

DAMAGE ASSESSMENT AND DIAGNOSIS FORM

SUMMARY OF DAMAGE DIAGNOSIS

Name of the building – Location

Cloister of St. Clara-a-Nova Monastery – Coimbra, Portugal.

Type of damage – decay pattern

1. Cracking of the render/paint system
2. Detachment of the paint layer
3. Detachment of the render superficial layer
4. Sanding and crumbling of the render
5. Crumbling of the paint due to sanding of the underlying render
6. Powdering / erosion
7. Efflorescences
8. Moisture spots
9. Biological development

Materials concerned

1. System cement-based render / white emulsion paint
2. System cement-based render / white emulsion paint
3. Cement-based render
4. Cement-based render
5. System cement-based render / white emulsion paint
6. Stone elements of walls and vaults
7. Stone elements of walls and vaults; (re)pointing mortar of walls and vaults; stone pavement
8. System cement-based render/white emulsion paint; stone of walls and vaults; (re)pointing mortar of walls and vaults; stone pavement
9. White emulsion paint; stone elements of walls and vaults; (re)pointing mortar of walls and vaults; stone pavement

Tests performed

- Moisture and hygroscopic moisture content profile at a wall (samples collected by powder drilling) for estimating moisture and total salt content distribution.
- Determination of the hygroscopic moisture content of samples resulting from the extraction of some render layers.
- Ion chromatography on three superficial samples the profile
- XRD characterization of efflorescences on stone

Diagnosis

Rising damp and direct contact with surface water (for example: from flooding due to heavy rain due to the lacking of adequate drainage, or from excess use of water for cleaning) are probably the main origin of moisture at the NE wall, which shows salt damage located close to the pavement.

A direct correlation between the fact that two of the cloister walls are semi-embedded and salt damage intensity was not found.

The moisture contents are of medium level. The maximum measured values were around 10% at the base the wall. The cations detected also at the base of this NE wall were mainly nitrates (with a high concentration), but also chlorides. The alkali anions were mainly sodium, but also potassium. Carbonates relevance is still under evaluation.

The salt load concentration (as indicated by the hygroscopic moisture content) seems very high in the superficial coat 0-2 cm (mainly render) at the bottom of the wall. On the other points, namely deep inside the walls, the salt load seems to be low

The penetration of paint particles seems to give different hydric characteristics to the render superficial layer (around 2 mm thick). The salts preferentially crystallize beneath this superficial layer, making it to detach. The damage then progresses in depth, with sanding of the underlying render.

Advice

Measures should be taken for trying to lower the amount of moisture reaching the base of the walls, namely to improve the drainage of the cloister garden and to prevent the excessive use of water in cleaning operations.

Replace the damaged cement-based render. Renders of low capillary absorption or low water vapour permeability, which may amplify the effects of the capillary rise, should be avoided. A transporting render seems adequate. Not very strong lime-pozzolana, lime-cement or lime-cement-pozzolana traditional mortars may be used. The constitution materials should have low alkali, sulphate and chloride contents, as well as be sulphate resistant (cement with low aluminates content and aggregates without reactive alumina). These new renders should have a good resistance to cracking.

A paint with high adherence to the support, high vapour permeability and high capillary absorption should be used.

DAMAGE ASSESSMENT AND DIAGNOSIS FORM

Date of inspection + description

2003-09-28	Preliminary inspection
2003-09-28	Inspection (with TU Delft)
2003-11-27	Sampling (by powder drilling)
2004-01-08	Sampling (WP4) and inspection
2004-02-05	Inspection
2004-03-23	Technical visit (Lisbon COMPASS meeting)
2004-04-21	Sampling (by powder drilling and for extraction of some render layers)

Investigator / Institute in charge of the investigation

LNEC

Reference Number

GENERAL INFORMATION

Name of the building

Cloister of St. Clara-a-Nova Monastery

St. Clara-a-Nova Monastery is composed of three main buildings (monastery, church and cloister), which were independently designed and built. The present work concerns mainly the ground floor of the cloister. It includes the cloister garden and the surrounding gallery. However, some walls are common to the other buildings.

