

DAMAGE ASSESSMENT AND DIAGNOSIS FORM

SUMMARY OF DAMAGE DIAGNOSIS

Name of the building – Location St. Sebastian Church – Almada
Type of damage – decay pattern <ul style="list-style-type: none">• Detachment of paint coats• Sanding and crumbling of original lime-plasters and lime-renders• Detachment of cement plasters and renders, which correspond to localized repairs• Sanding and crumbling of the masonry bedding lime-mortars• Scaling of the ceramic bricks, which correspond to localized repairs to the original masonry
Materials concerned <ul style="list-style-type: none">• Ancient lime-plasters and lime-renders• Ancient paints at both the exterior and the interior of the church• Cement plaster and render repairs• Ordinary masonry made of argillaceous lime-mortar and soft sandstone
Tests performed <ul style="list-style-type: none">▪ Moisture and hygroscopic moisture content (HMC) profiles at two walls for estimating moisture and salt content distribution▪ Ion chromatography on six superficial samples▪ For estimating the relation between the amounts of moisture transported through the masonry bedding mortar and through the masonry stone:<ul style="list-style-type: none">▪ Water absorption at low pressure (pipe method) on the masonry bedding lime-mortar and on the masonry stone.▪ Graphic estimation of the relation between the superficial areas of the bedding mortar and the masonry stone▪ Calculation of the percentage of moisture absorbed by each of the two masonry materials
Diagnosis <p>Damage seems to be due to salt crystallization. Capillary rise seems to be the main source of moisture. Nitrates are apparently the main type of salt and chlorides were also detected. The high damage state of the lime-mortars seems to be due, in a great extent, to their low mechanical resistance and very high absorption.</p>
Advice <p>The new plasters and renders should prevent crystallization from occurring inside the weak substrate lime-mortars, which easily deteriorate.</p>

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Date of inspection + description

Several inspections were carried out during 2002 for assessment of damage

2003-10-16	Water absorption tests
2003-11-13	Sampling by powder drilling
2004-01-13	Water absorption tests

Investigator / Institute in charge of the investigation

LNEC

Reference Number

GENERAL INFORMATION

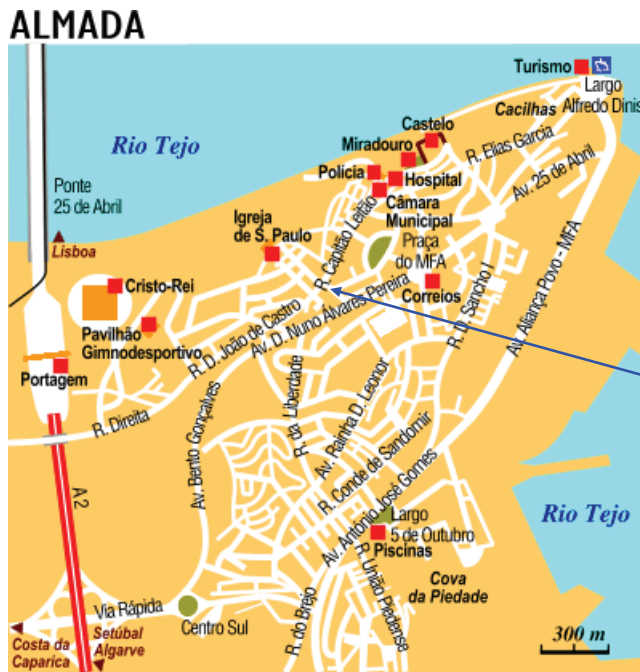
Name of the building St. Sebastian Church
Address Lg. das Andorinhas Almada
Owner of the building / Responsible authority of the building Public: City Hall of Almada (local authority)
Construction phases + data (year) The church was built in the beginning of the XVIII century over a late XVI century chapel 1775 – likely date of the conclusion of repairs after the 1755 Lisbon earthquake 1904 – the church is divided in two floors, the ground one became a tavern and the other was adapted to dwellings 1955 – some of the buildings adjacent to the church are demolished 1999 – demolition of the remaining adjacent buildings and of the church first floor and roof (a temporary roof is built)
Relevant historical calamities In 1755 the building suffered extensive damaged due to the earthquake of Lisbon
Function(s) of the building during time From the beginning of the XVIII century to 1839 – Cult (church) 1839 – the church was closed to cult by the city hall that owned the building 1880/1890 – the church building was used by the city hall as stables 1904 – the church was sold and divided in two floors: the ground floor become a tavern and the first floor was adapted to dwellings 1993 – the city hall bought back the church 1999 – the last tenants moved out; demolition of the adjacent buildings and of the church first floor and ceiling began (a temporary ceiling was built)
Present function (use of installations) Since 1999, the church is closed, on works. Archaeological and architectural researches are also going on.

