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 coat
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 profiles at two walls (samples collected by powder drilling) for estimating moisture and total salt content distribution.
- Ion chromatography several samples of the two profiles
- XRD characterization of efflorescences on stone

Diagnosis

The walls moisture and the HMC profiles point for the existence of two simultaneous sources of moisture and salts: in depth, capillary rise seems to be the only source; at the surface of the walls, an upper-located source seems to exist. Direct observation (fig. 10) indicates that the stone elements are this second source of moisture.

Ion chromatography showed at the base of the SE wall, mainly nitrates, sulphates and alkalis were found and at the top, mainly nitrates, chlorides and alkalis. Carbonates relevance is still under evaluation.

The moisture contents are of medium level. The maximum measured values were around 10% and localized at the base of both the NW and SE walls. Somehow important values of moisture (around 6%) were also found at the upper part of the walls.

The salt load seems very high in the superficial coats 0-5 cm at both the bottom and at the top of the SE wall and mainly at the top of the NW walls. On the other points, namely deep inside the walls, the salt load seems to be low.

Salt damage probably starts at the render cracks or at dry moisture spots.

Advice

Solve the infiltrations of water from the rain, by repairing the roof of the cloister building.

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

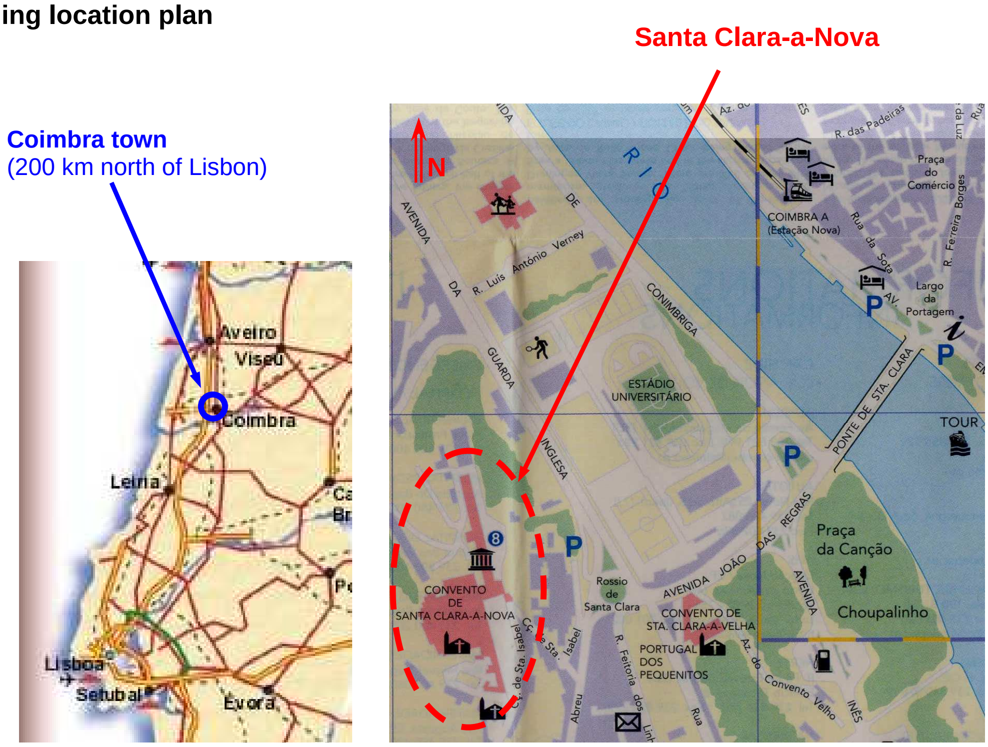


Fig. 4 – Location of Sta. Clara-a-Nova Monastery

Building plan

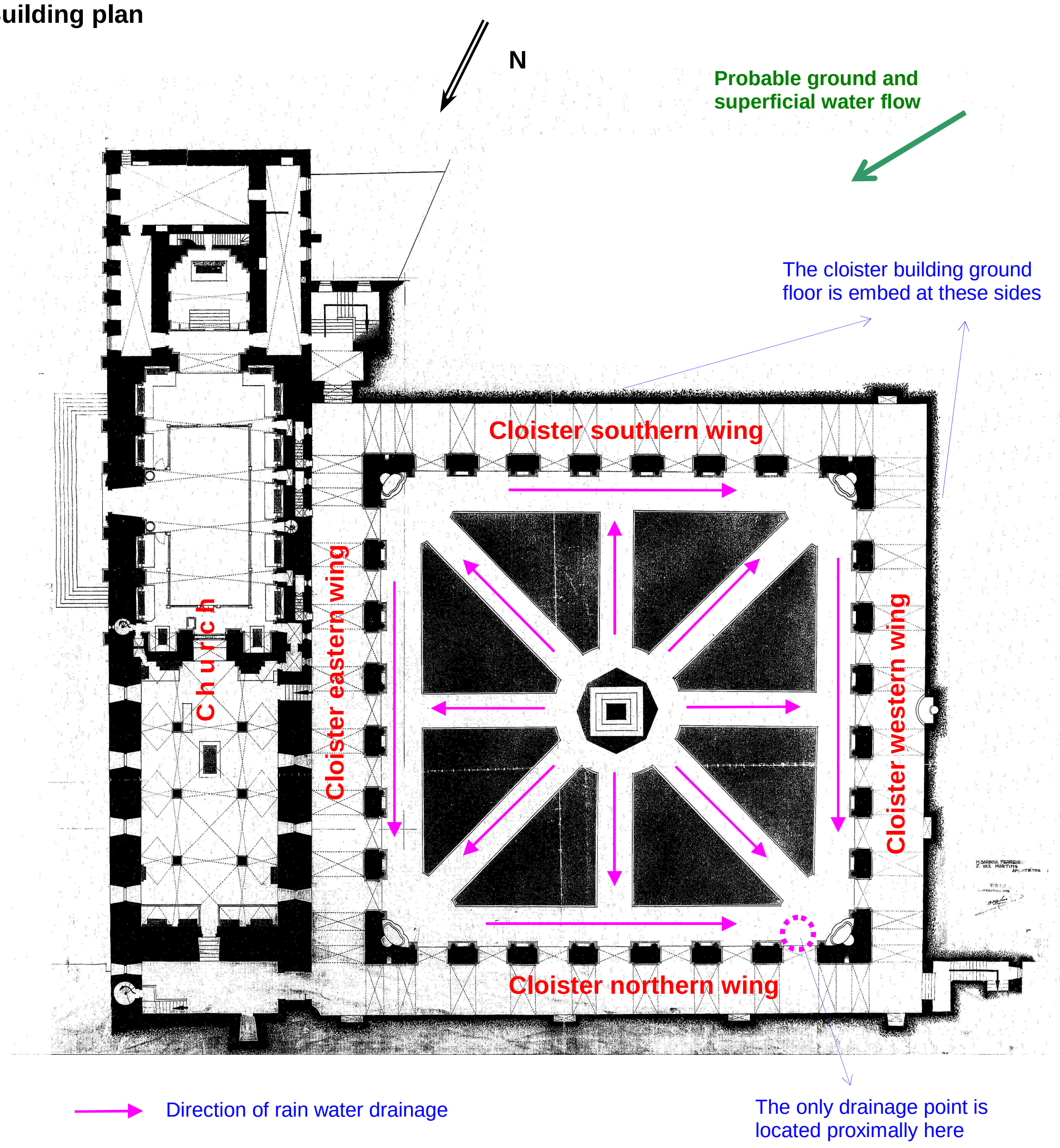


Fig. 5 – Plan of the ground floor and comments

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 of walls and vaults

5) Moisture spots
6) Efflorescences
7) Powdering / erosion
8) Biological development
    - 8.1) Pink spots
    - 8.2) Moss

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 concentrated at higher zones next to stone elements (the damage seems to be spread from the render/stone interface). 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, were 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. Another form of biological development, not yet clearly identified, appears upper on the walls (more or less above 1.5 m) and on the vaults. When removed, this last biological form leaves a little (around 2 mm) hole on the wall, damaging the paint.