Address

Largo de St. Clara
Coimbra
Portugal

Owner of the building / Responsible authority of the building

Public building – Owner: Ministry of Defence; Responsible heritage authority: DGEMN (General Direction of National Buildings and Monuments); Administration: Catholic Church, Brotherhood of Santa Isabel (church and cloister) and Ministry of Defence (monastery)

Constrution phases + data (year)

1649 –	Construction of the monastery started
1677 –	Monastery mainly concluded; construction of the church started
1688 –	Church structure mainly concluded
1696 –	26 June: Inauguration of the church
1704 –	Arch. Manuel do Couto designs the cloister building and the work starts
1709 –	Ground floor of the cloister concluded
1717 –	Two wings of the cloister are concluded (with the second floor); work continues in a third wing
1734 –	One of the already concluded cloister wings collapses (probably the South one).
1738 –	In the cloister building, aesthetical changes and structural reinforcements were introduced by Arch. Custódio Vieira, namely: larger arches and columns are built in the gallery corners columns; a frieze and an architrave were added, surrounding the gallery, to the façade facing the garden and work as a structural belt; pairs of smaller round columns, supporting the architrave, were added to the original columns. The cloister south wing is completely rebuilt.

1744 – Arch. Carlos Mardel succeeds Arch. Custódio Vieira and introduces more aesthetical and reinforcement alterations in the cloister. These alteration were mainly in the second floor, following what was already made in the first floor: introducing, for example, the cloister second floor smaller round columns.

1760 – Cloister building concluded

Around 1910 – The monastery and three wings of the cloister second floor suffer significant alterations (a detailed description was not obtained) for being converted into a military barrack.

Relevant historical calamities

Function(s) of the building during time

1677 to 1891 – The monastery building, the cloister building and part of the church (low choir) are part of the Clarissas nuns monastery. The other part of the church (high choir) is opened to the public.

1891 to 1896 – The monastery and the cloister are converted into a homeless shelter.

1896 to 1910 – A missionary college is established in the monastery and cloister.

1910 to 1985 – The monastery and three wings of the cloister second floor (north, south and east) are converted into a military barrack. The church, the cloister ground floor and one wing of the cloister upper floor (probably the West wing, which is next to the church) belong to the Catholic Church and are generally open to the public.

1985 to 2000 – In the monastery building, a military museum is established.

Present function (use of installations)

2000 to present Cloister building - The ground floor is opened to the public. It is visited by tourists due to its architectural and historic interest, as well as due to presence in the church of Rainha Santa Isabel (a catholic saint) tomb. The second floor north, south and east wings are not presently being used. The west wing second floor (next to the church) is used by the scouts (for meetings and for storing material).

Pictures of the building



Fig. 1 – St. Clara Monastery, aerial view (DGEMN)

Pictures of the building (continuation)



Fig. 2 –St. Clara cloister
Northern and Western wings
(2004-01-08)



Fig. 3 –St. Clara cloister, eastern wing (2003-11-27)

Building location plan

Coimbra town
(200 km north of Lisbon)



