

LIME PLASTER TESTING BY LIME ARTISAN SOLÈNE DELAHOUSSE

TESTING REPORT

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TABLE OF CONTENTS

1. INTRODUCTION	1
1.1 Framework & Aim of the research	1
2. PREPARATION OF RAW MATERIALS	1
2.1 Lime Preparation & Properties	1
2.1.1 Industrial Lime	1
2.1.2 Shell Lime	1
2.1.3 Village Lime	2
2.2 Aggregates	3
2.2.1 Sand	3
2.2.2 Quarry Dust	3
2.2.3 Marble Powder	3
2.3 Densities of Components	3
3. PLASTER SAMPLES	3
3.1 Sample Preparation & Application Surface	3
3.2 Plaster Sample Details	3
3.2.1 Panel 1: Plasters with Industrial Lime and Varied Aggregates	8
3.2.2 Panel 2: 'Marmorino' Stucco with Industrial Lime	8
3.2.3 Panel 3: 'Marmorino' and 'Tadelakt'	8
4. SAMPLE TESTING & OBSERVATION	9
4.1 Observed Behavior of the Samples	9
4.2 Pathologies Observed	10
4.2.1 Pock-marks	10
4.2.2 Cracking	10
4.2.3 Spalling	10
4.2.4 Surface hardness	10
4.2.5 Waterproofing performance	10
5. CONCLUSIONS & RECOMMENDATIONS	10
5.1 Conclusions	10
5.2 Recommendation for Further Research	10
5.2.1 Black Soap	10
5.2.2 Soap Nut	11
5.2.3 Kaddukai water, Jaggary and Lime paste	11
5.2.4 Cactus Juice	11
5.2.5 Stabilised earth waterproofing (SEW)	11
5.2.6 Earthen Pigments	11
6. ANNEXES	11

1. INTRODUCTION

1.1 FRAMEWORK & AIM OF THE RESEARCH

Solène Delahousse is a French lime artisan who has been in discussion with AVEI to offer a course on decorative limes and tadelakts. She spent several days at the Earth Institute testing some of the local limes with various plaster samples. The following report provides documentation of her work in these days, and will offer follow-up assessment on the behaviours of the lime samples throughout 2017.

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2. PREPARATION OF RAW MATERIALS

2.1 LIME PREPARATION & PROPERTIES

2.1.1 Industrial Lime

A conventional industrial hydrated lime was used for test panels 1 and 2 (Calcium Hydroxide – $\text{Ca}(\text{OH})_2$). This lime required no soaking, as it is already hydrated.

2.1.2 Shell Lime

A quick lime from burned shells, produced in Kerala and distributed by Regikumar, was used for test panels 2 and 3. The Shell Lime was soaked in water at 2:00 pm on 19th January 2017, 12 days before the first day of plaster sample preparation. Quantity: 10 kg of lime was soaked in 20 liters of water.

A small sample of this shell lime was hydrated with only the amount of water required for full hydration. This sample was dried and dry sieved to determine its grain size distribution. The entire sample appears to be all less than 0.106 mm.

Total initial weight of Sample: 44.75 g

Grain Size (mm)	Weight (g)	Percentage (% by weight)
< 0.106 mm	TBD	TBD
Loss of material	n/a	TBD

Table 1: Grain size distribution of Industrial lime



Figure 1: Shell lime before and after hydration

2.1.3 Village Lime

A village quick lime, produced in a village nearby to Auroville, was used for test panels 3. As this lime was brought by Solène, not much is known about the soaking and preparation of the lime. This lime is known to be very coarse with a lot of unburned or over-burned aggregate components. Solene had estimated that for this lime, there would be approximately 1 part lime to $\frac{1}{2}$ part of aggregates.

A small sample of this village lime was hydrated with only the amount of water required for full hydration. This sample was dried and dry sieved to determine its grain size distribution. This sample is extremely varied in its granularity, with the greatest percentage of particles (23.33 %) between 0.500 and 1.00 mm.

Total initial weight of Sample: 64.55 g

Grain Size (mm)	Weight (g)	Percentage (% by weight)
15 mm	2.16	3.35 %
4.00 mm	3.79	5.87 %
2.00 mm	7.95	12.32 %
1.00 mm	11.48	17.78 %
0.500 mm	14.99	23.22 %
0.212 mm	8.81	13.64 %
0.106 mm	4.08	6.32 %
< 0.106 mm	10.60	16.42 %
Loss of material	n/a	1.08 %

Table 2: Grain size distribution of Local village lime



Figure 2: Grain size distribution of Local village lime

2.2 AGGREGATES

2.2.1 Sand

River sand (sieved with a 2 mm and 1 mm mesh). River sand generally has rounder particle shapes.

