DAMAGE ASSESSMENT AND DIAGNOSIS FORM

SUMMARY OF DAMAGE DIAGNOSIS

Name of the building – Location

Basement of the SW building of Jesus (or Eleven Thousands Virgins) College

Type of damage – decay pattern

1. Efflorescences, sanding and crumbling, detachment of the superficial coat of plaster, dark (moisture) spots, red spots (probably of biological origin)
2. Efflorescences, dark (moisture) spots
3. Efflorescences between the plaster and the paint, blistering and further detachment of the paint
4. Efflorescences on the tiles, efflorescences on the mortar joints
5. Dark (moisture) spots

Materials concerned

1. Painted lime plaster
2. Stone
3. Painted cement plaster
4. Ceramic wall tiles
5. Cement-based pavement

Tests performed

- Moisture and hygroscopic moisture content (HMC) profiles of the plaster and of its substrate.
- HMC of adjacent samples of mortar and of stone, directly collected (by hammer and graver) at different depths.
- Ion chromatography on three superficial samples of each one of the two profiles
- XRD characterization of 5 samples of efflorescences
- Water absorption at low pressure (pipe method) on the lime-plaster.

Diagnosis

The HMC test done on adjacent samples of mortar and of stone (fig. 31) indicates a much higher HMC for the mortar samples.
Capillary rise at wall 2 and capillary rise plus an income of moisture from the ground at the back of wall 1 are consistent hypothesis.
Nitrates are the main type of salts responsible for the plasters deterioration. They may come from the soil. On the WC tiles, the efflorescences are carbonates and sulphates. They are probably coming from the bedding cement mortar.
The present lime-render is in a quite good state, especially if we consider its age and the walls high salt and moisture load. The internal high RH (and reduced ventilation) is probably contributing for the plasters low degradation rate because it results in a low evaporation rate at the walls surface.

Advice

For an effective interpretation of the moisture and HMC profiles, we need to know which materials are present in the drilled samples and also which are their relative contents.
Repair of this basement damaged plasters could be done with a lime-mortar, as similar as possible to the existing one, namely in its high capillary absorption (shown by the water absorption tests). A paint that does not constitute a barrier to the incoming salt solutions (i.e. providing a good hydric continuity with the plaster, as well as with high capillary absorption and high water vapour permeability) should be used.
Attention must be paid to the fact that a sudden increase of the building internal ventilation may result in a relevant increase of the plasters degradation rate.

DAMAGE ASSESSMENT AND DIAGNOSIS FORM

Date of inspection +description

1. 2002-06-27 preliminary inspection
2. 2003-09-11 preliminary inspection
3. 2003-09-28 inspection (with TU Delft)
4. 2003-12-04 sampling (including powder drilling)
5. 2004-01-06 water absorption tests and inspection

Investigator / Institute in charge of the investigation
LNEC

Reference number

GENERAL INFORMATION

Name of the building
Basement of the SW building of the Jesus (or Eleven Thousands Virgins) College (adjacent to Coimbra New Cathedral)

Address
Lg. da Feira, Couraça dos Apóstolos, Lg. Marquês de Pombal, Coimbra

Owner of the building / Responsible authority of the building
Owner: Factory of the New Cathedral
Administration: Roman Catholic Church
IPPAR is the authority responsible for the monuments conservation since 1992. Between 1960 and 1992, the responsible authority was DGEMN.

Construction phases + data (year)

1547 –	Construction of Jesus College starts
1598 –	Construction of the church (New Cathedral) starts
1640 –	The church nave is opened to the public
1698 –	Construction of the church finished (exact date of finishing of the college was not possible to identify at this stage)
1850 / 75 –	In the second half of the XIX century the church and the adjacent buildings suffer important (not possible to document at this stage) rehabilitation interventions.
1910 –	The church is classified as national monument
around 1940 -	Demolition of buildings adjacent, namely, to the W façade of the College SW building. The ground level next to this W façade was then lowered for building a new street (the basement of the College SW building cessed to be embedded at this side).

Relevant historical calamities

Function(s) of the building during time	
until 1759 –	Cult (church) and educational (college).
1759 / 72 –	The building (college and church) was unoccupied (in the sequence of the Jesuits expulsion from Portugal)
1772 –	The church (including the college SW building, which the basement is our case-study) became the headquarters of Coimbra diocese.
1772 / 75 –	The rest of the college became part of Coimbra University (including the Public Hospital and the Natural History Museum)

Present function (Use of installations)	
1772 to present –	Cult (church), headquarters of the Coimbra diocese (College SW building), educational (rest of the College buildings). The SW building basement, which is our present case-study, is presently occupied with several activities under the responsibility of Coimbra diocese (catechism, scouts, etc.).