Pictures of the building

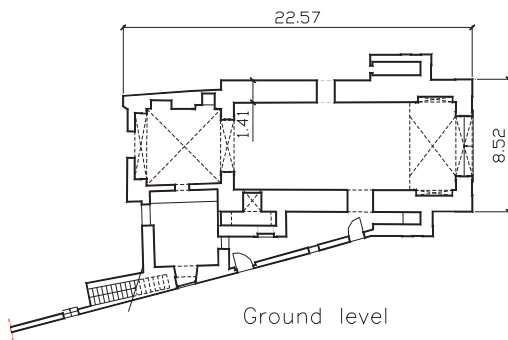


Fig. – S. Sebastião Church main façade (NE) 1999

Building location plan



Building plan



STATE OF PRESERVATION OF THE BUILDING

	Type of damage	condition assessment					
		Excellent	Good	Reasonable	Not adequate	Poor	Very poor
Roof	Demolished						
Facades							x
Structural elements						x	
Interior							x
Floor	Inexistent (archaeological works in progress)						
Ceiling	Demolished						

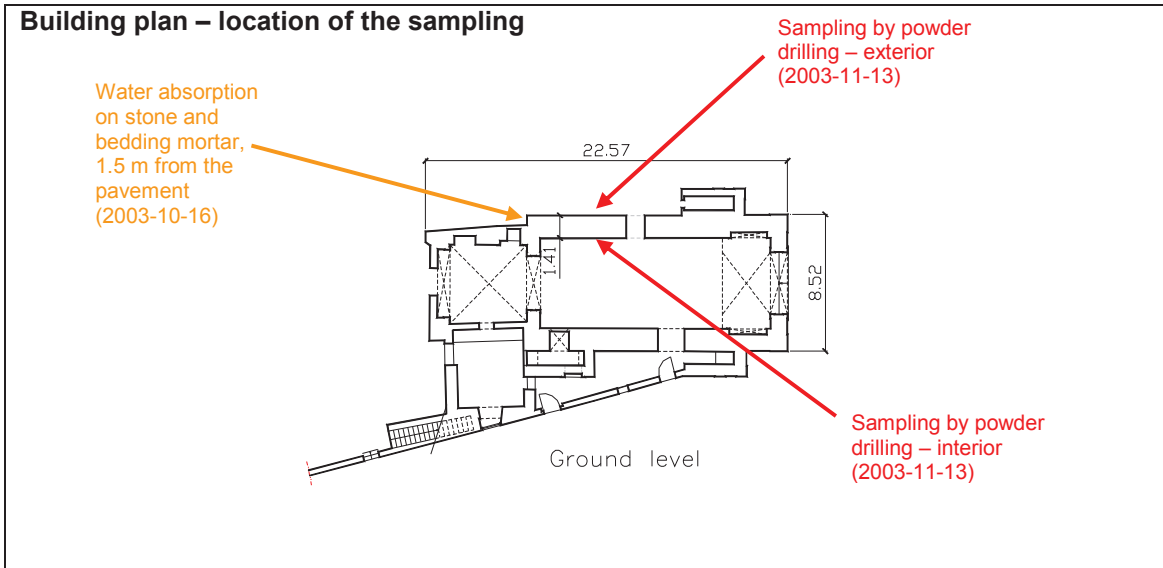
RESTORATION OR MAINTENANCE INTERVENTIONS PERFORMED IN THE PAST

<p>Type of restoration or maintenance: Demolition</p>
<p>Building part: Buildings adjacent to the church and church second floor and roof (a temporary roof was built)</p>
<p>Date: 1999</p>
<p>Company performing the restorations:</p>
<p>Reason for restoration: The church was (and still is) in a very bad general condition and will be rehabilitated to work as a church again.</p>
<p>Further information: Large areas of the church masonry are exposed. The absence of renders/plasters at these areas is due, either to their deterioration or removal (resulting from demolition of adjacent buildings or for execution of experimental panels).</p>