2.2.2 Quarry Dust

Quarry dust (from crushing “blue metal” stone) (sieved with a 2 mm and 1 mm mesh). Quarry dust is generally more faceted.

2.2.3 Marble Powder

Marble powder (sieved with a 0.5 mm mesh)



Figure 3: Aggregates and Lime raw materials used

2.3 DENSITIES OF COMPONENTS

Densities (kg/L) of components used for the samples are as follows:

Lime	Sand	Quarry Dust	Marble Powder	Water
0.5860 *	1.4600 *	**	1.4060 *	1.0000

Table 3: Dry densities of components

* To be checked again for all raw materials; ** To be tested.

3. PLASTER SAMPLES

3.1 SAMPLE PREPARATION & APPLICATION SURFACE

All samples were plastered on walls of 5% stabilized rammed earth walls (24 cm). The thickness of each plaster is 3x the size of the largest aggregate (varying between 3 mm and 10mm). The walls were wet extensively before and throughout the plastering (for approximately 2 days).

3.2 PLASTER SAMPLE DETAILS

Solène made three panels of lime plaster samples. Broadly speaking, Panel 1 tested industrial lime with varying ratios of aggregates (sand, quarry dust and marble powder. Panel 2 tested a special 3-layer Italian stucco technique, Marmorino, which is difficult to plaster in large surfaces. Panel 3 tested varying proportions of the Shell lime and Local lime available. NOTE: Sample names are ordered from right to left, in the direction that samples were made.



Figure 4: Panels 3, 2 and 1 (left to right)

Shortlist of Ratios

	Ref.	Sample	Ratio	Finish; Technique
PANEL 1	A	A ₁	1 ind. lime : 2 quarry dust (2mm) : ½ marble powder (0.5 mm)	Wooden float
		A ₂	1 ind.lime : 2 quarry dust (2mm) : ½ marble powder (0.5 mm)	Steel float
		A ₃	1 ind. lime : 2 quarry dust (2mm) : ½ marble powder (0.5 mm)	Steel float (worked more); 2 nd coat of ind. lime; Neem oil
	B	B ₁	1 ind. lime : 2 quarry dust (1mm) : ½ marble powder (0.5 mm)	Wooden float
		B ₂	1 ind. lime : 2 quarry dust (1mm) : ½ marble powder (0.5 mm)	Steel float
		B ₃	1 ind.lime : 2 quarry dust (1mm) : ½ marble powder (0.5 mm)	Steel float (worked more); 2 nd coat of ind. lime
	C	C ₁	1 ind. lime : 2 sand (2mm) : ½ marble powder (0.5 mm)	Wooden float
		C ₂	1 ind. lime : 2 sand (2mm) : ½ marble powder (0.5 mm)	Steel float
		C ₃	1 ind. lime : 2 sand (2mm) : ½ marble powder (0.5 mm)	Steel float; 2 nd coat of ind. lime
	D	D ₁	1 ind. lime : 2 sand (1mm) : ½ marble powder (0.5 mm)	Wooden float
		D ₂	1 ind. lime : 2 sand (1mm) : ½ marble powder (0.5 mm)	Steel float
		D ₃	1 ind. lime : 2 sand (1mm) : ½ marble powder (0.5 mm)	Steel float; 2 nd coat of ind. lime
	E	E ₁	1 ind. lime : 1 sand (1mm) : 1 quarry dust (1mm) : ½ marble powder (0.5 mm)	Wooden float
		E ₂	1 ind. lime : 1 sand (1mm) : 1 quarry dust (1mm) : ½ marble powder (0.5 mm)	Steel float
		E ₃	1 ind. lime : 1 sand (1mm) : 1 quarry dust (1mm) : ½ marble powder (0.5 mm)	Steel float; 2 nd coat of ind. lime
PANEL 2	F	1 st coat	1 ind. lime : 1 sand (1mm) : 1 quarry dust (1mm) : ½ marble powder (0.5 mm)	Wooden float
		2 nd coat	1 ind. lime : 2 marble powder (0.5 mm)	As soon as 1 st coat is finished, when still fresh
		3 rd coat	1 ind. lime : 1 marble powder (0.5 mm)	When still fresh
PANEL 3	G	G ₁	1 shell lime only	
		G ₂	1 shell lime : 1 marble powder (0.5 mm)	
		G ₃	1 shell lime : 2 marble powder (0.5 mm)	
		G ₄	1 st coat 1 shell lime : 2 marble powder (0.5 mm)	'Marmorino' Stucco
			2 nd coat 1 shell lime : 1 marble powder (0.5 mm)	
			3 rd coat 1 shell lime only	
	H	H ₁	1 village lime only (unsieved)	Tadelakt
		H ₂	1 village lime only (unsieved)	Tadelakt
	I	I ₁	1 shell lime only	Tadelakt
		I ₂	1 shell lime : ½ marble powder (0.5 mm)	Tadelakt

Table 4: Ratios of all plaster samples



Figure 5: Panel 1 with industrial lime and varied aggregates



Figure 6: Panel 2 with industrial lime and 3-layer 'Marmorino' stucco technique



Figure 7: Panel 3 with shell lime, village lime in stucco and Tadelakt techniques

3.2.1 Panel 1: Plasters with Industrial Lime and Varied Aggregates

All plasters are 1 layer only with the exception of A₁, B₁, C₁, D₁ and E₁.