Pictures of the building

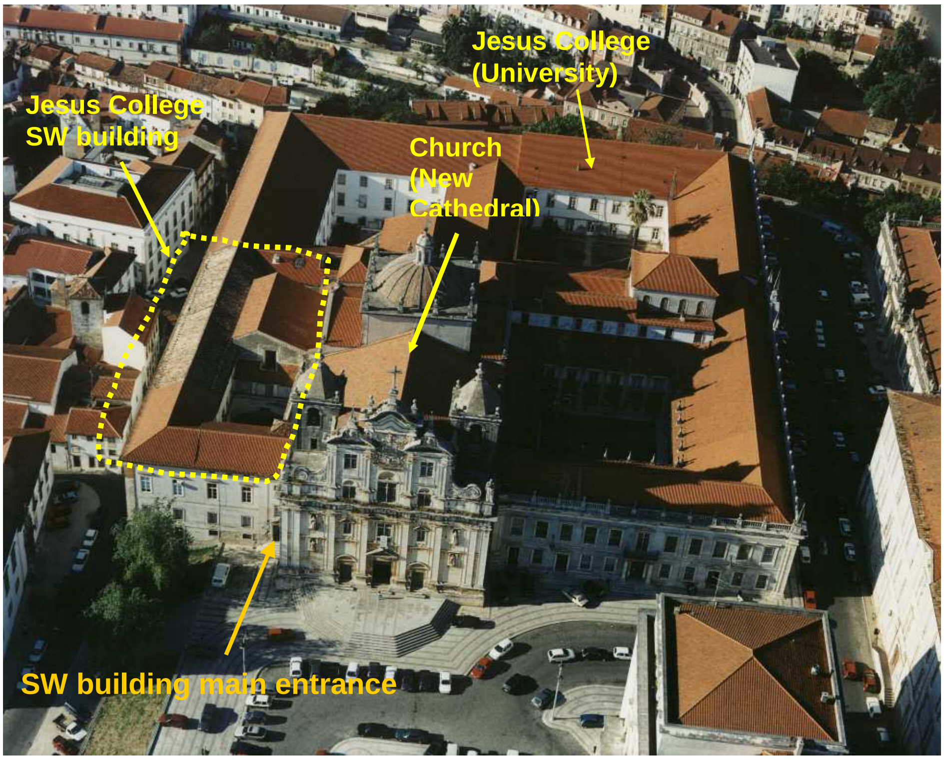


Fig. 1 – Jesus College and New Cathedral: aerial view

Fig. 2 – Interior of the basement of Jesus College SW building (2003-12-04)

Plan of the location of the building

Fig. 3 – Portugal map (left) and Coimbra map (rigth)