Stone of walls and vaults

The stone (Coimbra dolomia) is much damaged. Dark moisture spots appear all over its surface and efflorescences (either on the stone itself or spread from the joints) are usually visible. Moss is visible mainly on the joints. A pink superficial coloration (probably of biological origin) is present on a significant part of the stone surface, mainly on the sheltered elements of the cloister gallery. Powdering and strong erosion is especially visible on the outer elements.

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
    - 3.3) Moss is present at the base of the walls, on 60% of their length
    - 3.4) The other form of biological development affect 40% of the rendered area
4) The area affected by moisture spots varied along the several inspections.

Stone of walls and vaults

5) Moisture spots are usually present on most of the stone surface
6) Efflorescences on the stone itself could be seen at a few points; efflorescences spread from the joints are visible on 10% of the stone elements surface
7) 50% of the stone surface show erosion. Powdering could be seen at a few points
8) Biological development
    - 8.1) Pink spots affect 20 % of the gallery stone surfaces
    - 8.2) Moss is visible on 5% of the joints

Type of damage and material(s) concerned Wall as a whole
Masonry elements (brick or stone) Stone elements of walls and vaults: moisture spots, efflorescences, erosion / powdering, biological development
Mortar
(Re)Pointing Moss at the joints of the stone elements
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

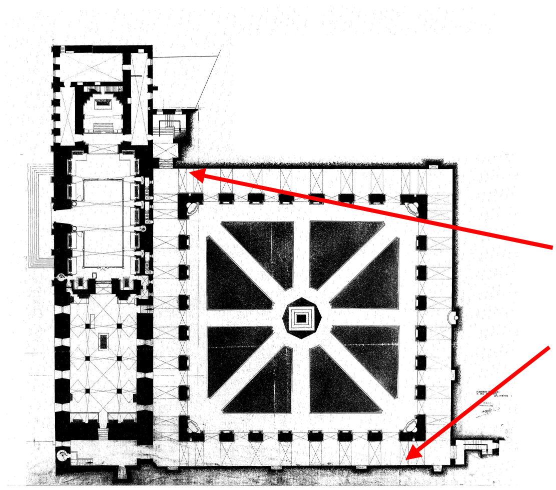


Fig. 6 – Location of the sampling

Picture of damaged area

Fig. 7 - Cloister gallery: plaster damaged on vaults and moisture spots on stone (2004-02-05)

Fig. 8 - Cloister gallery: detail of a damage spot of the render/paint system, next to a stone element (2004-01-08)

Fig. 9 – Detachment of the render superficial coat (2004-01-08)

Fig. 10 – Moisture spots on the interface render / stone element (2004-01-08)

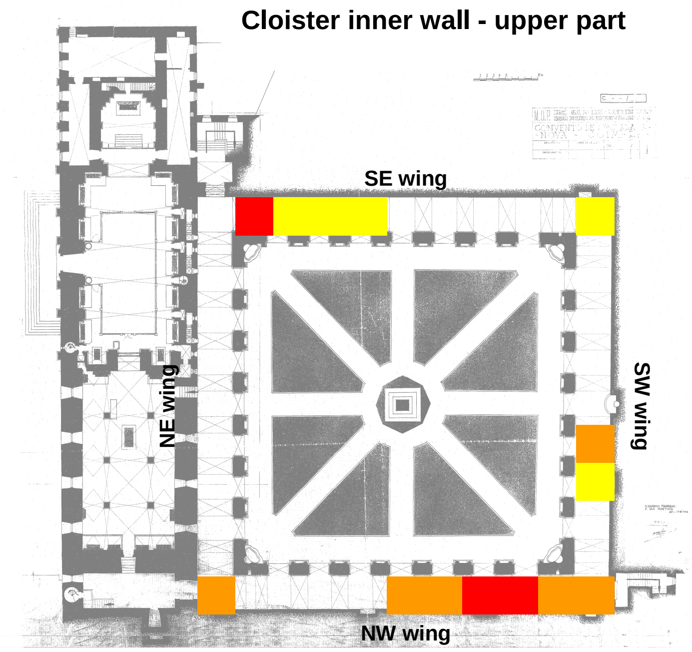
Fig. 11 – Unidentified biological development on the upper part of the walls and on the vaults render (2004-01-08)

