Case-studies in plastering and rendering mortars. Sampling and testing for salts

Teresa Diaz Gonçalves

Case-studies in plastering and rendering mortars. Sampling and testing for salts

Lecture contents

- Four case studies in Portugal (indicated by IPPAR + DGMN)
    - Methodology
    - Salvas church, Sines
    - Alhos Vedros tide-mill
    - House of Despacho, Pereira, Coimbra
    - Santa Clara-a-Nova Monastery, Coimbra
- Inspection form

Methodology for assessment and diagnosis of damage

Diagnoses are rarely based on 100% certainty:

- complexity of the problems

- financial restrictions (normal…) => limitations in the number and type of analyses

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- Sampling / testing

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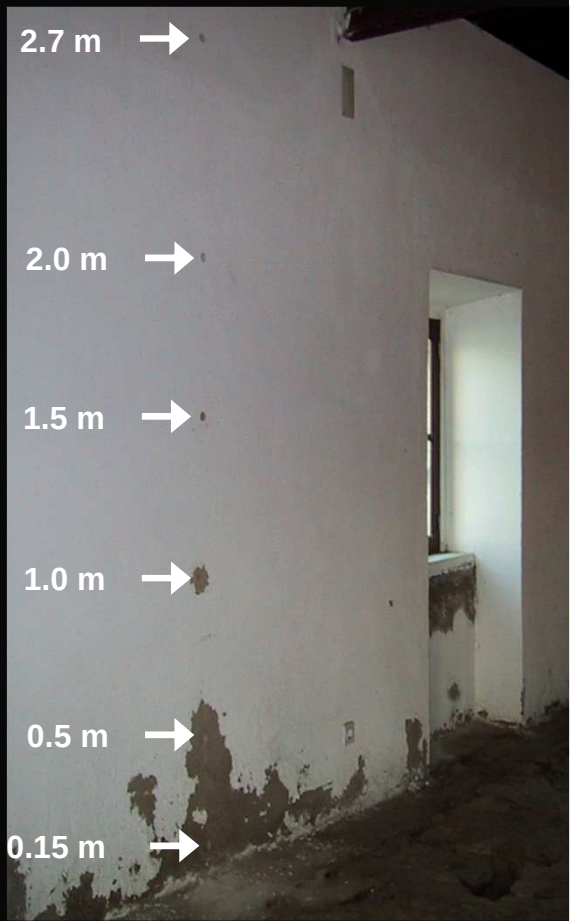

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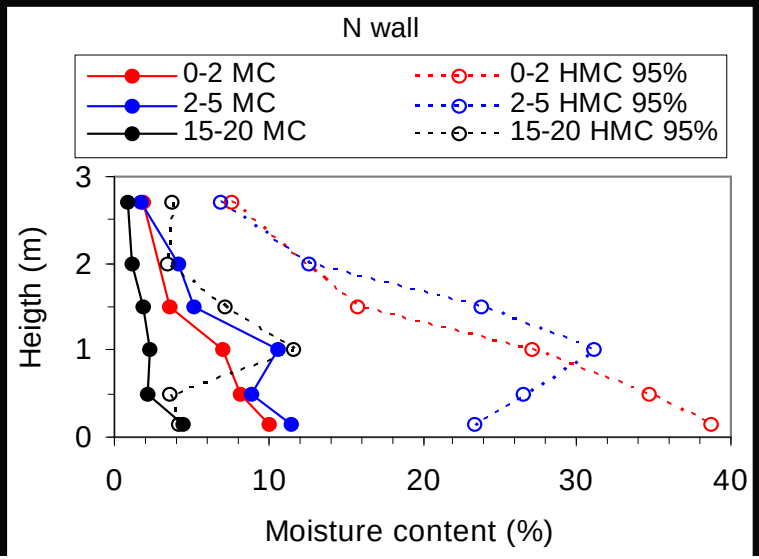

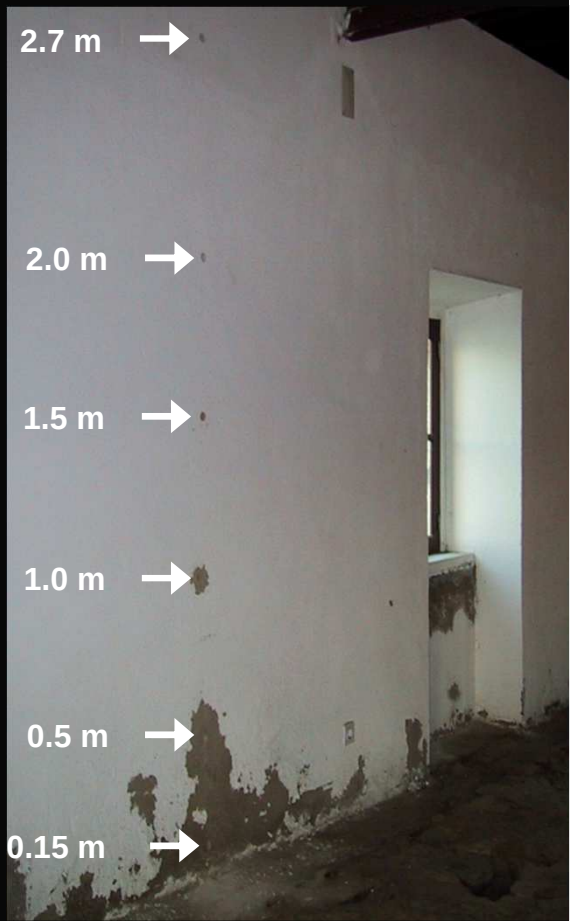

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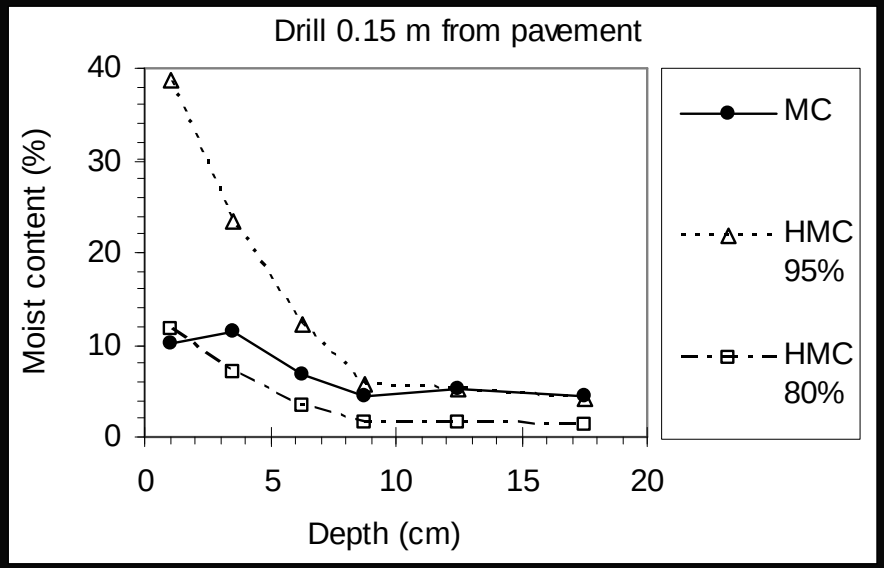