Santa Clara-a-Nova

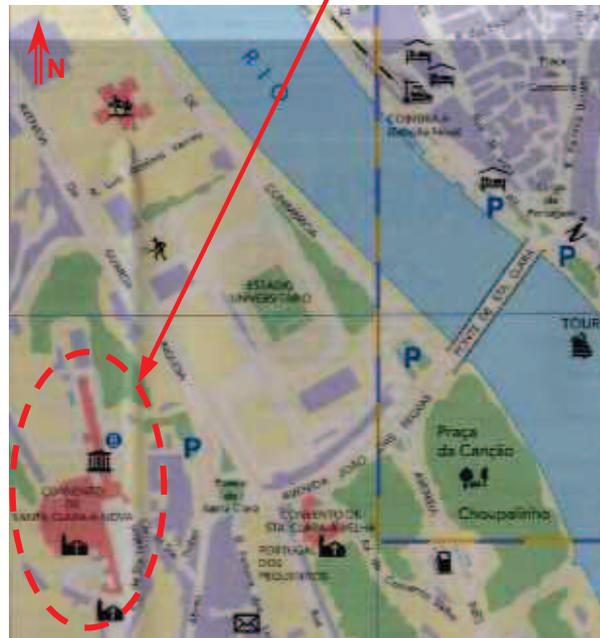
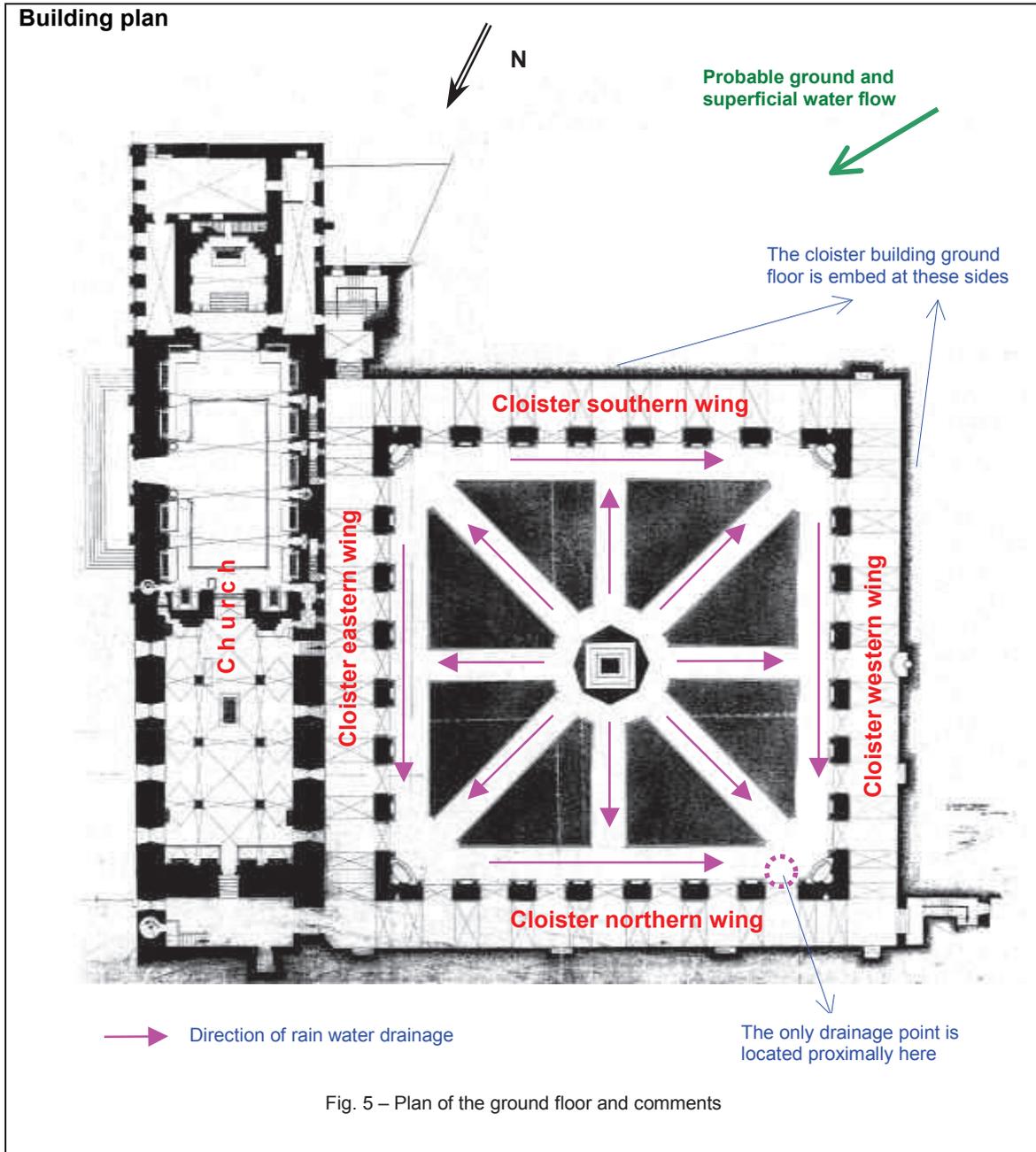