Fig. 12 – Detail of the unidentified biological form (2004-01-08)

Fig. 13 – Efflorescences spread from the joints of stone elements (2003-11-27)

Fig. 14 – Efflorescences, moss and moisture spots on stone (2004-02-05)

Building plan – Chart of damage intensity



Low damage intensity
Medium damage intensity
High damage intensity

Fig. 15 – Chart of damage intensity on the upper part of the cloister inner wall

Evolution of damage areas

Fig. 16 – Often damage seems to start at cracks

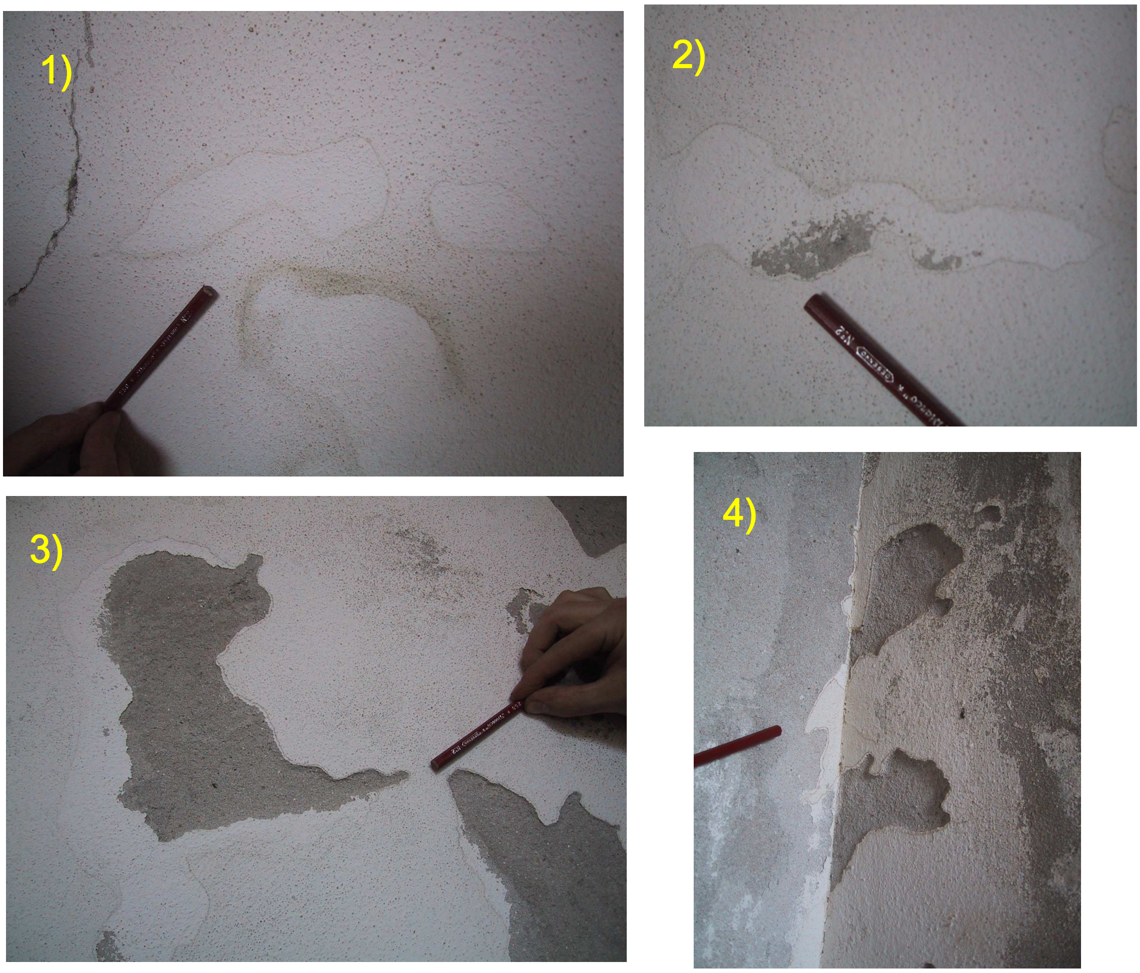


Fig. 17 – Evolution of damage starting from dry moisture spots. The dark lines may represent a microfissure

Fig. 18 – Evolution of damage in the higher areas

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.

Aditional data

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

In the same day, water infiltration through the terrace roof and accumulation of water on large puddles at the cloister building first floor pavement was directly observed. The outer roof coverings are blistered and cracked.

Fig. 19 – Damaged roof covering (2004-01-08)

Fig. 20 – Infiltration of water from the rain through the roof and accumulation on the second floor pavement (2004-01-08)

On 2004-02-05, a sunny day that followed several cold rainy days, spots of liquid water were observed on the stone surfaces of the walls of the cloister ground floor. These places are protected from the rain. This leads to the hypothesis of those water spots being due to condensation.

Fig. 21 – Liquid water on the vaults and pavement stones (2004-01-08)

DIAGNOSIS

Hypothesis(es)

Damage on renders at the cloister-building ground floor is due to salts crystallization.
Moisture may be due to:

- Water infiltration from the roof (first, it enters through the cloister-building roof, and then it accumulates on the second floor pavement and passes to the ground floor)
- Condensations are also a possibility
- Some penetration of water from the back of the semi-embedded walls may also occur.

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) at two walls (samples collected by powder drilling) for estimating moisture and total salt content distribution.
- Ion chromatography was performed on some superficial samples of each one of the two profiles
- XRD characterization of efflorescences on stone

Tests results

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

	Depth (cm)							
Height (m)	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
4.2	CM	-	-	-	-	-	-	-
3.0	CM	CM + S	CM + S	S	S	S	S	S
1.7	CM	CM	S	S	?	S	S	S
0.7	CM	CM	CM + S	S	S	S	S	S
0.2	CM	CM	CM+LM+S	LM	LM + S	S	S	LM + S