Building plan

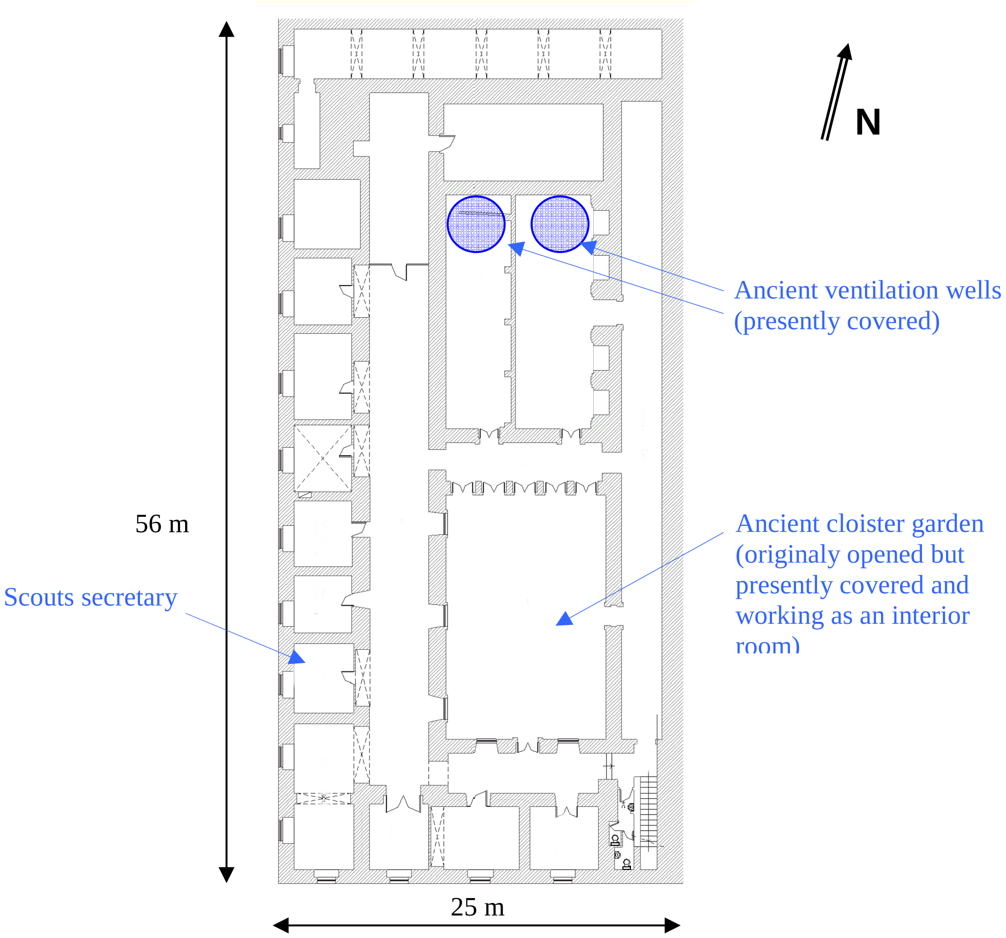


Fig. 4 – Plan of the basement of the Jesus College SW buiding

STATE OF PRESERVATION OF THE BUILDING

	type of damage	condition assessment					
		excellent	good	reasonable	not adequate	poor	very poor
Roof							
Facades		Condition not clear					
Structural elements			X				
Interior (walls)						X	
Floor			X				
Ceiling				X			

Restorations or maintenance interventions performed in the past
(as far as considered relevant)

Type of restorations or maintenance

There is no information on relevant restoration or maintenance interventions.

Building part

Date

Company performing the restorations

Reason for restorations

Further information

The cloister garden and the ventilation wells were covered around 1960 (verbal information of the responsible priest to IPPAR). They are now interior spaces. There was no adaptation of building ventilation and of the pluvial water drainage to these new circumstances.

We estimate the present lime plaster to be around 40 years old.

DAMAGE

Type of damage and architectural element affected

Painted lime plaster

1. Efflorescences
2. Sanding and crumbling of the plaster/paint system
3. Detachment of the superficial coat of plaster
4. Dark (moisture) spots
5. Red spots (probably of biological origin)

Stone

6. Efflorescences
7. Dark (moisture) spots

Painted cement plaster

8. Efflorescences between the plaster and the paint
9. Blistering and further detachment of the paint

Ceramic tiles covering

10. Efflorescences on the tiles

Ceramic tiles covering

11. Efflorescences on the mortar joints

Continuous cement pavement

12. Dark (moisture) spots

Location of damaged area

Damage was evaluated mainly on the corridors and WCs of the basement. Five main types of surfaces were found to be damaged:

A - Walls of irregular stone masonry and lime mortar, lime-plastered and painted
B - Wall of regular stone masonry
C - Walls (at the entrance stairs) with ceramic tiles until around 1,5 m from the pavement and a lime plaster/paint system above them (a cement plaster repair of 5 cm width exists between the ceramic tiles and the lime-plastered surface)
D - Walls (WCs) covered with ceramic tiles and a lime plaster/paint system above them
E - Continuous pavement of cementitious material

The five types of surfaces have the following location on the building:

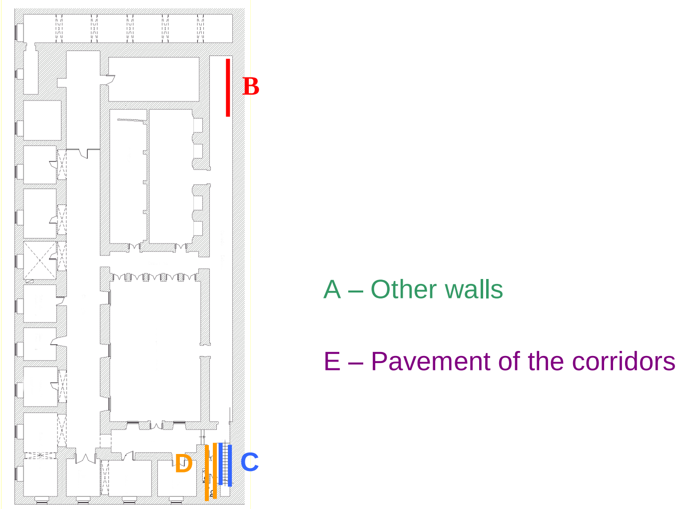


Fig. 6 - Distribution of the damage

Distribution of the damage was the following:

1. Zones A and C: Spread all over the walls
2. Zones A and C: In general, at the base of the walls (70% up to 15 cm; 30% up to 60 cm); in localized zones, higher damaged spots exist
3. Zones A and C: In general, at the base of the walls
4. Zones A and C: Spread all over the walls
5. Zones A and C: Spread all over the walls
6. Zone B: Spread all over the wall
7. Zone B: Spread all over the wall but more intense at its base
8. Zone D: Usually concentrated at the base of the plastered surface (on the top of the tilled surface)
9. Zone D: Usually concentrated at the base of the plastered surface (on the top of the tilled surface)
10. Zone D: Spread
11. Zone C: Spread
12. Zone E: Spots are mainly concentrated close to the base of the walls, but other localized spots also exist on the pavement current surface

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

1. Zone A: 20% of the plastered surface. Zone C: 50% of the plastered surface
2. Zone A: 10% of the plastered surface (deepness: up to 2.5 cm on the current surface of the walls and up to 5 cm on the walls corners). Zone C: 15% of the plastered surface (deepness: superficial)
3. Zone A: Localized. Zone C: Irrelevant
4. Zone A: 25% of the plastered surface. Zone C: Irrelevant
5. Zone A: 10% of the plastered surface. Zone C: 1% of the plastered surface
6. 50% of the stone surface
7. 30% of the stone surface
8. Localized
9. Localized
10. 50% of the tilled surface
11. Generalized
12. 5% of the pavement surface

The values for the efflorescences had to be estimated because the walls are periodically cleaned.