Fig. 4 – Location of Sta. Clara-a-Nova Monastery



STATE OF PRESERVATION OF THE BUILDING

	Type of damage	condition assessment					
		Excellent	Good	Reasonable	Not adequate	Poor	Very poor
Roof							X
Facades						X	
Structural elements				X			
Interior						X	
Floor				X			
Ceiling							X

**RESTORATION OR MAINTENANCE INTERVENTIONS PERFORMED IN THE PAST
 (as far as considered relevant)**

Type of restoration or maintenance of the cloister building: (a) rendering and painting (b) repair (some pavement slabs were replaced)
Building part: (a) cloister ground floor walls (b) cloister ground floor pavement
Date: (a) 1985 (b) 1998
Company performing the restorations: (a) Fonseca & Irmão Lda. (presently extincted) (b) There is no information
Reason for restoration:
Further information: There is no information on the renders composition. Observation suggests that it is a cement-based render, applied in two coats and finished with a common white “plastic” paint.

DAMAGE

Type of damage and architectural element affected

The following observations were carried during the winter of 2003/2004.

Renders of walls and vaults

- 1) Cracking of the render/paint system
- 2) Salt damage of render/paint system
 - 2.1) Detachment of paint
 - 2.2) Detachment of the render superficial coat
 - 2.3) Sanding and crumbling of render/paint system
- 3) Biological development
 - 3.1) Moss
 - 3.2) Other plants
- 4) Moisture spots

Stone pavement

- 5) Erosion
- 6) Moisture spots
- 7) Efflorescences

Location of damaged area

The present observations were made at the cloister building ground floor.

Renders of walls and vaults

The render/paint system shows very (salt) damaged areas located close to the pavement. The salt damaged areas are associated to the presence of moisture spots. At these areas, detachment of the render superficial coat, as well as sanding of the render and further crumbling of the render/paint system are visible. Detachment of paint is visible at a few places, where the degradation is not yet very severe.

Cracking of render/paint system is especially visible at these moist salt damaged areas (damage of render/paint system seems to start at the cracks), although it can also be seen at other zones that do not present salt damage.

Biological development is present under the form of moss, particularly at the base of the walls.

Stone pavement

Moisture spots are generalized. Moss is present in many places, mainly on the joints. Many stone plates are eroded. Dispersed efflorescences were observed during one of the inspections.

Extent of damaged area [%] and depth (mm)

Renders of walls and vaults

- 1) Cracking of the render/paint system affects 20% of the rendered area
- 2) The salt damaged total area of the render/paint system correspond to around 15% of the rendered surface. The area on which the render first coat already disappeared but the rest of the render is not yet damaged is 6% of the rendered area. The area on which the render first coat disappeared and the second coat is already being affected (dept: few mm) is 6% of the rendered area. The area on which only the paint disappeared is 3% of the rendered area.
 - 2.1) Detached paint is visible at a few points;
 - 2.2) Detachment of the render superficial coat is visible at a few points;
 - 2.3) Sanding of render is visible mainly at the zones where the damage already started to affect the render second coat.
- 3) Biological development: Moss is present at the base of the walls, on 60% of their length
- 4) The area affected by moisture spots varied along the several inspections.