Samples A₁, B₁, C₁, D₁, and E₁ are finished with a wooden float. These samples are highly absorbent.

Samples A₂, B₂, C₂, D₂, and E₂ are finished with a steel float. These samples are much less absorbent.

Samples A₃, B₃, C₃, D₃, and E₃ are finished with a steel float. These samples are relatively water resistant.

3.2.2 Panel 2: ‘Marmorino’ Stucco with Industrial Lime

Panel 2 is a ‘Marmorino’, an Italian stucco technique with 3 coats of plaster. The granularity is generally greatest in the base coat and diminishing progressively in the upper coats. When the 2nd and 3rd layers are applied, the aim is that the smaller grain sizes fill any existing gaps of the previous coat; thus all aggregates come inside of the base plaster.

The shiny surface of this plaster demonstrates that the carbonation process is occurring. Working the lime too early: Water coming (see film of water on surface or trowel, on surface this can be confused with shine). Working the lime too late: too carbonated.

This plaster is not 100% waterproof – but the carbonation process makes “leaves” or “sheets” of lime that are water resistant. It could be more waterproof with the application of a black soap in the final coat or on the surface.

Large walls are very difficult to plaster with this technique. This area of plaster is about the limit of what Solene can do herself, without a team of plasterers. It is generally better to have a team of 3 plasterers working in a linear progression, one laying the base coat, another laying the 2nd coat and the third the 3rd coat. For this reason, this is not a technique to apply in the hot season. Use in the humid season is the best.

The base coat of this sample is the same as E₂ of Panel 1. If less quarry dust was used, and more sand, or marble powder, there would be less color coming through the plaster. For the 3rd coat, an even finer aggregate could have been used (talc, chalk?, etc. down to 350 microns).

3.2.3 Panel 3: ‘Marmorino’ and ‘Tadelakt’

3.2.3.1 Marmorino

Sample G₄ uses the same technique of Panel 2, with coats of G₃, G₂ and G₁.

3.2.3.2 Tadelakt

Samples H and I are applied like a ‘Tadelakt’, a Moroccan plastering technique which uses the pressure of application and burnishing to make a relatively water resistant, but not fully waterproof, plaster. When the plaster is worked, the lime is brought to the surface by capillarity, though if it is worked too much, the base plaster loses too much lime and can become brittle. In tadelakt, small cracks are normal, and this is more evident when adding water to the surface. Normally black soap is used to waterproof cracks.

The tadelakt with the Village Lime is quite a bit more similar to Moroccan tadelakt, in that there is a relatively small proportion of aggregates to the lime, yet the aggregates are large and must be pressed into the plaster with a float. This plaster is significantly thicker (1.5 cm) on account of the size of the aggregates in this lime.

First, a trowel was used to apply the plaster. This plaster is very difficult to work in the early stages because of the large aggregates, although the largest aggregates (~10-15mm) are discarded. Then a wooden float is used to crush the aggregates and to push them into the thickness of the plaster. When the ‘greasy’ texture of the lime comes to the surface, then a steel float can be used to work the lime; a plaster tool is used to work the edges. Finally, when the surface is sufficiently smooth, a stone can be used to burnish the surface.

The tadelakt of the pure Shell Lime has a very interesting texture with black and white spots from the shells. This lime should be checked for shrinkage cracks, as its granularity is very smooth with no adequate aggregates.

4. SAMPLE TESTING & OBSERVATION

4.1 OBSERVED BEHAVIOR OF THE SAMPLES

Panel 1 – Samples A - E

Ref.	Sample	Industrial Lime	Sand 2 mm	Sand 1 mm	Quarry Dust 2 mm	Quarry Dust 1 mm	Marble powder 0.5 mm	Remarks
A	A ₁	1	–	–	2	–	½	
	A ₂	1	–	–	2	–	½	
	A ₃	1	–	–	2	–	½	Worked more than other samples
B	B ₁	1	–	–	–	2	½	
	B ₂	1	–	–	–	2	½	
	B ₃	1	–	–	–	2	½	Worked more than other samples
C	C ₁	1	2	–	–	–	½	
	C ₂	1	2	–	–	–	½	
	C ₃	1	2	–	–	–	½	
D	D ₁	1	–	2	–	–	½	
	D ₂	1	–	2	–	–	½	
	D ₃	1	–	2	–	–	½	
E	E ₁	1	–	1	1	–	½	Should be ~ 3mm thick
	E ₂	1	–	1	1	–	½	
	E ₃	1	–	1	1	–	½	