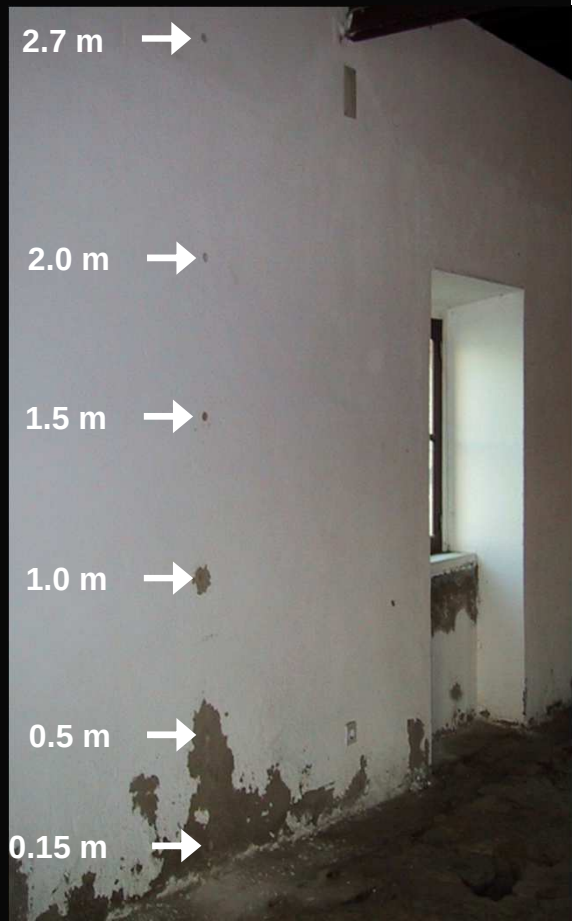

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    - Ion chromatography => Na^+, K^+, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-}
    - XRD / EDS
      - XRD => mineralogical composition (content ≥ 2 to 4% W)
      - EDS (energy-dispersive X-ray spectroscopy) => semiquantitative info about content
      - on efflorescence, when it was visible
      - on the fine fraction, after elimination of material retained on 106 µm sieve

1 - Salvas Church, Sines

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SW (front) façade

- Built 1529 by Portuguese navigator Vasco da Gama (to thank the success of his trip to discover the sea route to India)
- Façade dates from XVIII century
- 1997 => lime render (small percentage of cement) + lime-wash

<u>Damage (2004):</u>

- cracking, sanding of the render, erosion
- 60% of the surface damaged
- reached more than 4 m height
- mainly at the walls middle height