DAMAGE

<p>Type of damage and architectural element affected</p> <p><u>Exposed masonry:</u></p> <ol style="list-style-type: none">1. Sanding and crumbling of the bedding lime-mortars2. Scaling of the ceramic bricks, witch correspond to localized repairs to the original masonry <p><u>Original lime-plasters and lime-renders:</u></p> <ol style="list-style-type: none">3. Detachment of paint coats4. Sanding and crumbling of original lime-plasters and lime-renders5. Detachment of cement plasters and renders, witch correspond to localized repairs
<p>Location of damaged area</p> <p>Internal and external faces of walls</p>
<p>Extent of damaged area [%] and depth (mm)</p> <p>Damage of the masonry lime-mortar and of the plasters and renders is spread all over their surfaces. Damage of ceramic bricks is confined to a few bricks. Depth of the masonry bedding mortar erosion (by sanding and crumbling) varies from superficial to around 10 cm at several points.</p>
<p>Type of damage and material(s) concerned</p> <p>Mansory elements (brick or stone)</p> <p>Scaling of the ceramic bricks</p> <p>Mortar</p> <p>Sanding and crumbling of the masonry bedding lime-mortars</p> <p>(Re)Pointing</p> <p>Rendering or plaster</p> <p>Sanding and crumbling of original lime-plasters and lime-renders Detachment of cement plasters and renders</p> <p>Other coverings</p> <p>Detachment of paint coats</p>

ILLUSTRATIONS



Picture of damaged area



Fig. - Sanding and crumbling of the masonry bedding lime-mortars



Fig. - Sanding and crumbling of the masonry bedding lime-mortars; detachment of a cement render repair



Fig. - Scaling of ceramic bricks at a masonry repair

ENVIRONMENT

Climatologically circumstances

Mediterranean temperate

Exposition (rain, wind, etc.)

The building is located in the centre of the city of Almada, at a very busy location. It is closely surrounded by buildings with approximately the same height.

Surrounding environment (urban/rural/industrial, coastal/interior)

Urban, coastal (close to Tagus river estuary)

Additional data

The church presently shelters an enormous quantity of pigeons.

The original masonry of S. Sebastião Church is the so called “ordinary masonry” (made of irregular stones and a bedding lime-mortar), which is, from far, the most common one in Portuguese ancient buildings. In S. Sebastião Church, the bedding mortar is a very weak and absorbing argillaceous lime-mortar. The masonry stone is a sandstone and a shelly limestone from the nearby cliffs of the Tagus river mouth. They are very porous and absorbing stones, which includes many vestiges of marine life forms (shells and fossils).

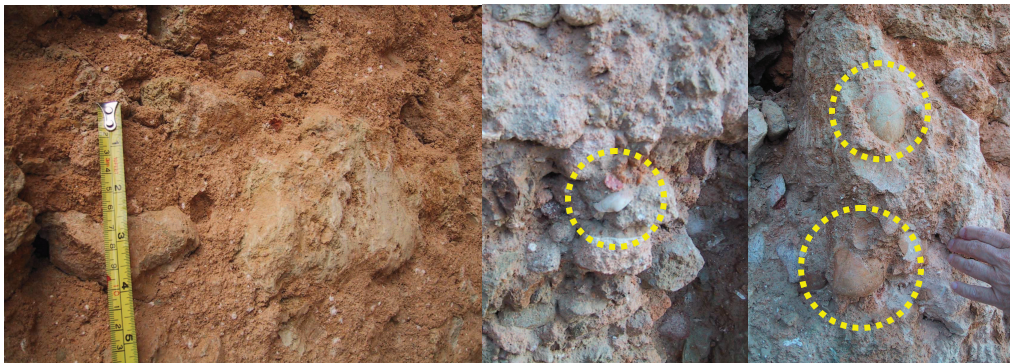


Fig. – Ordinary masonry of S. Sebastião church; shell and fossils incorporated in the stone elements

The historic research done by the municipality of Almada indicates that water and sand got directly from the Tagus estuary (very contaminated with sea water) are likely have been used in ancient Alamada constructions, namely in S. Sebastião church. This water was used for all the human activities, except for drinking.

