NAMO CONSERVATION CONCEPT

The Mortars of Qasr al Bint in Petra and Archaeological site in Bosra

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OBJECTIVES

- Open joints
- Detachment of plaster
- •Lacunae
- Cracking of plaster
- Salt crystallization



Formulation of restoration mortars

- Adhesion mortars for the stabilisation of damaged edges and small defects of stucco and renderings.
- Repair mortars to close larger missing parts of the renderings.
- Grouting mortars to renew the connection of detached layers of stucco and of the renderings.
 - A sacrificial plaster to cover areas affected by salt crystallization.

Testing wall near Qasr al Bint, Petra

- The testing wall was constructed from stone ashlars with a size of approximately 30x20x10 cm made from Petra sandstone.
- Size of the wall was approx. 6,5 x 1,2 m
- Each stone was soaked with water in order to supply the stone with a substantial amount of humidity needed for hardening process of mortars.



Before the application of the test mortars





Wetting of the protective textile cover

Application of mortars on testing wall

- The mortars have been applied as renderings (plasters) and as <u>adhesion</u> <u>mortars</u> on the edges of the so called "cornice".
- From each of testing mortars two plastered areas on the front side and one testing area on the backside of the testing wall was applied.

The procedure of plastering





The plastered areas



The plastered areas - front side, general view

Formula	w	PS	JLP	SLP	SG	JG	JT	JC	JP	NHL2
No	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(I)	(1)
140.	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
2	2,30	6,00								2,00
	2,30	9,20								1,40
3A	1,00	6,00	2,80					0,20	0,60	
	1,00	9,20	4,03					0,24	0,75	
3B	1,00	6,00	2,80						1,00	
	1,00	9,20	4,03						1,25	
4A	1,00	6,00	2,80				0,60	0,20		
	1,00	9,20	4,03				0,40	0,24		
4B	1,00	0,00	2,00				1,00			
	1,00	9,20	4,03				0,75			
4C	0,54	2,00	1.54				0,30			
	1.00	6.00	1,34	2.00	0.60		0,20			
5A	1,00	9,20		2,00	0.64					
	2 20	6.00	1 50	2,10		1 00				
5B	2.20	9,20	2,16			1,10				
	1.10	6.00	1,70							
6	1,10	9,20	2,45							
7A	0,65	6,0	2,80							
	0,65	9,20	4,03							
7B	0,74	8,00		3,20						
	0,74	12,27		3,97						
8	0,35	6,00	4,20							
	0,35	9,20	6,05							
٩	0,85	6,00	2,80							0,80
•	0,85	9,20	4,03							0,56
104.	1,75				3,50					
	1,75				3,72					
10A2	1,50				3,50					
	1,50				3,72					

Tab. 1 Mortar formulas used during the performing of on-site test walls at Qasr al Bint

Description of abbreviations:

W Water	JG Jordanian Gypsum
PS Petra Sand	JPJordanian Puzzolana
JLP Jordanian Lime Putty	JTJordanian Tripoli
SLP Syrian Lime Putty	JC Jordanian Cement
SG Syrian Gypsum	NHL2 Natural Hydraulic Lime

Evaluation of mortars - Summary

- The overall condition of the plasters on the test walls was good.
- Apparently good properties (low crack density, good adhesion to the support, acceptable texture of surface, acceptable colouring) for most of formulas.
- Adhesion of plasters to the stone was good.

The plastered areas after 10 months



Front side, mortar mixtures 2 (PS,NHL2), 3A(JLP,JC,JP), 4A(JLP,JT,JC) Formula 2 did not show any cracks

The plastered areas after 10 months



Front side, mortar mixtures 7A(SLP), 7B(JLP) and 8(JLP) Formula 7 B is nearly free of cracks. Formula 8 (high content of binder) showed highest crack density

The plastered areas after 10 months



Front side, mortar mixtures 5A(SLP,SG), 9(JLP,NHL2) and 6(JLP low) Formula 9 (lime with NHL 2 – admixture) is nearly free of cracks

The Sacrificial plaster on the stone block



Application on sandstone heavily affected due to the crystallization of soluble salts - material loss after 10 /16 months is recognizable.

Areas for on site application

Mortars were tested on small areas both in exterior and interior of Qasr al Bint.



Adhesion & Joint Mortar - On site tests

• formula 9 (in w-%): 69 PS, 24 JLP, 7 NHL2

formula 7Bmod (in w-%): 76 PS, 24 JLP

• formula 4Bmod (in w-%): 75 PS,20 JLP,5 JT

Reasons for application

- comparably low crack density
- overall good appearance
- high durability to the salt crystallization
- high porosity
- good adhesion to the support

- all mixtures are without the addition of cement, (possible source for soluble salts)

Adhesion mortar



Joint mortar



Workability of mortars

- very good handling properties
- good plasticity
- easy way of application
- good adhesion to the stone
- good adhesion to original plaster edges
- no tendency to run off
- no tendency to crack

During the test no cracking was observed on applied mortars.