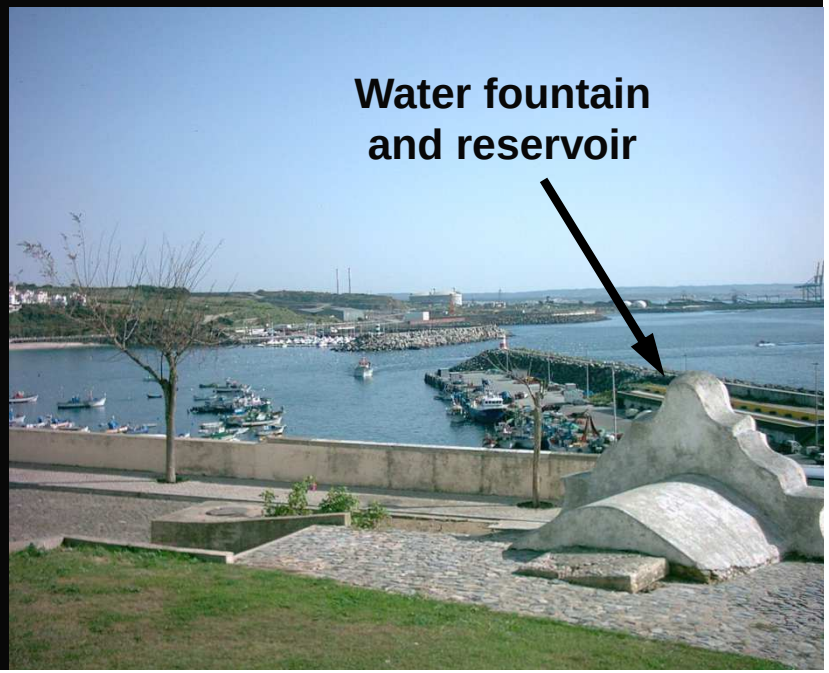
1 - Salvas Church, Sines

SW (front) façade

- Next to Sines harbour

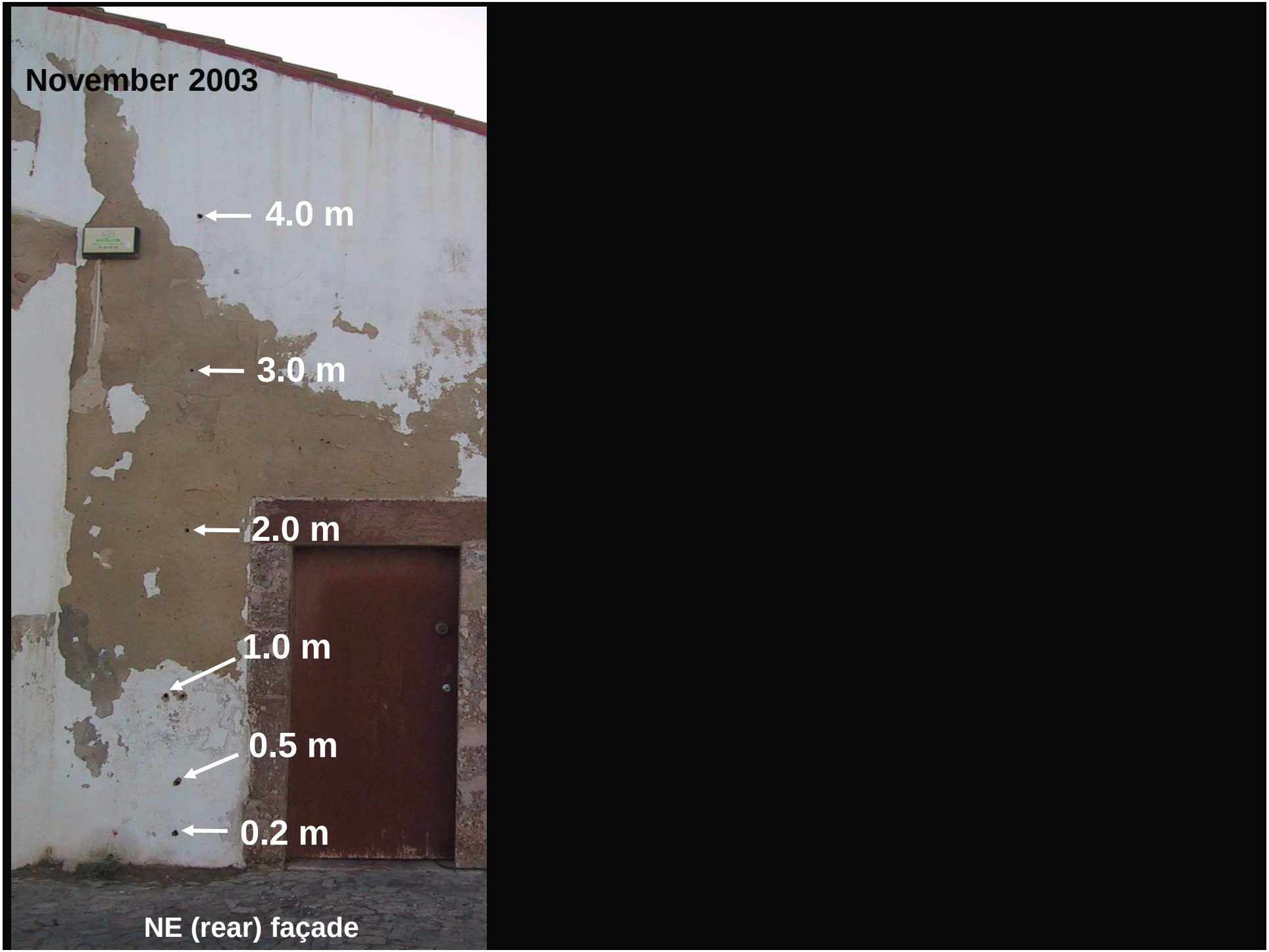
  lateral SE façade faces Sines harbour (150 km south of Lisbon)