Salt damage is a common problem at the whole ancient Almada. The following pictures show some common damage patterns: peeling of paints; detachment of new renders from the ancient supports (lime renders or ordinary lime/stone/brick masonries); powdering and crumbling of the lime-mortars (lime-renders and bedding lime-mortars of ancient ordinary masonries), which are left exposed.



Fig. – Damaged building surfaces at ancient Almada
(sanding and crumbling of lime-mortars; detachment of cement renders)



Fig. – Damaged building surfaces at ancient Almada (peeling of paints)

DIAGNOSIS

Hypothesis(es)

Salts crystallization is occurring in the ancient masonry of S. Sebastião church, although efflorescences are not visible. The materials degradation is being accelerated by this action.

Tests performed

- Moisture and hygroscopic moisture content (HMC) profiles were measured (by the weight method) at two walls (samples collected by powder drilling) for estimating moisture and salt content distribution
- Ion chromatography was performed on three superficial samples of each one of the two profiles
- For estimating the relation between the amounts of moisture transported through the masonry bedding mortar and through the masonry stone, the following tests and calculations were done:
 - Water absorption at low pressure (pipe method) was done on the masonry materials: bedding lime-mortar and masonry stone.
 - A graphic estimation of the relation between the superficial areas of the bedding mortar and the masonry stone was done
 - Calculation of the percentage of moisture absorbed by each of the two masonry materials

Tests results

Table – Main type of materials found at the exterior wall (visual observation of the powder)

Heigh (m)	Depth (cm)						
	0-5	5-10	10-15	15-20	20-25	25-30	30-35
3.5	LM	LM	LM + S	LM + S	S	S + LM	S + LM
2.5	LM	LM + S	LM + S	LM	LM	LM	S
1.5	LM	LM	LM + S	S	S	S	S
0.5	LM	LM + S	S	S	S	S	S
0.2	LM	LM	LM	LM	LM + S	LM+ S	LM + S