CM – cement mortar; LM – lime mortar; S – stone

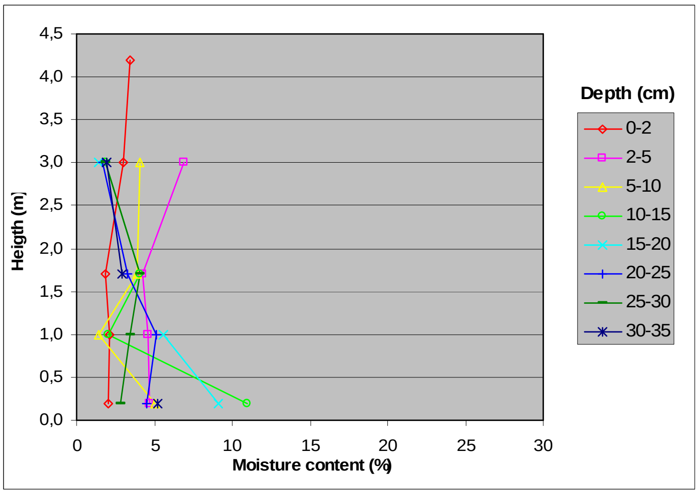


Fig. 22 – Moisture content profile of the SE wall

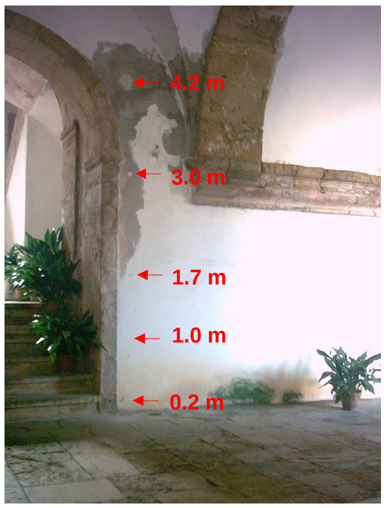


Fig. 23 – Sampling points at the SE wall – vertical profile

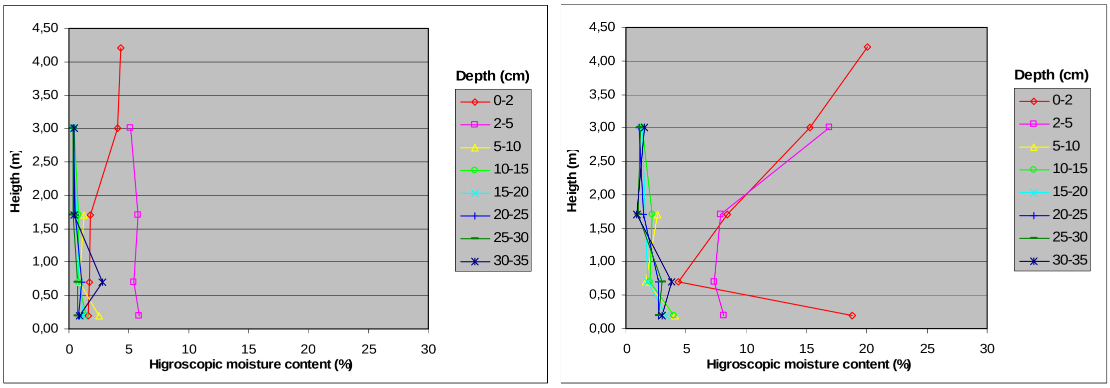


Fig. 24 – SE wall: HMC at 80% (left) and at 95% RH (right)

Table 2 – Powder drilling: type of materials apparently found at the NW wall – vertical profile (by visual observation of the plaster)

	Depth (cm)							
Height (m)	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
4.9	CM	CM + LM	LM	LM	LM	LM	LM	LM
3.9	CM	CM	S	S	S	S	S	S
3.4	CM	CM + LM	LM	LM	LM	LM	LM	LM
2.4	CM	CM	S	LM	–	LM	LM	LM
1.4	CM	CM + S	S	S	S	–	LM	LM
0.5	CM	CM	S + CM	S	S	S	S	S