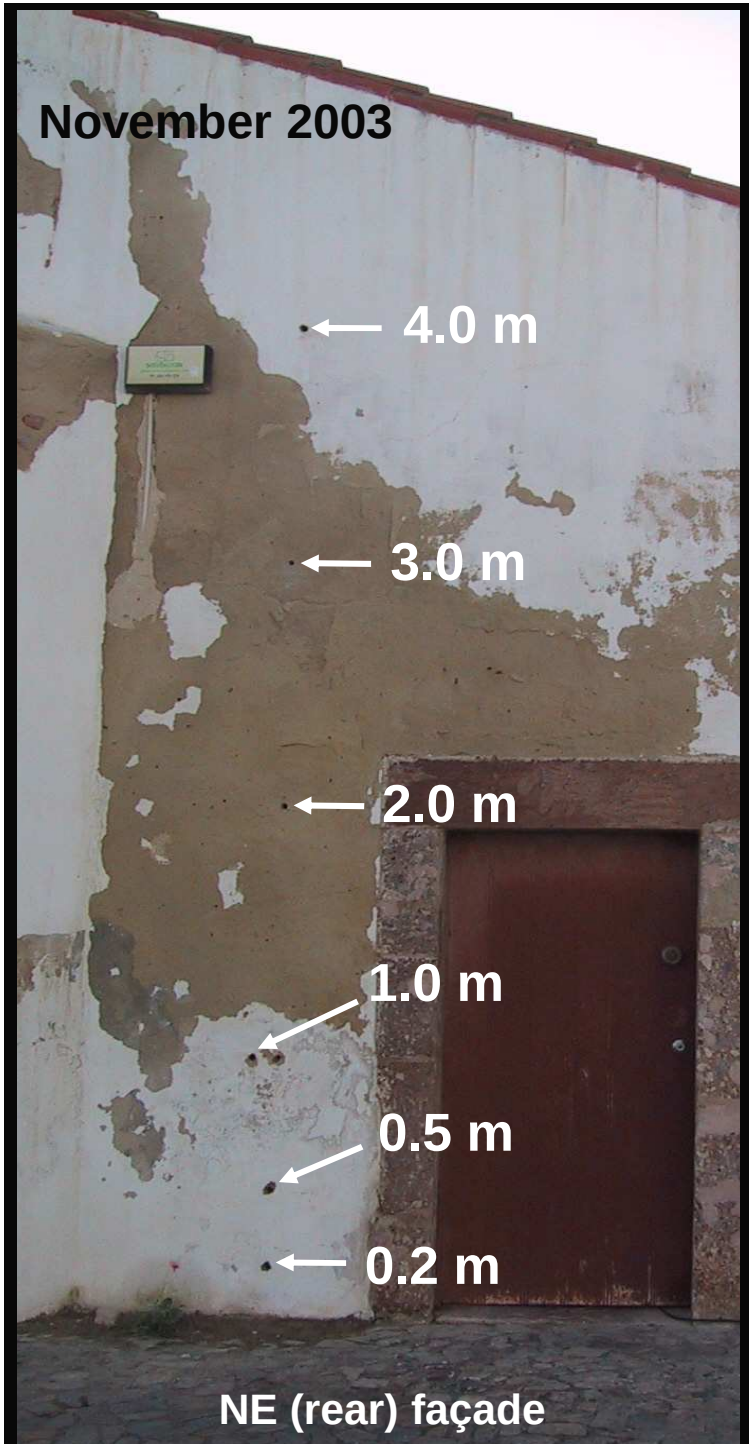
- Next to water fountain



1 - Salvas Church, Sines

damage seems to start at the cracks …


November 2003
4.0 m
3.0 m
2.0 m
1.0 m
0.5 m
0.2 m