Evolution of the damage

The efflorescences and moisture spots were visible in all the inspections: June 2002, September and December 2003 and January 2004.

Type of damage and material(s) concerned

wall as a whole

masonry elements (stone)

Efflorescences, dark (moisture) spots

mortar

(re)-pointing

rendering/plaster Painted lime plaster Efflorescences, sanding and crumbling of the plaster/paint system, detachment of superficial coat of plaster, dark (moisture) spots, red spots (probably of biological origin) Painted cement plaster Efflorescences between the plaster and the paint, blistering and further detachment of the paint
Other coverings Ceramic tiles Efflorescences on the tiles, efflorescences on the mortar joints Continuous cement pavement Dark (moisture) spots

ILLUSTRATIONS

Building plan – location of the sampling

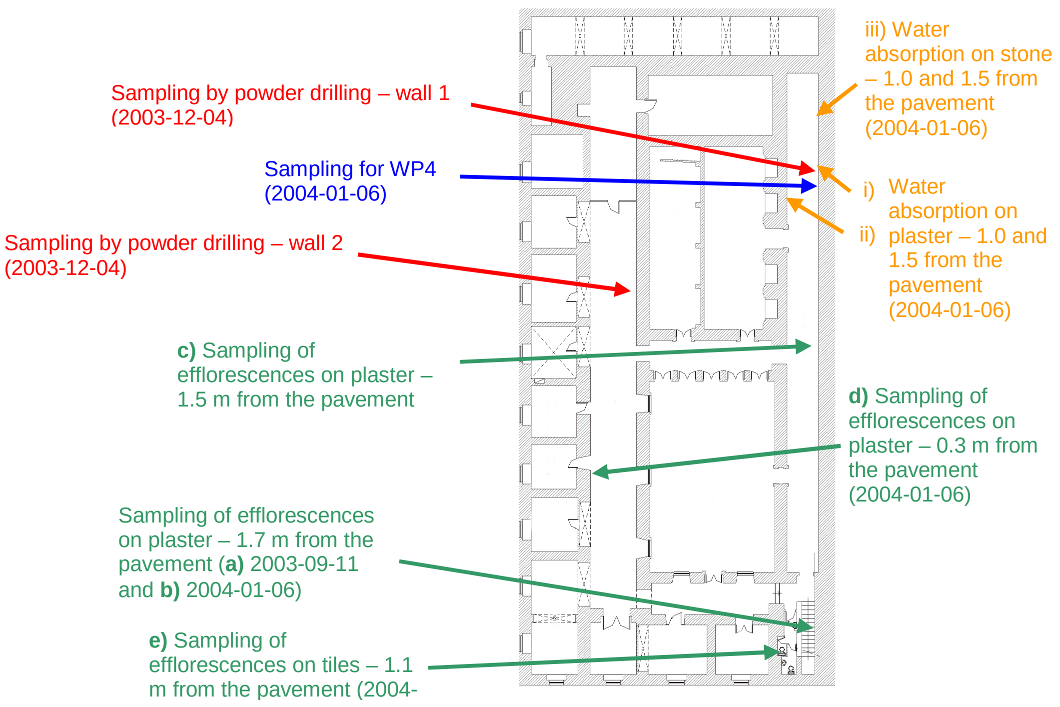


Fig. 7 – Location of the sampling

PICTURE OF DAMAGED AREA

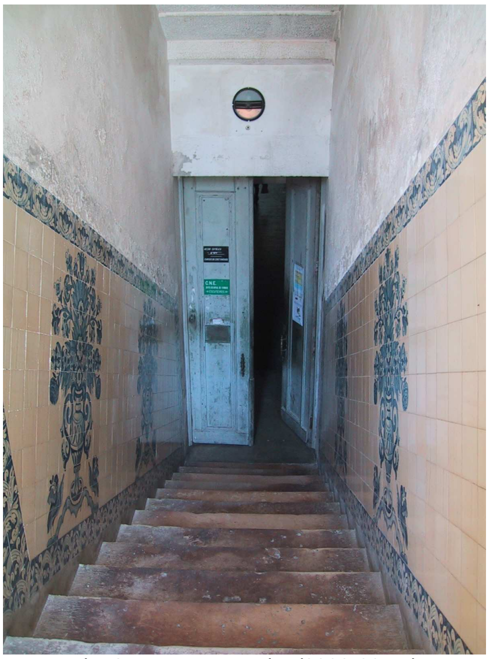


Fig. 8 – Entrance stairs (2003-09-11)