LM – lime-mortar; S – stone

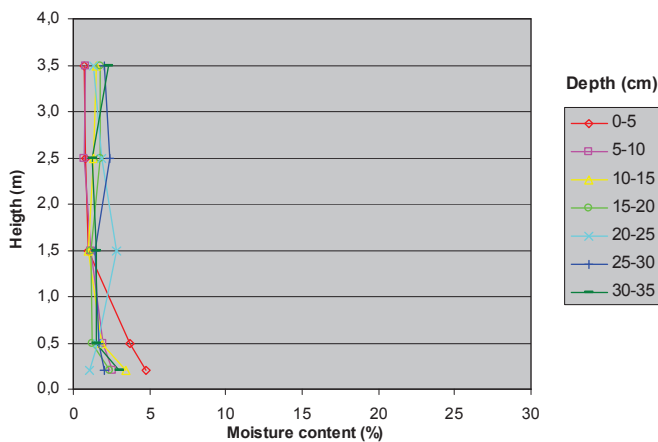


Fig. – Moisture content profile of the exterior wall

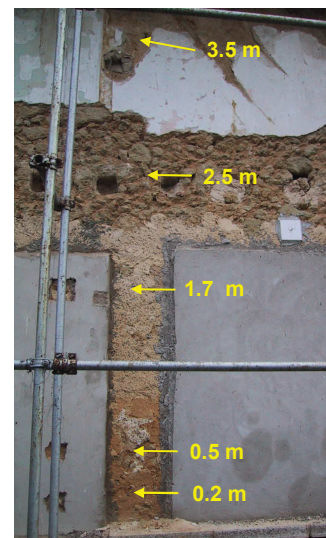


Fig. – Sampling points at the exterior wall

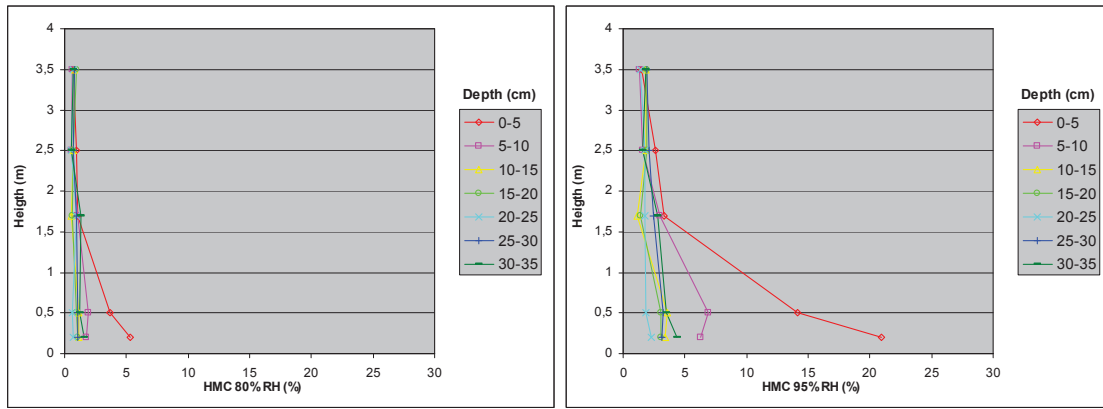


Fig. – Exterior wall: HMC at 80% (left) and at 95% RH (right)

Table – Main type of materials found at the interior wall (visual observation of the powder)

Height (m)	Depth (cm)							
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
3.0	LM	LM	LM	LM + S	LM + S	LM + S	LM + S	LM + S
2.0	LM	LM	LM + S	S	S	S	S	S
1.0	LM	LM	LM	LM	LM	LM	LM	LM
0.5	LM	LM	LM	LM	LM	LM	LM	LM
0.0	LM	LM	LM	LM	LM	LM	LM	LM