NE (rear) façade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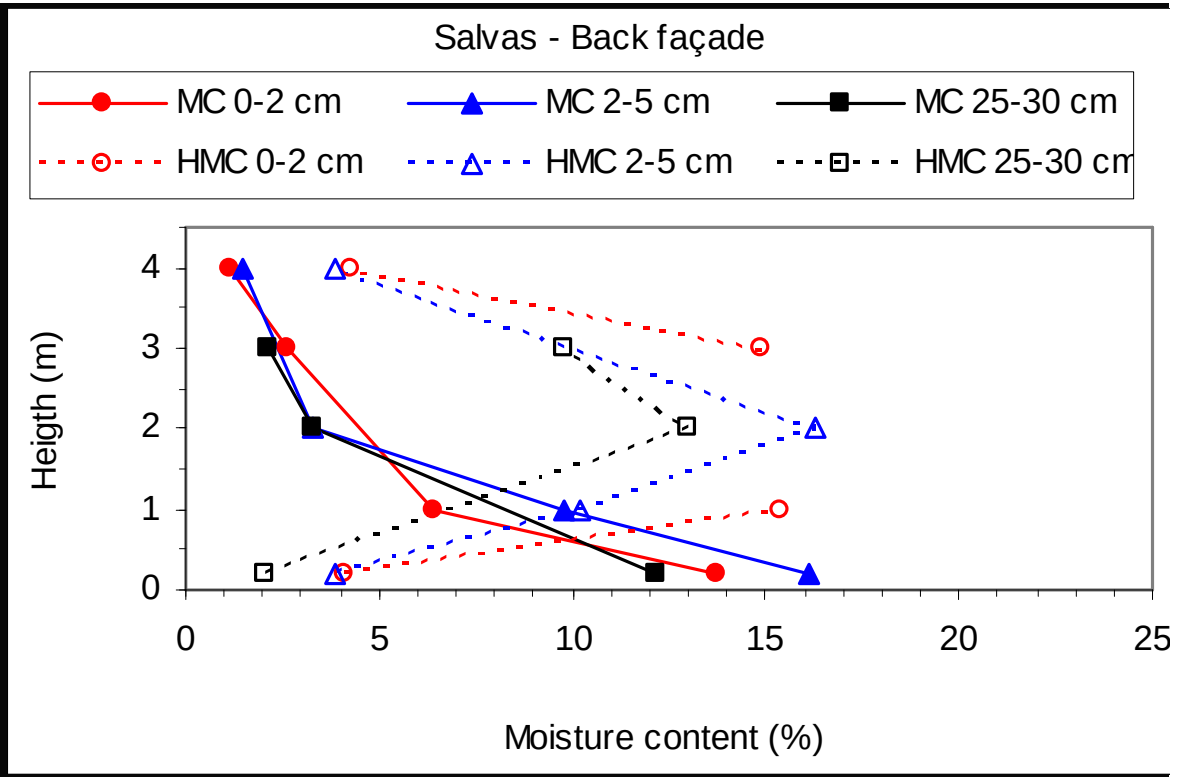
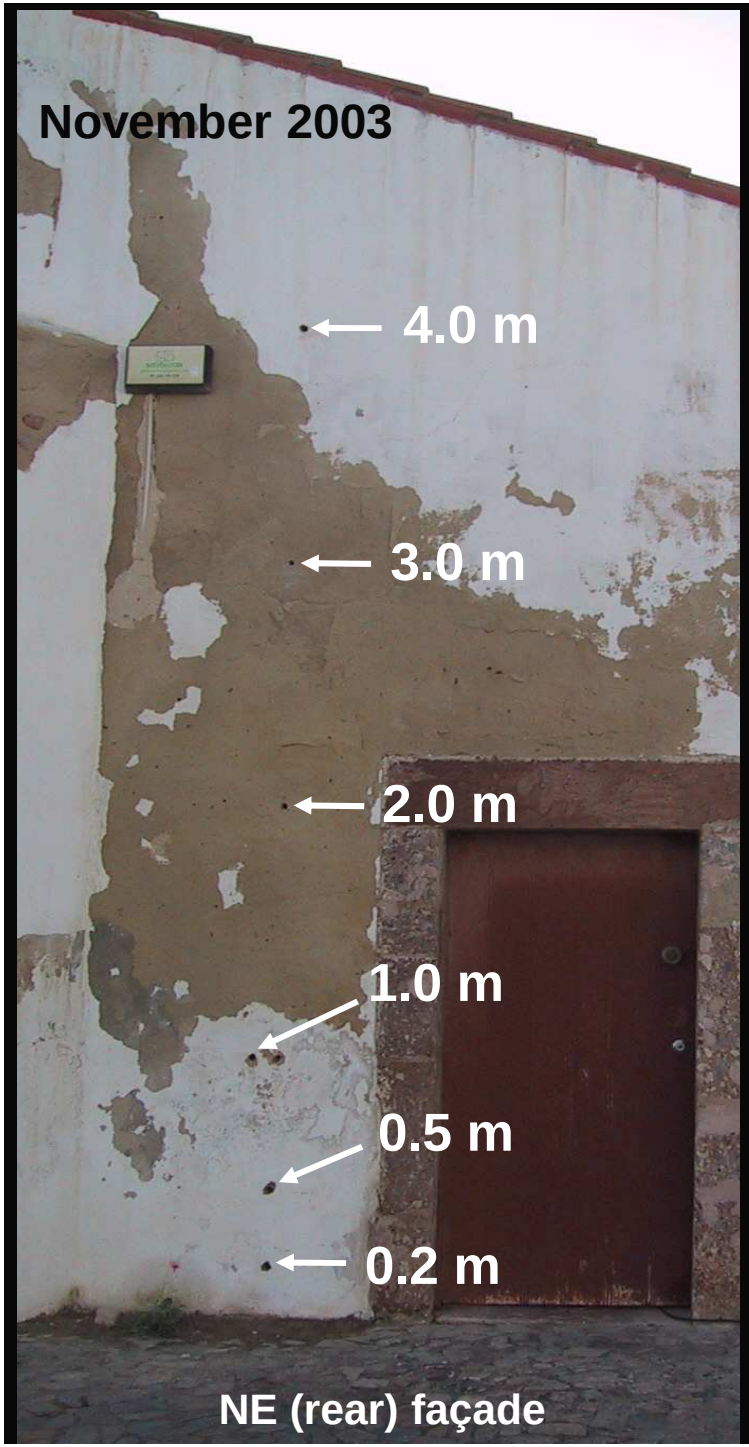
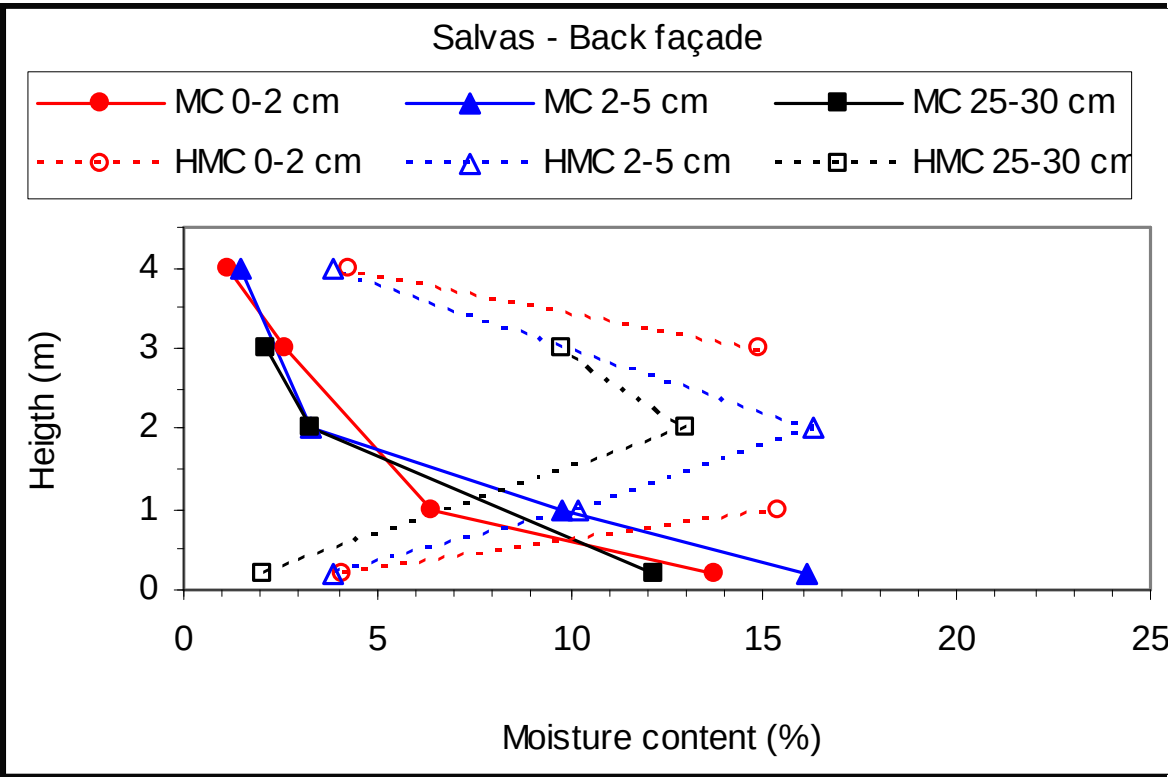
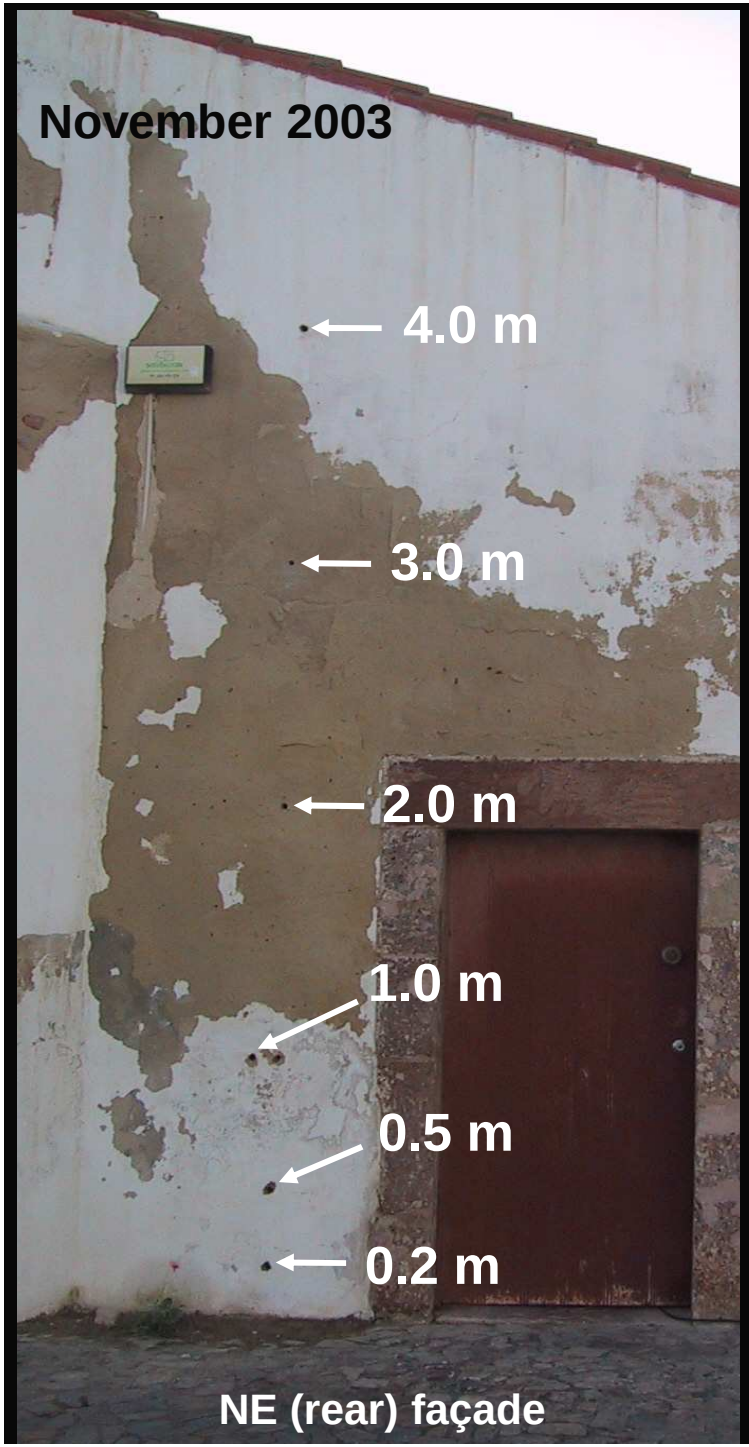