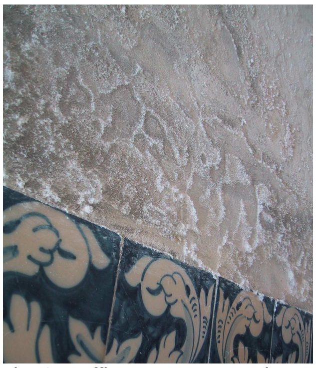


Fig. 9 – Efflorescences on plaster at the entrance stairs (2003-09-11)

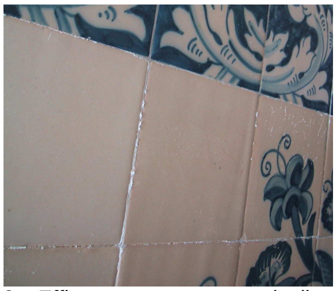


Fig. 10 – Efflorescences on ceramic tiles joints at the entrance stairs (2003-09-11)

Fig. 11 – Regular stone masonry wall (2004-01-06)

Fig. 12 – Efflorescences on stone (2004-01-06)

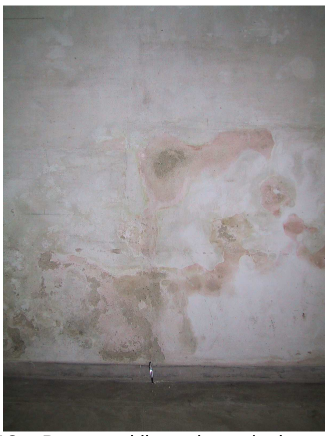


Fig. 13 – Damaged lime plaster/paint system at a corridor (2003-12-04)

Fig. 14 – Damaged lime plaster/paint system at a corridor (2003-09-11)

Fig. 15 – Damaged lime plaster/paint system at a corridor (2003-12-04)

Fig. 16 – Red spots (probably of biological origin) on painted lime-plaster (2004-01-06)

Fig. 17 – Damaged lime plaster/paint system at the base of a corridor wall (2003-12-04)

Fig. 18 – Sanding and crumbling of lime-plaster/paint system at a corridor (2004-01-06)

Fig. 19 – Efflorescences and salt damage on a lime-plaster/ paint system, at a corridor (2003-12-04)

Fig. 20 – Efflorescences on lime-plaster/ paint system, at a corridor (2004-01-06)

Fig. 21 – Moisture spots on the pavement and stone baseboard of a corridor (2004-01-06)

Fig. 22 – Efflorescences on the WC ceramic tiles (2004-01-06)

Fig. 23 – Efflorescences, blistering and detachment of the WC “plastic” paint (2004-01-06)

ENVIRONMENT

Climatological circumstances

Exposition (rain, wind, etc)

The basement of the SW budding of Jesus College is partially embedded: at S it is bellow the ground level; at W it is above the ground level; at N and E, it confines with the other buildings and, due to the scarce drawings available (there are no profiles), we have no information on the ground level in these sides of the building.

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

Urban/Interior.

Additional data

Water springs are likely to exist at this zone of Coimbra (information given to IPPAR by local residents). The existence of vestiges of a Roman Forum at this local also points to the presence of water springs.

The interior environment at the basement is extremely humid. At the scouts secretary, an electric air dryer is working in permanence to improve the conditions of habitability and of paper conservation. At this room, the damage on the lime plaster seems stronger, probably due to the higher evaporation rate of the walls moisture. The bottom of the walls was covered with gypsum boards and (probably also in consequence of this) there is strong damage until more than 2 m above the pavement.

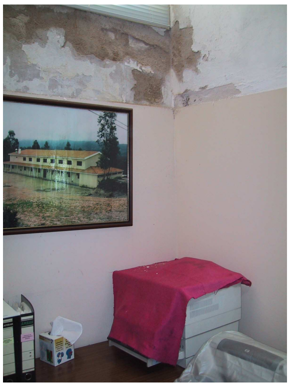


Fig. 24 – Scouts secretary: salt damage on plaster (2003-09-11)

A continuous cement-based pavement exists, covering almost all the basement floor area.

DIAGNOSIS

Hypothesis, -(es)
Damage is due to moisture and salts.

Tests performed

- Moisture and hygroscopic moisture content (HMC) 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
- HMC of adjacent samples of mortar and of stone, directly collected (by hammer and graver) at different depths, for helping to interpret the HMC profiles, on which different materials are “caught” by powder drilling
- Ion chromatography was performed on three superficial samples of each one of the two profiles
- XRD characterization of 5 samples of efflorescences was done
- Water absorption at low pressure (pipe method) was done on the lime-plaster (after removing the superficial paint) for characterization purposes.