Table 5: Mix ratios and component quantities for Panel 1 plaster samples A through E

Panel 2 – Sample F

Ref.	Coat No.	Industrial Lime	Sand 2 mm	Sand 1 mm	Quarry Dust 2 mm	Quarry Dust 1 mm	Marble powder 0.5 mm	Remarks
F	1 st	1	–	1	1	–	½	Same as Sample E2 in Panel 1; Wooden float
	2 nd	1	–	–	–	–	2	
	3 rd	1	–	–	2	–	½	

Table 6: Mix ratios and component quantities for Panel 2 plaster sample F

Panel 3 – Sample G - I

Ref.	Sam.	Village Lime	Shell Lime	Sand 2 mm	Sand 1 mm	Quarry Dust 2 mm	Quarry Dust 1 mm	Marble powder 0.5 mm	Remarks
G	G ₁	–	1	–	–	–	–	–	Texture: earth and shell pieces showing; Surprising that there is not already cracking
	G ₂	–	1	–	–	–	–	1	Addition of marble powder hides flaws and provides better cover. This is also due to the mixing process in which shells are crushed.
	G ₃	–	1	–	–	–	–	2	
	G ₄	–	1	–	–	–	–	2	
		–	1	–	–	–	–	1	
		–	1	–	–	–	–	–	
H	H ₁	1	–	–	–	–	–	–	
	H ₂	1	–	–	–	–	–	–	
I	I ₁	–	1	–	–	–	–	–	Check for cracking
	I ₂	–	1	–	–	–	–	½	

Table 7: Mix ratios and component quantities for Panel 3 plaster samples G through I

Note: All quantities above are given in parts.

4.2 PATHOLOGIES OBSERVED

4.2.1 Pock-marks

Lime expansion from un-slaked lime

4.2.2 Cracking

Shrinkage of surface (especially in lime-rich samples due to a higher ratio of lime/ aggregates)

4.2.3 Spalling

Separation of plaster from wall (slightly wetter mix / not pressed enough)

4.2.4 Surface hardness

Can the surface be easily scratched?

4.2.5 Waterproofing performance

How quickly is water absorbed when sample is splashed with water?

5. CONCLUSIONS & RECOMMENDATIONS

5.1 CONCLUSIONS

To be determined after testing and observation.

5.2 RECOMMENDATION FOR FURTHER RESEARCH

5.2.1 Black Soap

Many of these plasters could be more waterproof with the application of black soap. Black soap – or “savon noir” – is a liquid soap which is composed generally of oil, soda and potassium. As soap is a base, when the lime is still fresh, it reacts to the lime and produces a plastifying effect.

Can put black soap in the mix of the last layer, or put some on the final surface. This can be added the same day or 1 day later (as a lime is still considered fresh the following day).

Quantity to use: For a 20 L. tub of lime putty, add ~ 100 mL black soap.

5.2.2 Soap Nut

Ayyappan asked if soap nut could be used for this purpose, in place of black soap. The nut itself is oily; it remains to be explored if soaking the nut and using soak water could be sufficient, or this must be mixed with oil.

5.2.3 Kaddukai water, Jaggary and Lime paste

1st coat SEW 1 = 1: 2: 4: 8

– 1 Cement, 2 Lime Alum Paste (400-40-400), 4 Soil (Sieved # 5 mm), 8 Sand (Sieved # 5 mm)

2nd coat SEW 2 = 1: 2: 3: 6

– 1 Cement, 2 Lime Alum Paste (400: 40: 400), 3 Soil (Sieved # 5 mm), 6 Sand (Sieved # 5 mm)

3rd coat SEW 3 = 3: 1: 2

– 3 Lime Alum Paste (400: 30: 200), 1 Soil (Sieved # 2 mm), 2 Sand (Sieved # 2 mm)

5.2.4 Cactus Juice

Refer to Davis and Maine (2012) “Research On Stabilised Earth Waterproofing with Natural Additives (Cactus, Alum & Tannin): Testing Report”.

5.2.5 Stabilised earth waterproofing (SEW)

Much previous research with SEW's done at the Earth Institute could be
STP: Using soil for pigment in top layer? If using soil, more binder – can crack. Can use earthen pigments.

5.2.6 Earthen Pigments

Must be sourced in the Indian market.

6. ANNEXES

To be determined.