Salvas - Back façade
MC 0-2 cm
MC 2-5 cm
MC 25-30 cm
HMC 0-2 cm
HMC 2-5 cm
HMC 25-30 cm
Heigth (m)
0
1
2
3
4
0
5
10
15
20
25
Moisture content (%)

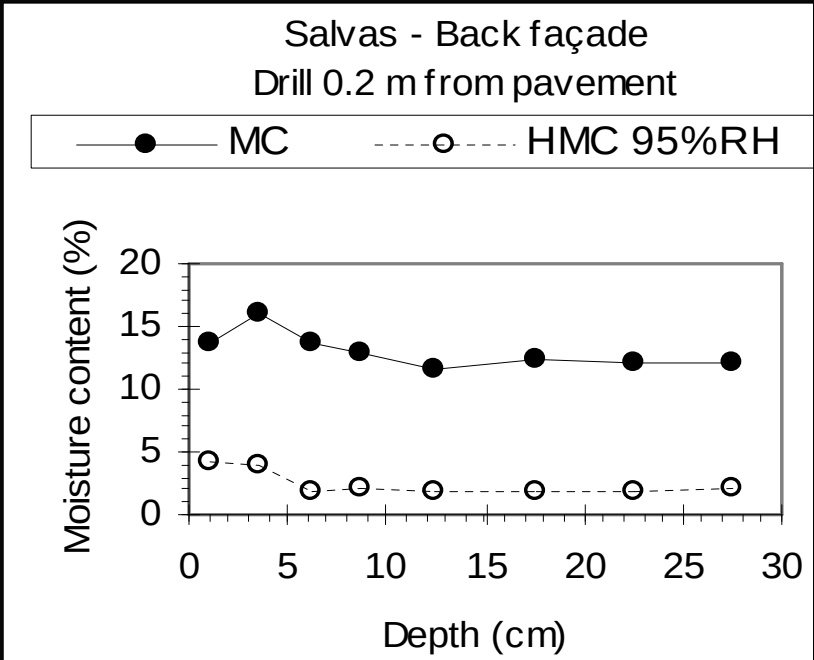


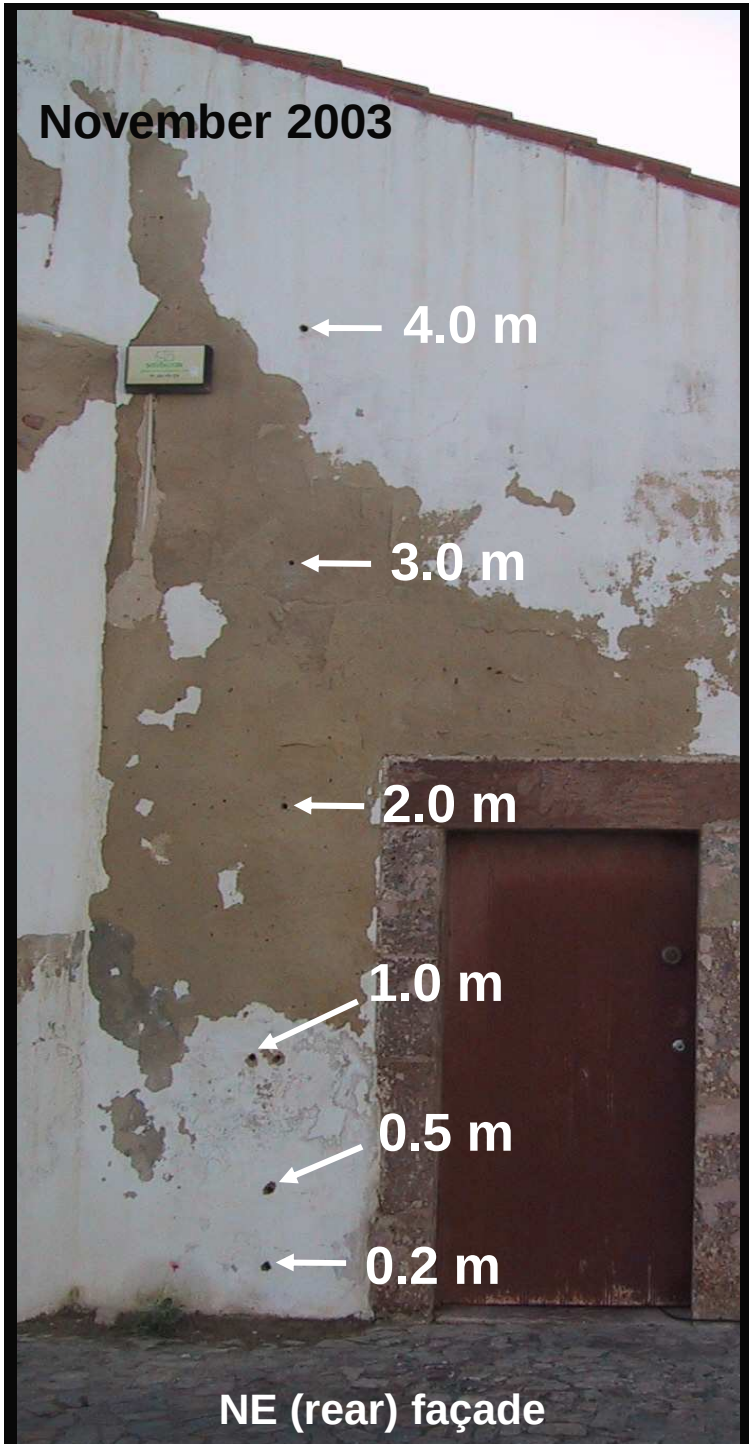


- MC => rising damp seems very significant:
  - at the base of the wall, the MC is very high (and much higher than the HMC)
  - MC decreases with the distance to the pavement
- HMC => the stronger accumulation of salt occurs at around 2m from the pavement
  - close to the ground the moisture content is very high => stage I conditions => efflorescence (washed out …)



In-depth analysis at the lower drilling hole (0.2 m from the pavement)

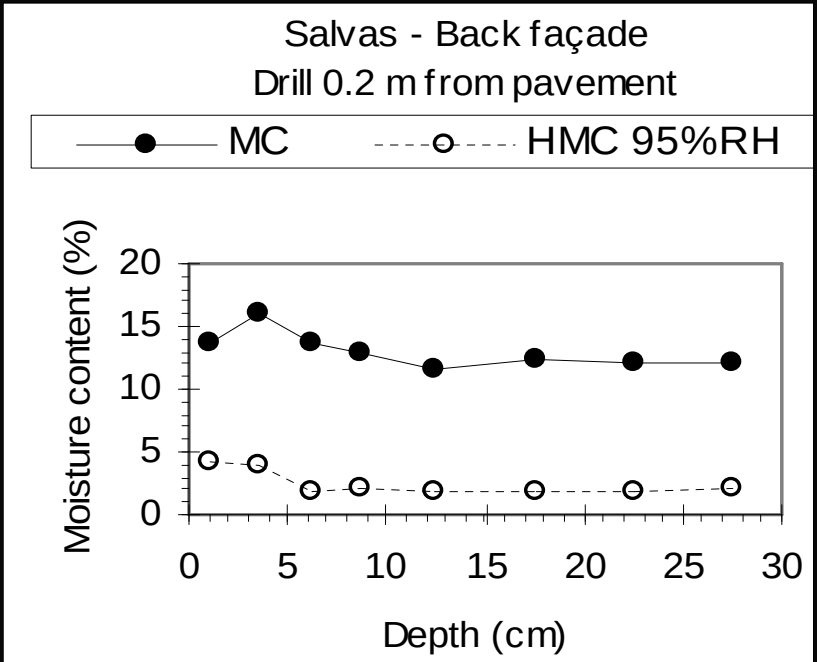




In-depth analysis at the lower drilling hole (0.2 m from the pavement):

