – Down)
UHM-H9c	Mosaic Mortar from Room 12 (Rudus)
UHM-H10a	Mosaic Mortar from Room 13 (Rudus – Upper)
UHM-H10b	Mosaic Mortar from Room 13 (Rudus – Down)

THIN-SECTION MICRO-PHOTOGRAPHS OF MORTAR SAMPLES

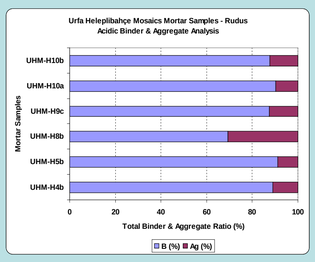


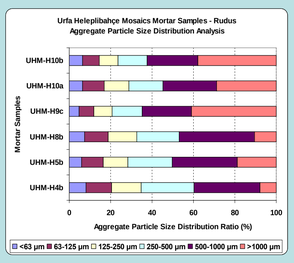
AGGREGATE & BINDER ANALYSIS OF NUCLEUS MORTAR SAMPLES





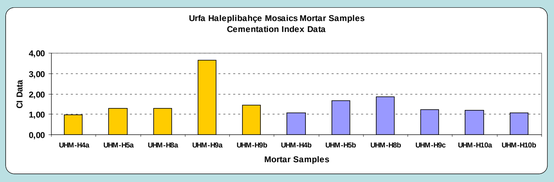
AGGREGATE & BINDER ANALYSIS OF RUDUS MORTAR SAMPLES





CEMENTATION INDEX VALUE FOR THE LIME TYPE

Mortar Lime Type	Notations	Cementation Index Value
Fat Lime	FL	Close to zero
Weakly Hydraulic Lime	WHL	0.30 – 0.50
Moderately Hydraulic Lime	MHL	0.51 – 0.70
Eminently Hydraulic Lime	EHL	0.71 – 1.10
Cement/Natural Cements	C/NC	1.11 – 1.70
Cement	C	1.70<



LOCATIONS OF TESSERA SAMPLES

Samples	Locations (Colours)
UHM-Ts1a	Tesserae from Room 1 (White)
UHM-Ts1b	Tesserae from Room 1 (Red)
UHM-Ts1c	Tesserae from Room 1 (Yellow)
UHM-Ts1d	Tesserae from Room 1 (Grey)
UHM-Ts1e	Tesserae from Room 1 (Black)
UHM-Ts2a	Tesserae from Room 2 (White)
UHM-Ts2b	Tesserae from Room 2 (Red)
UHM-Ts2c	Tesserae from Room 2 (Yellow)
UHM-Ts2d	Tesserae from Room 2 (Grey)
UHM-Ts2e	Tesserae from Room 2 (Black)
UHM-Ts2f	Tesserae from Room 2 (Green)
UHM-Ts3a	Tesserae from Room 3 (White)
UHM-Ts3b	Tesserae from Room 3 (Red)
UHM-Ts3c	Tesserae from Room 3 (Yellow)
UHM-Ts3d	Tesserae from Room 3 (Grey)
UHM-Ts3e	Tesserae from Room 3 (Black)
UHM-Ts3f	Tesserae from Room 3 (Claret Red)
UHM-Ts4	Tesserae from Room 11 (Yellow)
UHM-Ts5a	Tesserae from Room 12 (Red)
UHM-Ts5b	Tesserae from Room 12 (Yellow)
UHM-Ts5c	Tesserae from Room 12 (Grey)
UHM-Ts5d	Tesserae from Room 12 (Black)
UHM-Ts5e	Tesserae from Room 12 (Green)
UHM-Ts6	Tesserae from Room 13 (Yellow)

CHARACTERISATION OF THE MORTAR SAMPLES BY THIN-SECTION OPTICAL MICROSCOPY

Mortar Groups	Ba (%)	Ag (%)	Matrix Binder Composition (%)				Matrix Aggregate Composition (%)		
			L	MP	Cm	Clay	Rocks & Minerals*	BP	Org
Mortar Gr1**	77	23	65	-	-	35	65 (Ls,Ch,Op)	35	-
Mortar Gr2	85	15	25	-	-	75	85 (R,Ch,Op)	15	-
Mortar Gr3	82	18	95	-	-	5	92 (Q,Ch,O,B,S)	8	-
Mortar Gr4	75	25	85	15	-	-	90 (Ls,Q,B,Op)	10	-
Mortar Gr5***	79	21	100	-	-	-	94,5 (C,Op,S)	5,5	-