Stone pavement

- 5) Erosion affects 15% of the stone surface
- 6) Moisture spots varied along the inspections (maximum: 90% of the stone surface)
- 7) Efflorescences could be seen at a few points

Type of damage and material(s) concerned

Wall as a whole

Rendering or plaster

Detachment of the render superficial coat, sanding, crumbling, biological development, moisture spots

Other coverings

Peeling of the paint;
Crumbling due to the sanding of the underlying render, moisture spots and efflorescences on the stone pavement

ILLUSTRATIONS

Building plan – location of the sampling

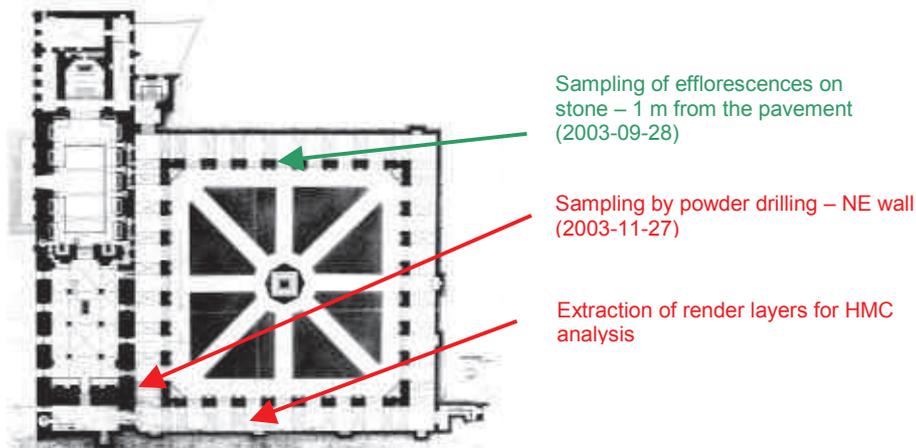


Fig. 6 – Location of the sampling

Picture of damaged area



Fig.7 - Cloister gallery: damage of the render/paint system at the base of a wall (2003-11-27)



Fig. 8 – Cracking and erosion of the render/paint system (2004-01-08)



Fig. 9 – Moss and moisture spots on the base of a wall and on the pavement (2004-02-05)



Fig. 10 – Efflorescences on stone (2004-01-08)



Fig. 11 – Erosion of stone pavement (2004-02-05)



Fig. 12 – Efflorescences on stone pavement (2004-02-05)

Building plan – Chart of damage intensity

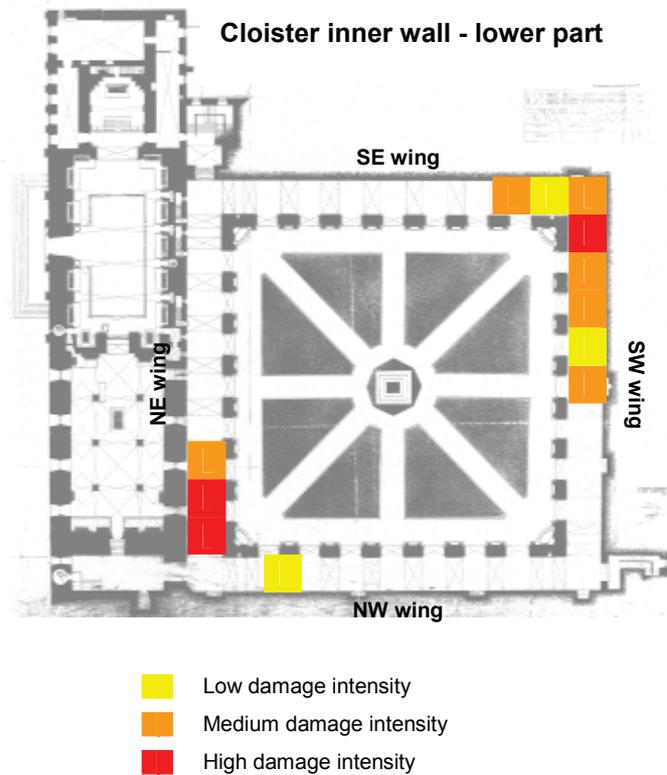


Fig. 13 – Chart of damage intensity on the lower part of the cloister inner wall

ENVIRONMENT

Climatologically circumstances

Exposition (rain, wind, etc.)