- both the MC and the HMC are constant inside the wall
- the MC is high and much higher than the HMC

Features characteristic of rising damp…



XDR/EDS on the fine fraction
(3 mm thick sample)

Halite (NaCl)	+/++
Calcite, $CaCO_3$	+++
Quartz, SiO_2	++
Feldspars	vtg/+
Mica	vtg

Ion content of samples 0-2cm

Height (m)	Na^+	K^+	Mg^{2+}	Cl^-	NO_3^-	SO_4^{2-}
3.0	**0.33**	**0.07**	**nd**	**0.60**	**0.33**	**0.08**
0.5	**0.05**	**0.04**	**nd**	**0.16**	**0.04**	**0.09**

WTA classification for anion content (WTA 1991):
low content, **medium content**, **high content**

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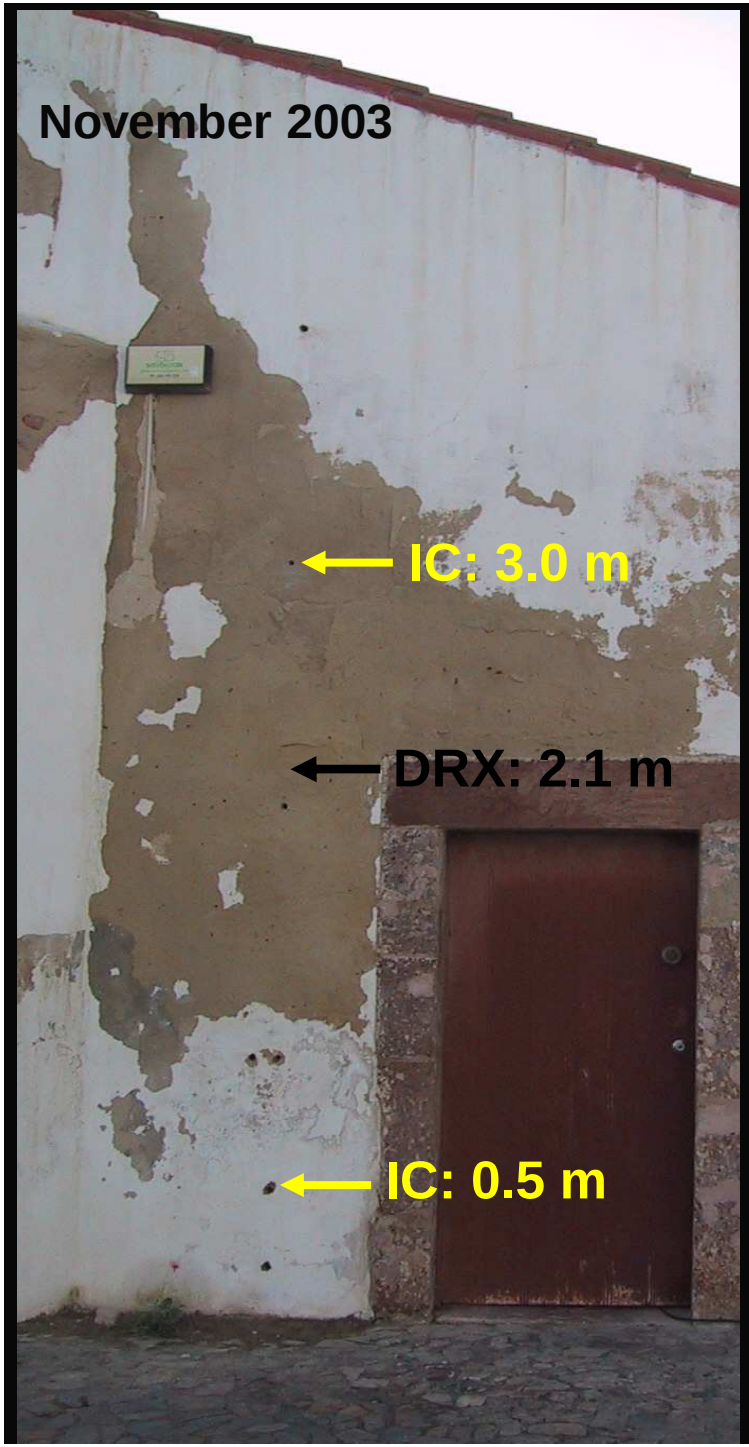

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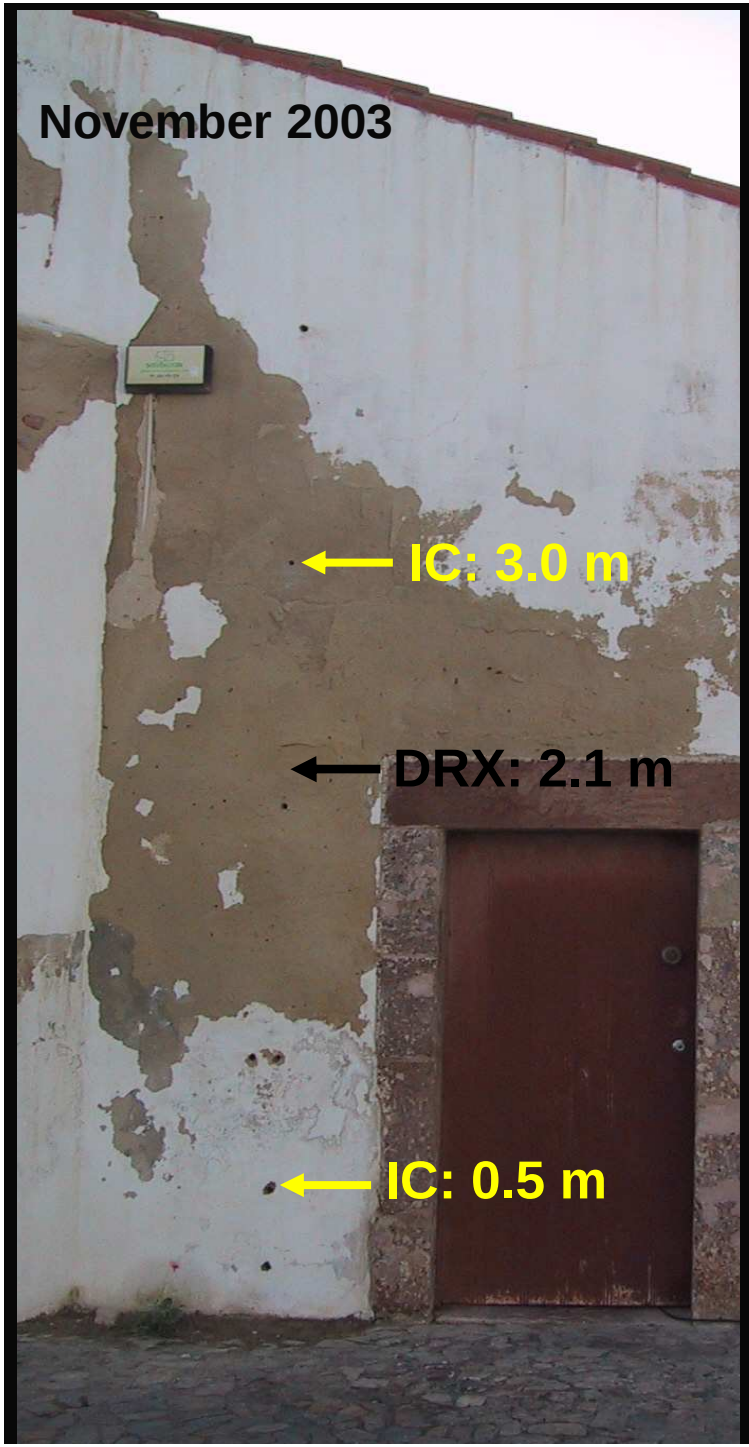