LM – lime-mortar; S – stone; B - brick

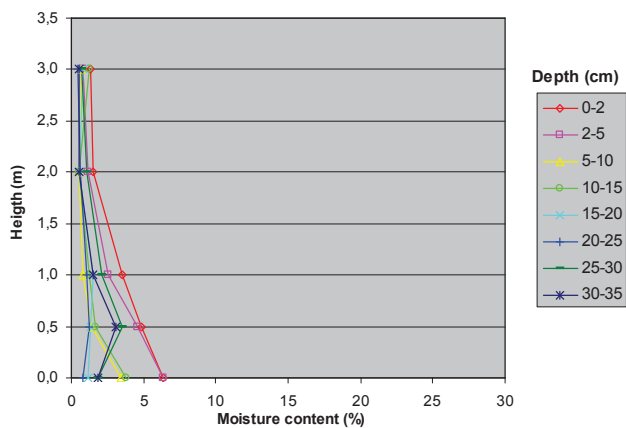


Fig. – Moisture content profile of the interior wall

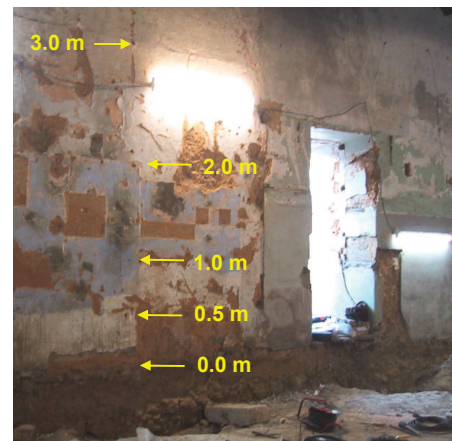


Fig. – Sampling points at the interior wall

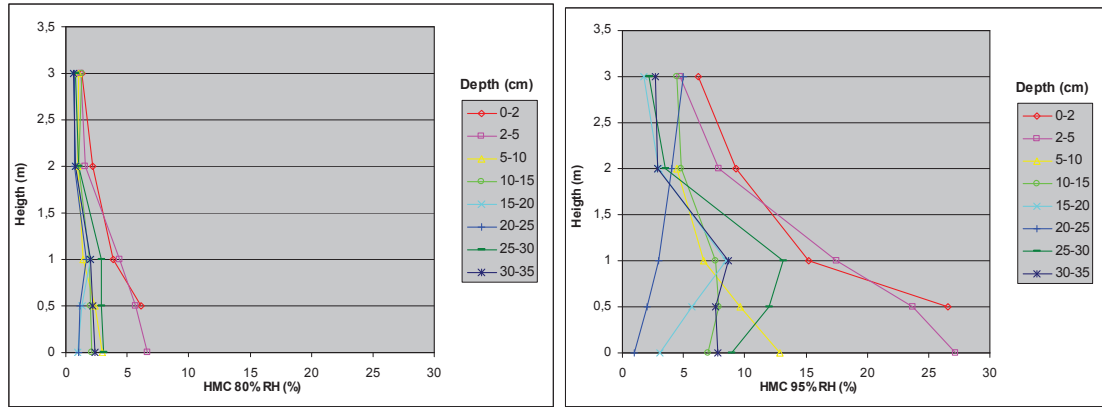


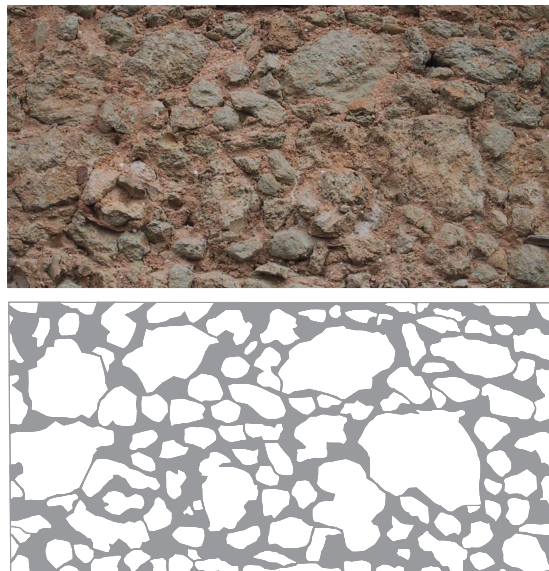
Fig. – Interior wall: HMC at 80% (left) and at 95% RH (right)

Note: After 4 weeks inside the chamber at 20°C and 95% RH complete stabilization of the samples mass doesn't seem to have been totally reached yet. When stabilization is reached, the HMC 95% chart will be corrected; for the present form, this preliminary chart, which is "on the security side" was used.

Table – Ion chromatography on some of the superficial samples (0-2 cm) collected by powder drilling

Wall	Height (m)	Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻	CO ₃ ⁻ (1)
Exterior	1.5	0,06	0,01	nd	0,44	0,12	0,12	0,06	*
	0.5	0,27	0,13	nd	0,82	0,48	0,71	0,49	*
	0.2	0,34	0,19	nd	0,81	0,54	1,01	0,26	*
Interior	1.0	0,16	0,05	nd	0,82	0,56	0,72	0,07	*
	0.5	0,29	0,12	nd	0,89	0,71	1,03	0,17	Nd
	0.0	0,32	0,05	nd	0,99	0,83	1,22	0,28	Nd

(1) The carbonates were qualitatively detected by titration * - Present Nd - non-detected
 The colours indicate the classification of the chloride, nitrate and sulphate contents, according to the WTA specification E-2-6-99/D: low content, medium content, high content



Stone: Area = 66% => As = 1.94 Am
 Mortar: Area = 34%

Fig. – Graphic estimation of the relation between the superficial areas of the bedding mortar and the masonry stone