The cloister gallery surrounds the garden. This gallery is opened to the side of the garden. The cloister gallery inner walls are protected from direct rain and midday sunlight.

The cloister ground floor is embedded at SE and SW. The building is located on a downhill and these two walls are expected to be a barrier to the superficial and sub-superficial water which drains in the direction of Mondego river.

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

Urban/Interior.

Additional data

The stone (Coimbra dolomia) is a very porous and absorbing stone.

On 2004-01-08, a rainy day, accumulation of water at the cloister garden pavement was seen (fig. 14). This water drains slowly (due to the low slopes of the garden pavement) towards a perimetral gutter and then (also slowly) in the direction of a single drainage point (as shown in fig. 5).

On 2004-02-05, a sunny day that followed several cold rainy days, spots of liquid water were observed on the pavement of the cloister ground floor (fig. 15). This place is protected from the rain, so that leads to the hypothesis of those water spots being due to condensation or rising damp.

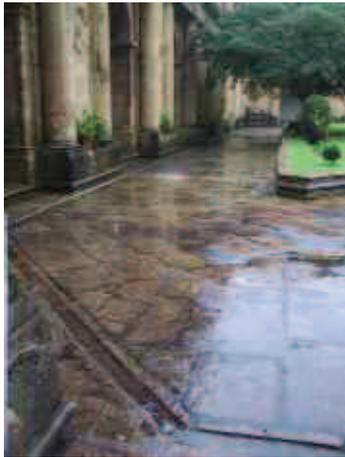


Fig. 14 – Accumulation of water at the cloister garden
(2004-01-08)



Fig. 15 – Liquid water on the vaults and pavement stones
(2004-01-08)

DIAGNOSIS

Hypothesis(es)

The damage on the renders at the cloister walls that appears close to the ground floor is due to salts crystallization.

Moisture is mainly due to capillary rise and contact with surface water. In the embedded walls (see fig. 5) some infiltration of the water from the surrounding terrain may also occur. Condensations are also a possibility.

Tests performed

- Moisture and hygroscopic moisture content (at 80% RH and at 95% RH) profiles of the plaster and of its substrate were measured (by the weight method – samples collected by powder drilling) for estimating moisture and total salt content distribution. The selected wall presents damage located close to the pavement.
- Ion chromatography was performed on three superficial samples of the profile
- For evaluation of the preferential location (in depth) of the salt deposition in the render:
 - Observation of crossed sections of the render with a binocular glass
 - HMC on the different layers of the render (detached superficial layer of the first application coat, powder beneath this superficial layer, second layer of the first application coat, second application coat)

Tests results

Table 1 – Powder drilling: type of materials apparently found at the NE wall (by visual observation of the plaster)

Height (m)	Depth (cm)							
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
4.0	CM	LM	RM	RM	RM	RM	RM	RM
2.5	CM	LM + S	S	S	S	S	S	S
1.5	CM	LM + S	S	S	S	S	S	S
0.7	CM + S	S	S	S + LM	S + LM	S + LM	S	S + B
0.2	CM	LM + S	S + RM	RM	RM	RM	RM	-

CM – cement mortar; LM – lime mortar; RM – rough argillaceous mortar; S – stone; B - brick