Results of the tests

Table 5 – Powder drilling: type of materials found at wall 1

	Deepness (cm)							
Heigth (m)	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
2.6	LM	LM + S	LM + S	S?(+LM?)	S (+LM?) + B	LM + S + B	LM ?	LM + S
1.8	LM	LM + S	S (+LM?)	S (+LM?)	S	LM + S	S ?	S
1.0	LM	LM + S	LM + S	LM + S	LM	LM	LM	LM ?
0.3	LM	S + LM	S	S	S	S	LM or S ?	S ?
0.15	LM	LM	DLM	DLM	DLM	LM	B + LM	B

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

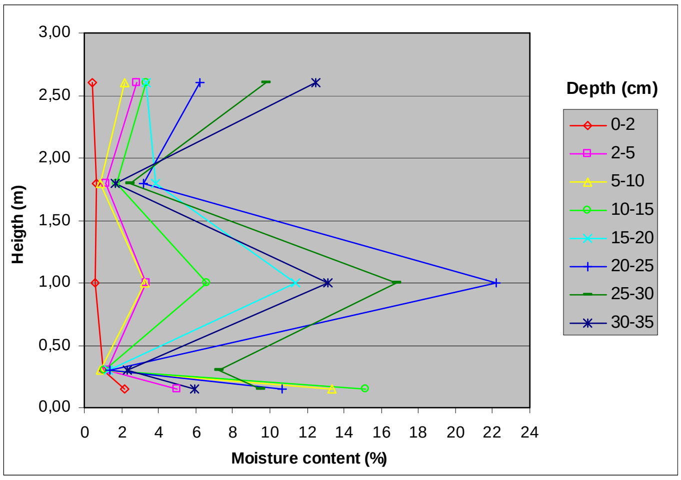


Fig. 25 – Moisture content profile of wall 1

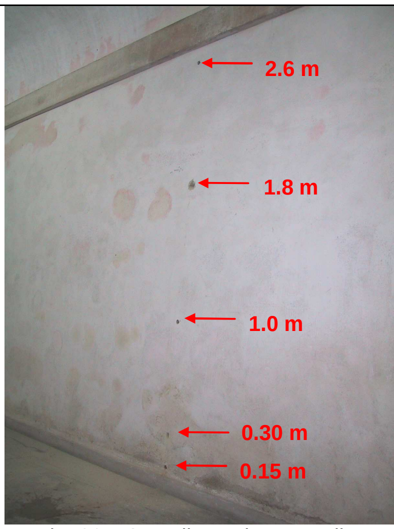
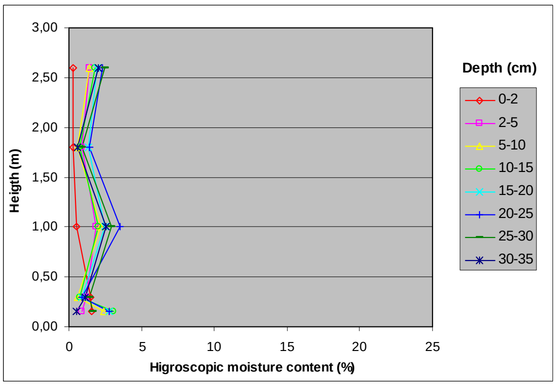


Fig. 26 – Sampling points at wall 1



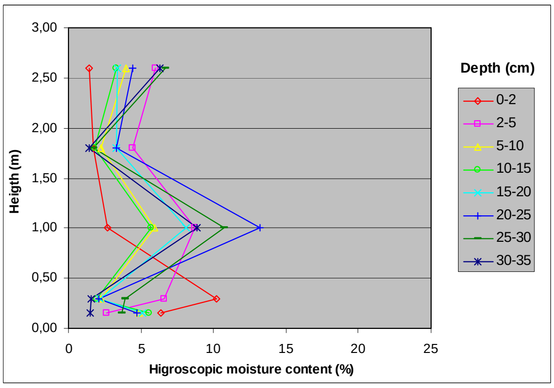
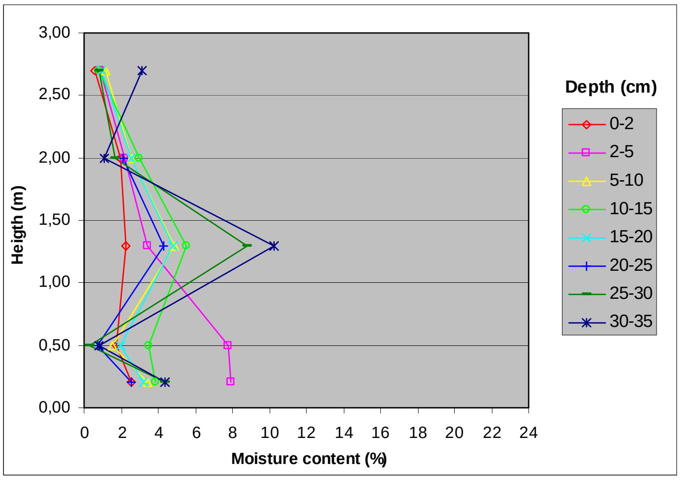