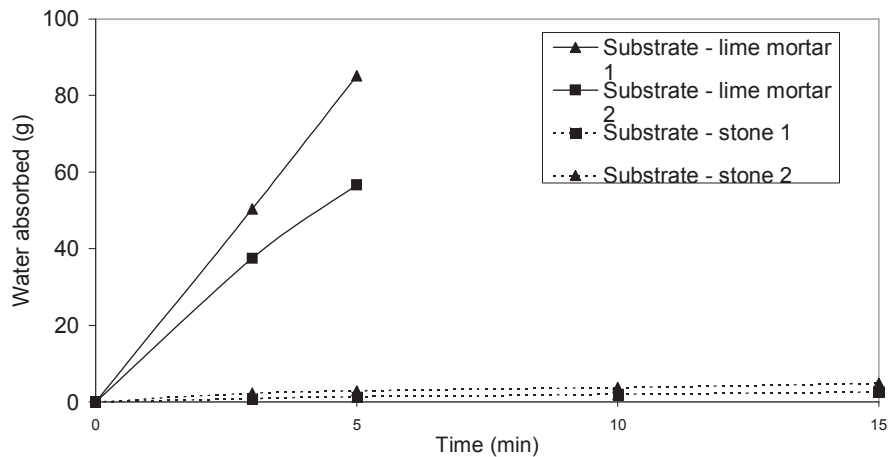


Fig. - Results of the water absorption tests

Table 1 – Analytical results of the absorption tests

Absorption time (min)	Absorbed water (g)						a_s / a_m
	Bedding mortar			Masonry stone			
	1	2	Average a_m	1	2	Average a_s	
0	0	0	0	0	0	0	-
3	50.4	37.5	43.95	0.9	2.3	1.6	0.036
5	85.2	56.7	70.95	1.3	2.9	2.1	0.030
10	-	-	-	2	3.75	2.88	-
15	-	-	-	2.6	4.9	3.75	-
Average =							0.03

Relation between the amounts of moisture transported through the masonry bedding mortar and through the masonry stone

$$a = Q/(t.A) \quad (1)$$

a – water absorption of a material [$L^3/(T \cdot L^2) = L / T$]

Q – quantity of water absorbed by the material in a period of time t through an area A [L^3]

A – area of the material [L^2]

t – period of time during which the absorption occurs [T]

m – mortar

s – stone

Assuming the values indicated by the tests:

$$a_s = 0,03 \cdot a_m \quad (2)$$

$$A_s = 1,94 \cdot A_m \quad (3)$$

If we consider a portion of a masonry wall absorbing a unitary quantity of water $Q_t=1$, during a period of time t :

$$Q_t = Q_s + Q_m \Leftrightarrow Q_s + Q_m = 1 \Leftrightarrow Q_s = 1 - Q_m \quad (4)$$

From (2) and (1):

$$Q_s/(t.A_s) = 0.03 Q_m/(t.A_m) \quad (5)$$

Replacing (3) and (4) in (5), results the equation:

$$(1-Q_m)/(t \cdot 1.94 A_m) = 0.03 Q_m/(t A_m) \Leftrightarrow Q_m \approx 0,95 \quad (6)$$

Replacing (6) in (4):

$$Q_s \approx 0,05$$

The mortar absorbs around 95% of the total amount of the water absorbed by this masonry, in its current surface. The stone absorbs only around 5%.

Diagnosis

Damage seems to be due to salt crystallization.

Capillary rise seems to be the main source of moisture. At the exterior (this wall is without render until about 2.7 m from the ground), some direct absorption of water from the rain may also exist. Moisture contents are not, however, very high (a maximum of around 6.5% was measured at the interior, on the base of the wall).

Nitrates are apparently the main type of salt and chlorides were also detected, as shown by a combined analysis of HMC and ion chromatography results. Some sulphates also appeared but in a generally low quantity. Nitrates are likely to have origin in the decomposition of organic material (dead pigeons and excrements), which are deposited in the ground and absorbed, or even directly deposited on the walls. Sulphates may also have any of these origins. Chlorides are likely to come from the walls construction materials (sandstone, sand and mortars mixing water). Carbonates are still being evaluated.

The materials salt content shows a general decrease with the distance from the ground, as indicated by HMC and ion chromatography. At the exterior, it seems to be irrelevant above 1.5 m. At the interior, the salts content is still relevant at the maximum height sampled (3.0 m). HMC points to an expected tendency for a superficial deposition of salts. Salts content at the interior seems significantly higher than at the exterior of the chapel.

The high damage state of the lime-mortars seems to be due, in a great extent, to their low mechanical resistance (which results in a very low salt resistance) and very high absorption (which make them the main way for the solutions to circulate and the place where the salts preferentially crystallize).

ADVICE

The new plasters and renders should prevent crystallization from occurring inside the weak substrate lime-mortars, which easily deteriorate. These new plasters and renders should mainly:

- Provide a good hydric continuity with the underlying lime-mortars;
- Possess a very absorbing base layer, which should be able to quickly absorb the solutions supplied by these lime-mortars.