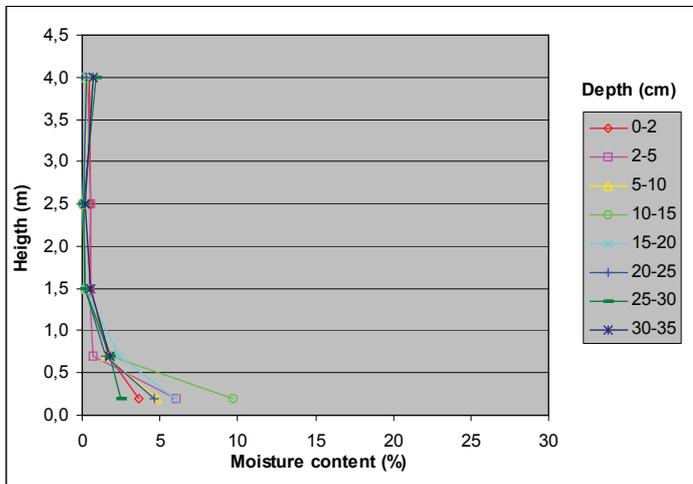


Fig. 16 – Moisture content profile of the NE wall

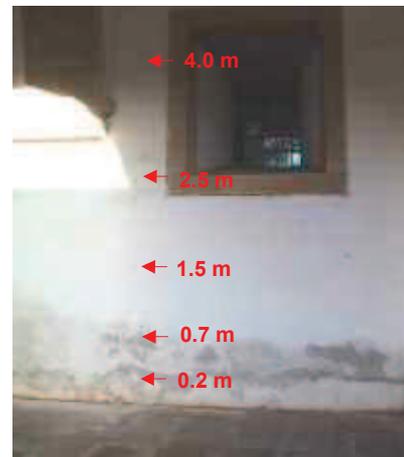


Fig. 17 – Sampling points at the NE wall

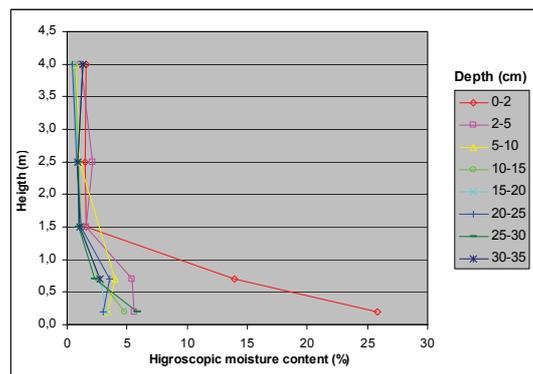
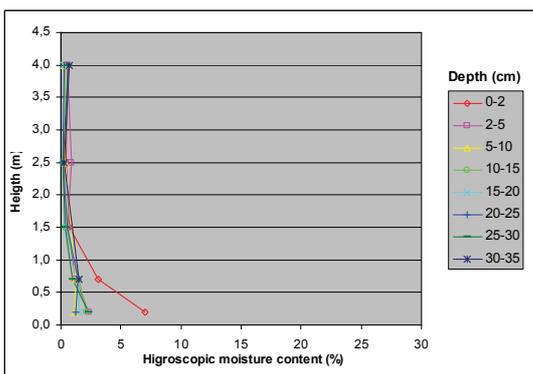


Fig. 18 – NE wall: HMC at 80% (left) and at 95% RH (right)

Observation of crossed sections of the render with a binocular glass: the thickness of the detached superficial layer (2 mm) of the render first application coat corresponds to the paint penetration depth