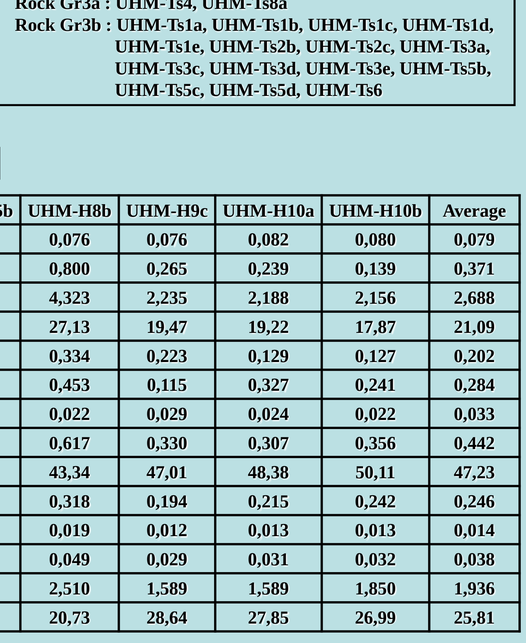
(*) Ag: Aggregate, BP: Brick Particles, C: Calcite, Ch: Chert, Cm: Cement, B: Basalt, Ba: Binder, Ls: Limestone, L: Lime, MP: Marble Powder, O: Olivine, Op: Opaque Minerals, Org: Organic Particles, Q: Quartz, R: Radiolarite, S: Serpantinite

(**) Mortar Groups - Nucleus Layer;
Mortar Gr1 : UHM-H1a, UHM-H1b, UHM-H1c, UHM-H2, UHM-H3, UHM-H4a, UHM-H6 and UHM-H9a
Mortar Gr2 : UHM-H9b
Mortar Gr4 : UHM-H5a, UHM-H7, UHM-H8a

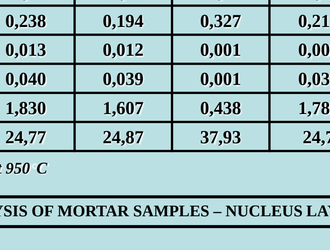
Mortar Groups - Rudus Layer;
Mortar Gr1 : UHM-H8b
Mortar Gr3 : UHM-H4b, UHM-H5b, UHM-H9c
Mortar Gr4 : UHM-H10a, UHM-H10b

(***) Mortar - Setting Bed Layer around UHM-Ts4

THIN-SECTION MICRO-PHOTOGRAPHS OF TESSERA



TESSERA SAMPLES UHM-Ts4 IN SETTING BED



Limestone tessera (UHM-Ts4) in setting bed (cracks on tessera filled with quartz)

Serpantinite, calcite and opaque minerals beside brick particles in setting bed lime matrix

CEMENTATION INDEX VALUE FOR LIME TYPE

$$CI = \frac{[2{,}8\ (\%SiO_2) + 1{,}1\ (\%Al_2O_3) + 0{,}7\ (\%Fe_2O_3)]}{[(\%CaO) + 1{,}4\ (\%MgO)]}$$

CEMENTATION INDEX VALUE FOR LIME TYPE OF MORTAR - NUCLEUS

Samples	CI	Lime Type
UHM-H4a	0.97	EHK
UHM-H5a	1.28	C/NC
UHM-H8a	1.30	C/NC
UHM-H9a	3.67	C
UHM-H9b	1.45	C/NC
Nucleus Ave.	1.73	C

CEMENTATION INDEX VALUE FOR LIME TYPE OF MORTAR - RUDUS

Samples	CI	Lime Type
UHM-H4b	1.08	EHL
UHM-H5b	1.67	C/NC
UHM-H8b	1.87	C
UHM-H9c	1.24	C/NC
UHM-H10a	1.19	C/NC
UHM-H10b	1.08	EHL
Rudus Ave.	1.35	C/NC