CM – cement mortar; LM – lime mortar; S – stone

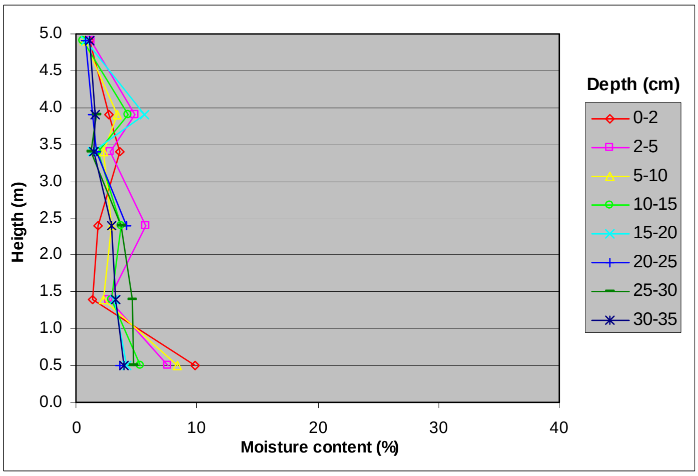


Fig. 25 – Moisture content – vertical profile of the NW wall

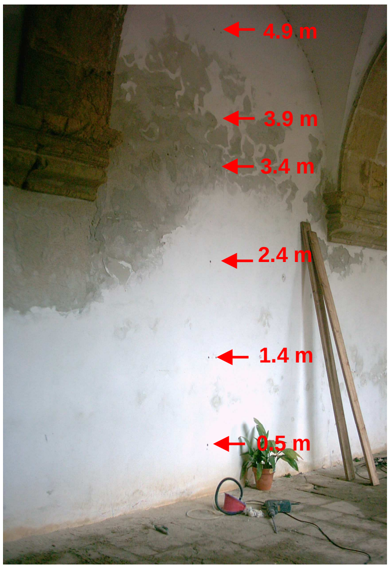


Fig. 26 – Sampling points at the NW wall – vertical profile

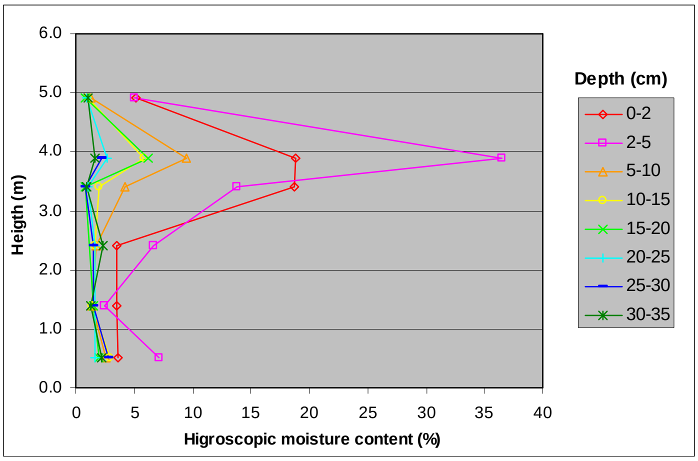


Fig. 27 – NW wall – vertical profile: HMC at 95% RH

Table 3 – Powder drilling: type of materials apparently found at the NW wall – horizontal profile at 3.4 m high (by visual observation of the plaster)

	Depth (cm)							
Length* (m)	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
1.50	CM	CM + LM	LM	LM	LM	LM	LM	LM
0.85	CM	CM+LM+S	LM+S	LM+S	LM?	–	–	LM
0.20	CM	CM	CM?	?	LM	LM	LM	LM