Fig. 27 – Wall 1: HMC at 80% (left) and at 95% RH (right)

Table 6 – Powder drilling: type of materials found at wall 2

	Deepness (cm)							
Heigth (m)	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
2.7	LM	LM	S ?	S ?	S	?	?	LM
2.0	LM	LM	LM (+S?)	LM (+S?)	LM (+S?)	LM (+S?)	LM (+S?)	LM ?
1.3	LM	LM	LM ?	LM ?	LM ?	LM ?	LM ?	LM ?
0.5	LM	LM (+S)	S	S	S	S	S	?
0.2	LM	LM	LM (+S?)	LM	LM (+ S?)	LM	LM	LM

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



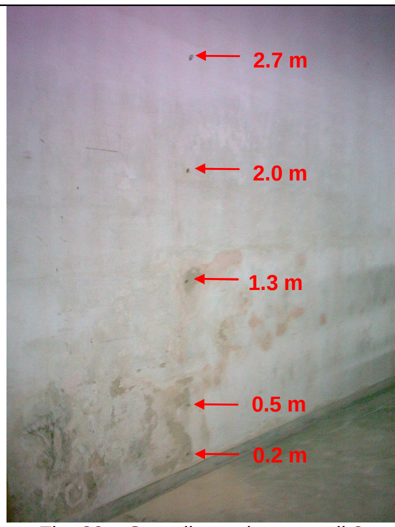


Fig. 29 – Sampling points at wall 2

Fig. 28 – Moisture content profile of wall 2

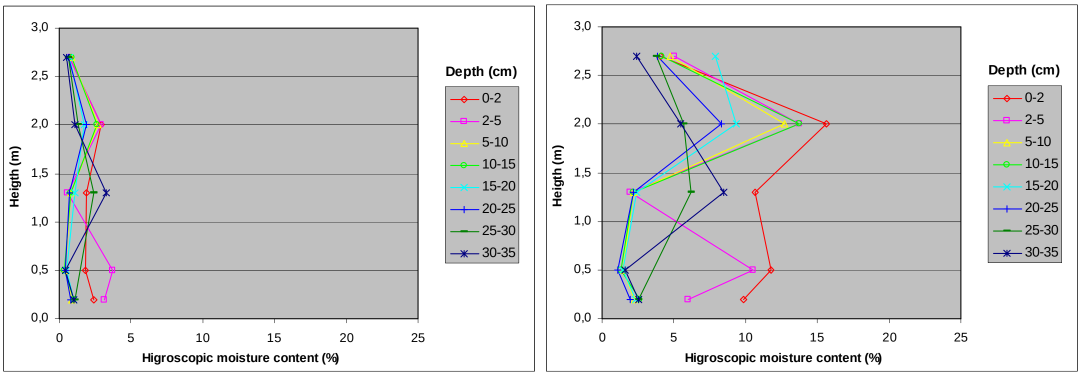


Fig.30 – Wall 2 : HMC at 80% (left) and at 95% RH (right)

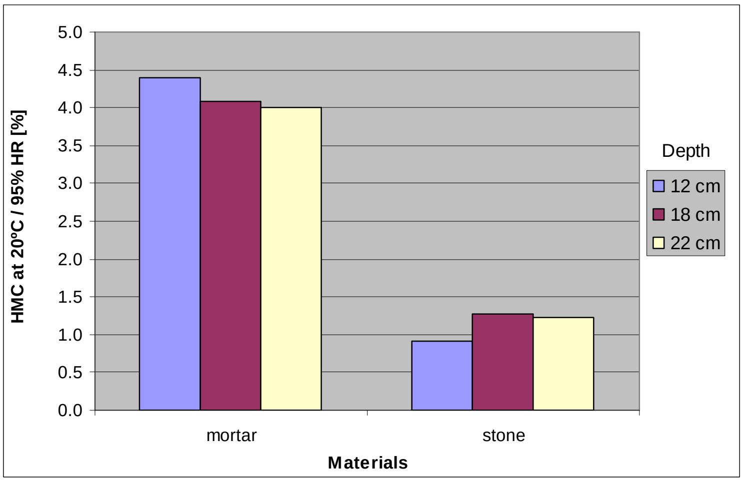


Fig.31 – Ongoing HMC 95% test (preliminary results after 5 days of test)

Table 7 – 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)
1	1.00	0,12	0,12	0,35	0,26	0,15	0,25	Nd	*
	0.30	0,31	0,34	0,28	0,21	0,14	0,60	0,02	*
	0.15	0,24	0,26	0,52	0,24	0,13	0,44	0,06	*
2	1.20	0,33	0,41	0,49	0,18	0,22	0,42	0,06	*
	0.50	0,37	0,42	0,22	0,26	0,12	0,47	0,25	*
	0.20	0,31	0,52	0,13	0,32	0,21	0,43	0,42	*