CHARACTERISATION OF THE TESSERA SAMPLES BY THIN-SECTION OPTICAL MICROSCOPY

Tessera Rock Groups	Tessera Rock Types	Hardness (Mohs)	Descriptions
Rock Gr1*	Clay Stone	2.5 – 3.0	
Rock Gr2a	Pelagic Limestone	3.0	Hydrothermal alterations in iron oxide matrix, calcite, limonite and opaque minerals
Rock Gr2b	Pelagic Limestone	3.0 – 3.5	Clay/Carbonate matrix, fossils (radiolaria)
Rock Gr2c	Pelagic Limestone	3.5 – 4.0	Quartz in micro cracks
Rock Gr3a	Sparitic Limestone	3.0	Calcite
Rock Gr3b	Sparitic Limestone	3.0	Calcite and opaque minerals

(*) Tessera Rock Groups;
Rock Gr1 : UHM-Ts5a
Rock Gr2a : UHM-Ts2a
Rock Gr2b : UHM-Ts2d, UHM-Ts2e, UHM-Ts3b, UHM-Ts3f
Rock Gr2c : UHM-Ts2f, UHM-Ts5e
Rock Gr3a : UHM-Ts4, UHM-Ts8a
Rock Gr3b : UHM-Ts1a, UHM-Ts1b, UHM-Ts1c, UHM-Ts1d, UHM-Ts1e, UHM-Ts2b, UHM-Ts2c, UHM-Ts3a, UHM-Ts3c, UHM-Ts3d, UHM-Ts3e, UHM-Ts5b, UHM-Ts5c, UHM-Ts5d, UHM-Ts6

PED-XRF ELEMENTAL ANALYSIS OF THE MORTAR SAMPLES

Element	UHM-H4a	UHM-H5a	UHM-H8a	UHM-H9a	UHM-H9b	Average
Na_2O	0,079	0,079	0,078	0,210	0,080	0,079
MgO	0,166	0,403	0,476	0,591	0,414	0,365
Al_2O_3	1,741	2,573	2,466	4,825	2,947	2,432
SiO_2	17,74	20,69	21,46	30,47	22,40	20,57
P_2O_5	0,177	0,204	0,207	0,524	0,180	0,192
SO_3	0,129	0,191	0,207	0,395	0,279	0,201
Cl	0,029	0,081	0,017	0,077	0,082	0,052
K_2O	0,241	0,461	0,382	0,686	0,418	0,375
CaO	54,19	48,47	48,80	24,00	46,24	49,43
TiO_2	0,140	0,238	0,194	0,327	0,217	0,197
Cr_2O_3	0,009	0,013	0,012	0,001	0,009	0,011
MnO	0,033	0,040	0,039	0,001	0,038	0,038
Fe_2O_3	1,125	1,830	1,607	0,438	1,789	1,588
LOI*	24,70	24,77	24,87	37,93	24,7	24,76

Element	UHM-H4b	UHM-H5b	UHM-H8b	UHM-H9c	UHM-H10a	UHM-H10b	Average
Na_2O	0,078	0,079	0,076	0,076	0,082	0,080	0,079
MgO	0,160	0,623	0,800	0,265	0,239	0,139	0,371
Al_2O_3	1,933	3,291	4,323	2,235	2,188	2,156	2,688
SiO_2	18,45	24,39	27,13	19,47	19,22	17,87	21,09
P_2O_5	0,149	0,252	0,334	0,223	0,129	0,127	0,202
SO_3	0,096	0,475	0,453	0,115	0,327	0,241	0,284
Cl	0,024	0,077	0,022	0,029	0,024	0,022	0,033
K_2O	0,434	0,610	0,617	0,330	0,307	0,356	0,442
CaO	50,83	43,72	43,34	47,01	48,38	50,11	47,23
TiO_2	0,206	0,299	0,318	0,194	0,215	0,242	0,246
Cr_2O_3	0,011	0,015	0,019	0,012	0,013	0,013	0,014
MnO	0,028	0,057	0,049	0,029	0,031	0,032	0,038
Fe_2O_3	1,479	2,600	2,510	1,589	1,589	1,850	1,936
LOI	26,74	23,88	20,73	28,64	27,85	26,99	25,81

(*) LOI: Loss on Ignition at 950 C

PED-XRF ANALYSIS OF MORTAR SAMPLES – NUCLEUS LAYER

PED-XRF ANALYSIS OF MORTAR SAMPLES – RUDUS LAYER

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