Injection (Grouting) Mortar

MIXTURE	W	PS	PS	ЛР	JT	NHL2	SG	MM
		White0,5	Red 0,25					
Volume	(b) /		(1)	(1)	(1)	(b) /		(1)
			(kg)		(kg)			
Weight	(kg)			(kg)		(kg)		
I1	0,04⁄	0,225		0,075	0,025		8ml	
	6 64	1 364		6 002	10.018			
12	0.07/	0,304	0.16 /	0.075	0.08			5ml
	0,0			0,072	0,00			
	0,07		0,253	Ø,092	0,058			
13	0,07⁄		0,16	0,075		0,08⁄		5ml
	,0,0 7		0,253	<i>,</i> Ø,092		0,056		
14	0,09⁄			0,075	0,16			5ml
	1							
	0,09			0,092	/0,117			

Injection mortars have to fill gaps completely and to make proper bond between support and plaster. To make the penetration easier admixture of liquidifier was used.

- 1. MELMENT L 10/40 solution of melamine methanal resin
- 2. Sodium gluconate (20 % solution in water)

Grouting mortar



Sacrificial plasters for desalination of stone walls

• formula 7Bmodified

(76 PS, 24 JLP)

good temporary resistance against salt crystallization

formula 6modified with admixture of 5 % of tripoli (82 PS, 13 JLP, 5 JT)

Both formulas were tested on the interior west wall of Qasr al Bint.



Sacrificial mortar



Adhesion mortar after 8 months





Lacunae and joint mortar after 8 months





Experimental - Testing Wall Bosra

It was decided not to test the mortars and renderings directly on the walls of the great cathedral.

-safety reasons to protect the test mixtures from vandalism;good environmental conditions



As an alternative an open corridor of the northern part of the Mabrak An Naka Mosque at the Bosra archaeological site has been chosen as a test site.

Experimental - Testing Wall Bosra

- Four basic mortar mixtures were used for the tests.
- The mixtures with coarse limestone aggregate were subsequently partially covered by a fine grained plaster.
- The mortars containing coarse limestone aggregate were applied both with a rough and a smooth surface.
- According to the original use the fine mortars were applied on top of coarse grained mortars.
- Mortars with hemp fibre were applied either directly on the stone block or on top of coarse grained mortars.

Mortar mixtures used for on-site test

Formula	W	SLP	SLSC	SLSF	SBPC	SBPF	SVFH	SPS
No	(I)	(I)	(I)	(I)	(I)	(1)	(I)	(I)
NO.	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
110.	1,00	2,40	5,00	2	1,00			
	1,00	2,98	9,00	3	1,33			
110	1,15	2,40	5,00		1,00			
1142	1,15	2,98	9,00	2	1,33	-		
110	1,10	2,40	5,50		0,50			
ПВ	1,10	2,98	9,90	85	0,66			
124	0,30	0,60		1,50				
12A	0,30	0,74		2,25				
120	0,40	1,20		2,00				
120	0,40	1,49		3,00				
120	2,27	2,40			6,00			
154	2,27	2,98		<i>1</i> 0	7,95		0,10	
130		1,00						
156		1,24		10			0,02	
14	0,75	2,50		1,50				3,50
14	0,75	3,10		2,25				3,31
15	0,70	1,00	2,00	1,00		0,50		
15	0,70	1,24	3,60	1,50		0,66		

Description of abbreviations:

W Water

SLP Syrian Lime Putty

SLSF..... Syrian Lime Sand Fine

SBPC Syrian Basaltic Powder Coarse SBPF......Syrian Basaltic Powder Fine SLSC Syrian Lime Sand Coarse SVFH Syrian Vegetable Fibres Hemp SPS.....Syrian Puzzolana Shahba

Plastering by a local craftsman



Preparation of hemp-fibres (repulping)



Plastered areas after their finishing, mortar mixtures





Sketch of the above plastered areas with the number of the mixtures given:

Mixtures after 10 months

Test site for April 2005 Deir Al Raheb Bahera (Monastery of the Monk of Baheera)

Mixtures to be tested in April 2005

Mixture 11: SLP-SLSC (1:2,5 by vol.)

- Pure
- with hamp
- Without fraction below 0,15 mm
- With 5 % of fraction below 0,15 mm
 Mixture 13: : SLP-SBPC (1:2,5 by vol.)
 -with increasing content of hemp (1-6)

Aplication of selected mortars/April 2005

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Mixtures in detail

EVALUATION / DECEMBER 2005 Mixture 11: SLP-SLSC (1:2,5 by vol.)

original composition

with hamp

without grains under 0,15 mm

EVALUATION / DECEMBER 2005 Mixture 13: SLP-SBPC (1:2,5 by vol.)

Mixture with basaltic filler with increasing content of hemp

CONCLUSION

- GOOD ADHESION TO THE STONE SUPPORT
- FAST CRACKING AFTER APPLICATION IF NO HAMP ADDED
- DIFFICULT MIXING WHEN USING HEMP

To avoid cracking in plasterworks:

- REMOVAL OF FINE FRACTION OF AGGREGATE
- ADDITION OF APPROPRIATE AMOUNT OF HEMP

Thank you for your attention