CM – cement mortar; LM – lime mortar; S – stone

* The length was measured from the adjacent stone arch

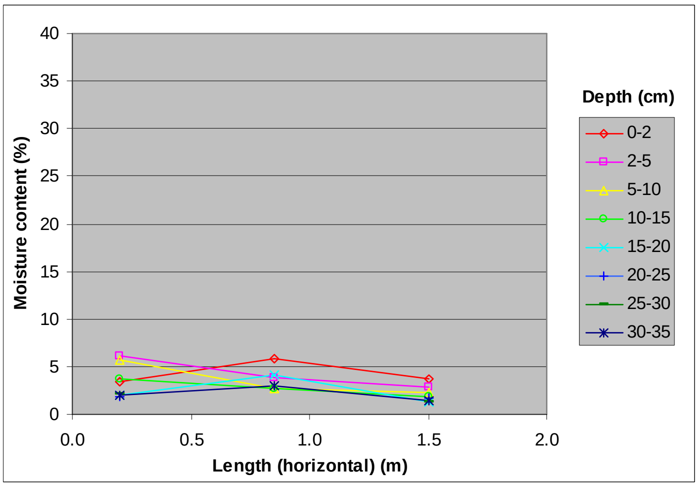


Fig. 28 – Moisture content – horizontal profile of the NW wall

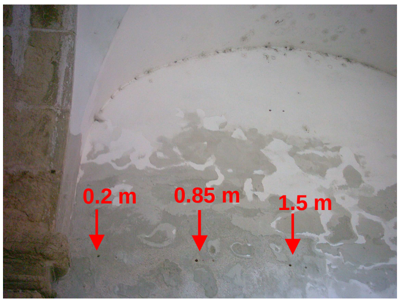


Fig. 29 – Sampling points at the NW wall – horizontal profile

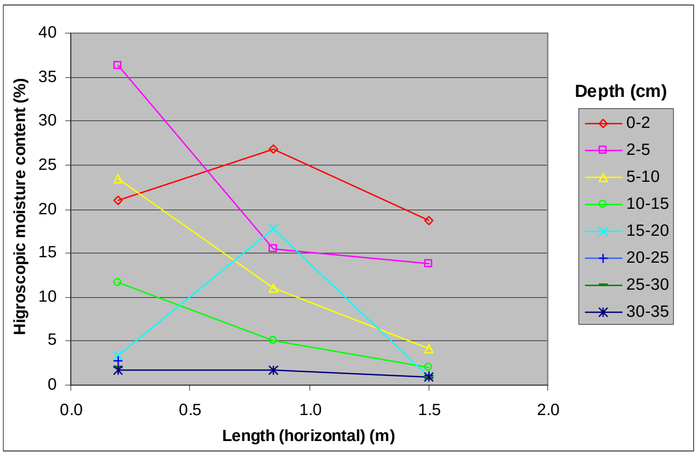


Fig. 30 – NW wall – horizontal profile: HMC at 95% RH

Table 4 – 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^-
SE	4.2	0,72	0,60	nd	0,26	0,37	0,22	0,11	*
	3.0	0,38	0,25	nd	0,40	0,46	0,42	0,18	*
	0.2	0,47	1,27	nd	0,27	0,10	0,16	1,47	*

(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

Table 5 – XRD characterization of the efflorescences on stone

Crystalline compounds	Efflorescences
Epsomite ($MgSO_4.7H_2O$)	++
Gypsum ($CaSO_4.2H_2O$)	+
Calcite ($CaCO_3$)	vtg

Diagnosis

The walls moisture and the HMC profiles point for the existence of two simultaneous sources of moisture and salts: in depth, capillary rise seems to be the only source; at the surface of the walls, an upper-located source seems to exist. Direct observation (fig. 10) indicates that the stone elements are this second source of moisture. Condensation of water-vapour from the air on the stone elements and its further movement to the renders is the main hypothesis. It requires, however, further confirmation. The existence of epsomite on the stone (eflorescences, table 5) and the absence of magnesium in the renders is another factor that needs further explanation (table 4).

A direct correlation between the fact that two of the cloister walls are semi-embedded and salt damage intensity was not found (fig 15).

On the vaults, penetration of water from the upper floor (first, the water from the rain enters through the cloister building roof, and then it accumulates on the second floor pavement and passes to the ground floor) seems a consistent hypothesis.

Ion chromatography showed at the base of the SE wall, mainly nitrates, sulphates and alkalis were found and at the top, mainly nitrates, chlorides and alkalis.

The analysis of the horizontal moisture profile clear indicates that (except for the more superficial samples) the salt content increases with the proximity of the stone elements. This indicates that the preferential path of water transport seems to be the stone elements.

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

The moisture contents are of medium level. The maximum measured values were around 10% and localized at the base of both the NW and SE walls. Somehow important values of moisture (around 6%) were also found at the upper part of the walls.
The salt load seems very high in the superficial coats 0-5 cm at both the bottom and at the top of the SE wall and mainly at the top of the NW walls. On the other points, namely deep inside the walls, the salt load seems to be low.

Visual observation of the damaged areas (see Pictures of Damaged Areas), indicate that salt damage starts at the mortar cracks (see fig. 16) or at dry moisture spots (fig. 17).

ADVICE

Solve the infiltrations of water from rain, by repairing the roof of the cloister building. For permitting a certain drying of the walls, one summer, at least, should pass after these repairs, before the execution of the new cloister render.

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.