(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 8 – XRD characterization of efflorescences

Crystalline compounds	Efflorescences				
	a) On lime-plaster	b) On lime-plaster	c) On lime-plaster	d) On lime-plaster	e) On WC tiles
Niter (KNO_3)	++	++/+++	+++	++/+++	vtg
Natron ($Na_2CO_3.10H_2O$)	-	++	-	-	-
Trona ($Na_3H(CO_3)_2.2H2O$)	vtg	-	-	+	+++
Aftitalite ($K_3Na(SO_4)_2$)	-	-	-	+	++
Calcite ($CaCO_3$)	+	+	vtg	-	-
Quartz	-	-	-	vtg	-

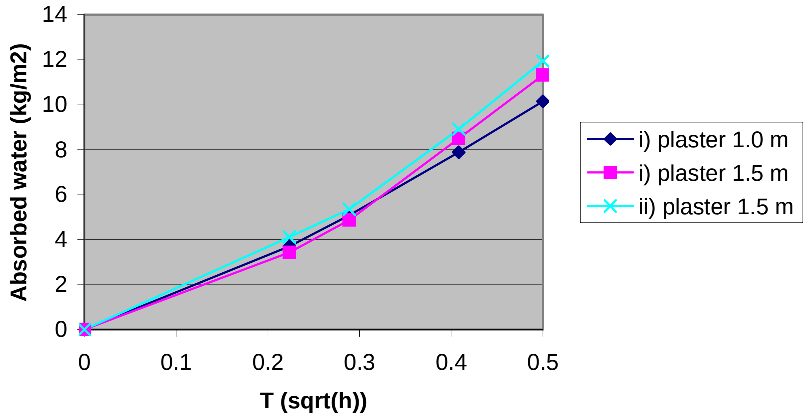


Fig.32 – Water absorption under low pressure (pipe method)

Diagnosis

The HMC test done on adjacent samples of mortar and of stone (fig. 31) indicates a much higher HMC for the mortar samples.

The moisture (fig. 25 and 28) and the HMC (fig. 27 and 30) profiles show discontinuities, which should therefore be due, at least partially, to the variable nature of the samples collected by powder drilling (tables 5 and 6). Evaluation of the materials of these samples was done by combining the visual observation of the powder with an "in situ" qualitative evaluation of the materials resistance to the drilling. However, this procedure does not often permit to have an effective determination of the sampled materials nature and contents, due to the following main factors:

- The drilling equipment is not a specific apparatus for measuring the drilling resistance. This evaluation is simply based on the operator sensitivity, which is not enough for detecting all the differences, mainly at the higher depths.
- Visual observation is not also usually enough for distinguishing between materials with close colours (some stones, lime mortar, etc.).
- Some stones have relevant colour variability; sometimes, several types of stone are used in the same masonry.
- It is common to get variable contents of different materials in the same sample (ex: stone + lime mortar + brick).

Having this considerations in mind, the moisture and HMC tests indicate that:

- From 0-2 cm and, in the case of wall 2, also from 2-5 cm always the same material (lime mortar) was colleted. These lines (red and pink) point for capillary rise as the origin of moisture.
- A general increase of moisture content seems to exist towards the interior of both walls.
- At wall 1 (peripheric wall, probably semi-embeded), significant moisture contents are also present deep inside at the to of the wall, while at wall 2 (interior wall) this does not occur.

Capillary rise at wall 2 and capillary rise plus an income of moisture from the ground at the back of wall 1 are consistent hypothesis.

Nitrates are the main type of salts responsible for the plasters deterioration, as indicated by the ion chromatography analyses of plaster samples and by the XRD of efflorescences. The nitrates may come from the soil.

On the WC tiles, the efflorescences are carbonates and sulphates. They are probably coming from the bedding cement mortar.

The present lime-render is in a quite good state, especially if we consider its age and the walls high salt and moisture load. The internal high RH (and reduced ventilation) is probably contributing for the plasters low degradation rate because it results in a low evaporation rate at the walls surface.

ADVICE

The main conclusion of this case-study analisys is, at the moment, is that, for an effective interpretation of the moisture and HMC profiles, we need to know which materials are present in the drilled samples and also which are their relative contents.

Repair of this basement damaged plasters could be done with a lime-mortar, as similar as possible to the existing one, namely in its high capillary absorption (shown by the water absorption tests). A paint that does not constitute a barrier to the incoming salt solutions (i.e. providing a good hydric continuity with the plaster, as well as with high capillary absorption and high water vapour permeability) should be used.

Attention must be paid to the fact that a sudden increase of the building internal ventilation may result in a relevant increase of the plasters degradation rate. For this reason, it is advisable to first proceed to the elimination of the moisture source. Then, monitoring of the walls moisture content (by periodic sampling) should be done. The internal ventilation should only be increased after the walls have dried.