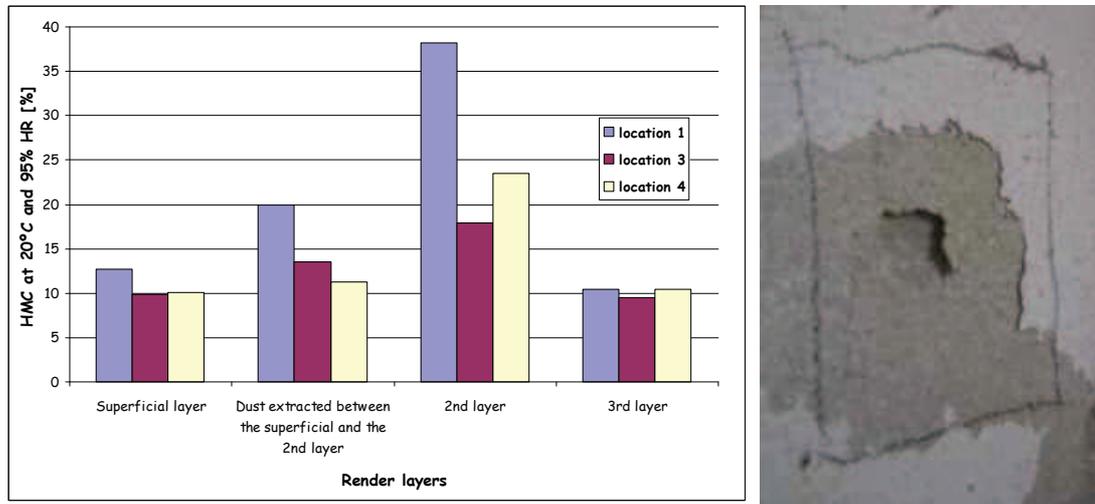


Fig. 19 –HMC at 95% of different layers of the render (left) and picture of one of the sampled areas showing the different layers (right)

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

Wall	Height	Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻	CO ₃ ⁻
NE	2.5	0,05	0,11	nd	0,44	0,03	0,02	0,07	*
	0.7	0,31	0,26	0,04	0,45	0,32	0,71	0,16	*
	0.2	0,35	0,25	nd	0,94	0,43	1,71	0,17	*

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

Diagnosis

The moisture profile of the NE wall clearly shows the rising damp (from the soil or surface water) as the fundamental origin of the moisture at this wall. Visual signs of superficial condensations were also detected but the relevance of this other source of moisture needs further investigation. A direct correlation between the fact that two of the cloister walls are semi-embedded and salt damage intensity was not found (fig 13).

The maximum measured moisture contents are of 10% at the base of the wall. The rising damp seems to be relevant until a maximum level located between the 0.7 m and the 1.5 m from the pavement. The renders salt damage maximum level is also located around 0.8 m from the pavement.

The HMC profiles in this wall indicate higher salts contents at the base. The ion chromatography analyses also indicate a decreasing content of ions from the base to the top of the wall, with relevant salt contents at 0.2 m and 0.7 m and irrelevant contents at 2.5 m. It is therefore likely that these damaging salts are being carried by the rising damp.

In depth, the maximum HMC was found in the superficial coat 0-2 cm (render).

The cations detected at the base of this wall were mainly nitrates (with a high concentration), but also chlorides. The alkali anions were mainly sodium, but also potassium. These ions are the ones usually proceeding from the soil. The chlorides are not commonly attributed to this origin but the HMC 80% profile seem to indicate that, in this case, they are in fact coming from the ground.

The presence of carbonates was detected by titration but their importance cannot be deduced from the results obtained until now. Further tests for evaluating the carbonate contents are under consideration.

The penetration of paint particles seems to give different hydric characteristics to the render superficial layer (around 2 mm thick). The salts preferentially crystallize beneath this superficial layer, making it to detach. The damage then progresses in depth, with sanding of the underlying render.

ADVICE

Measures may be taken for trying to lower the amount of moisture reaching the base of the walls, namely to improve the drainage of the cloister garden and to prevent the excessive use of water in cleaning operations.

The present moisture contents due to capillary rise do not seem high enough for justifying the introduction of capillary-cuts at the base of the cloister ancient and very thick walls, as long as renders which may amplify its effects (low capillary absorption or low water vapour permeable renders) are avoided. Therefore, a transporting render should be used.

For the new render, not very strong lime-pozzolana, lime-cement or lime-cement-pozzolana traditional mortars may be used. The main composition requirements of the materials are the following:

- Low alkali content (the alkali ions may originate very soluble alkali carbonate salts). The cement and/or pozzolana should therefore be as free as possible of alkalis and sand should be very well washed.
- Due to the presence of moisture and sulphates, sulphate resistant binders and aggregates (cement with low aluminates content and aggregates without reactive alumina) should be used.
- All the materials should have very low sulphate (and also chloride) content, namely cement, which is many times responsible for the introduction of sulphates in the walls of ancient buildings. In what concerns the aggregates, again, only well washed sands should be used.

The new renders should be resistant to cracking, namely to cracking due to the drying shrinkage.

A paint with high adherence to the support, high vapour permeability and high capillary absorption should be used.