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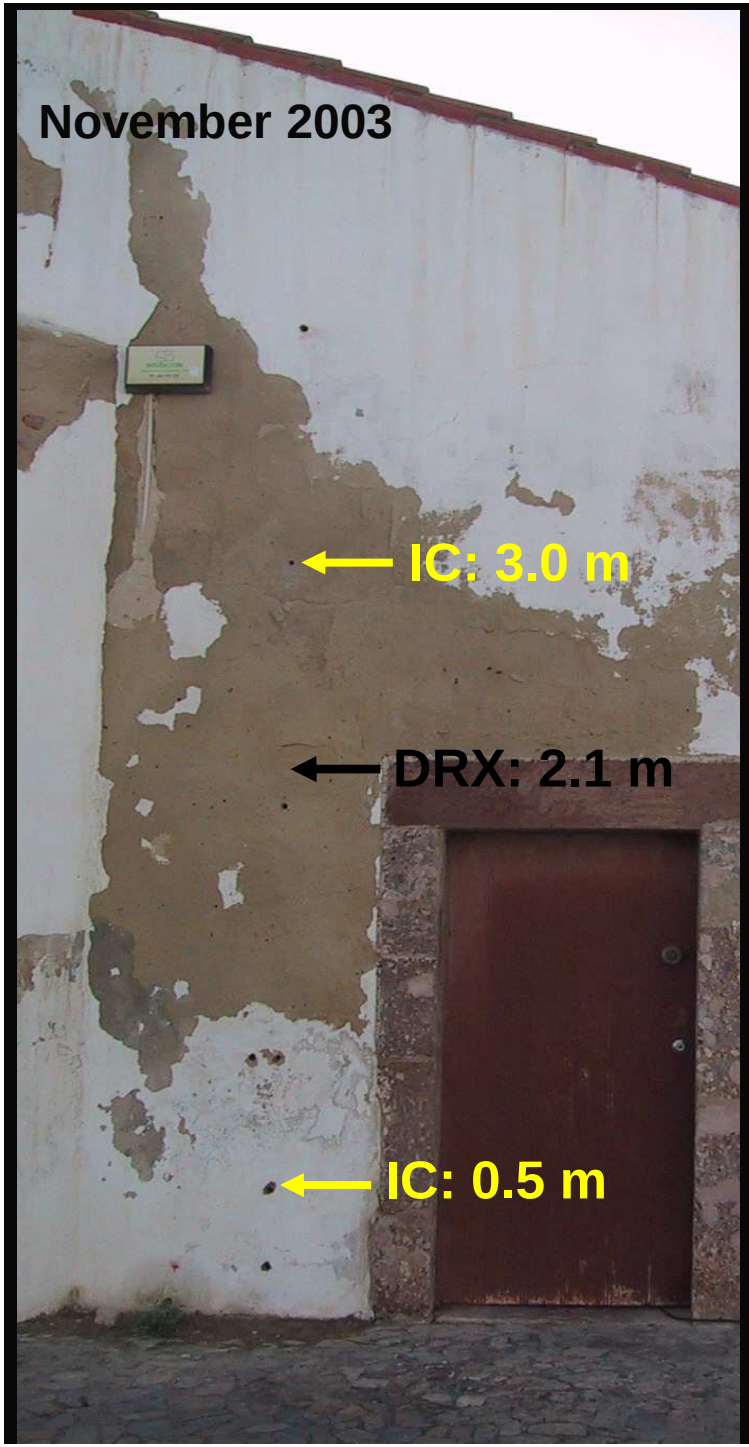

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1 - Salvas Church, Sines

Conclusions

- Rising damp is very significant
- Salts: chloride (sea) + some nitrate (ground)

Key recommendations

- Prevent the ingress of chloride => hardly feasible …

⇒ Prevent rising damp (prevents also the access of the nitrate):

  - investigate possible contribution of the old fountain
  - damp proof course ?

- Use a plaster that allows drying of the wall (salt transporting)
- Use a paint with good adherence (some surface decay is still expected) … silicate?

2 - Alhos-Vedros tide-mill

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NW (front) façade

situated between the kettle (artificial lake meant to accumulate water during the high tide) and the river branch

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Materials (1999):

- plasters were replaced up to:
  - 2.6m in the NW wall
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  - 1.0m in the SE wall
  - around NW windows
- traditional artificial hydraulic lime mortar
- common emulsion paint (interior + exterior)

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Damage (2002):

- efflorescence, peeling of the paint, sanding of the plaster – in the interior
- affects mostly the (new) plaster

2 - Alhos-Vedros tide-mill

XDR on efflorescence (NW wall)

Termonatrite ($Na_2CO_3.H_2O$)	+
Gaylussite, $Na_2Ca(CO_3)2.5H_2O$	+
Trona ($Na_2H(CO_3)2.2H_2O$)	+
Halite (NaCl)	+
Calcium hydroxide (Ca(OH)2)	+
Calcite, $CaCO_3$	+
Quartz, SiO_2	++
Feldspars / mica / caulinite	+

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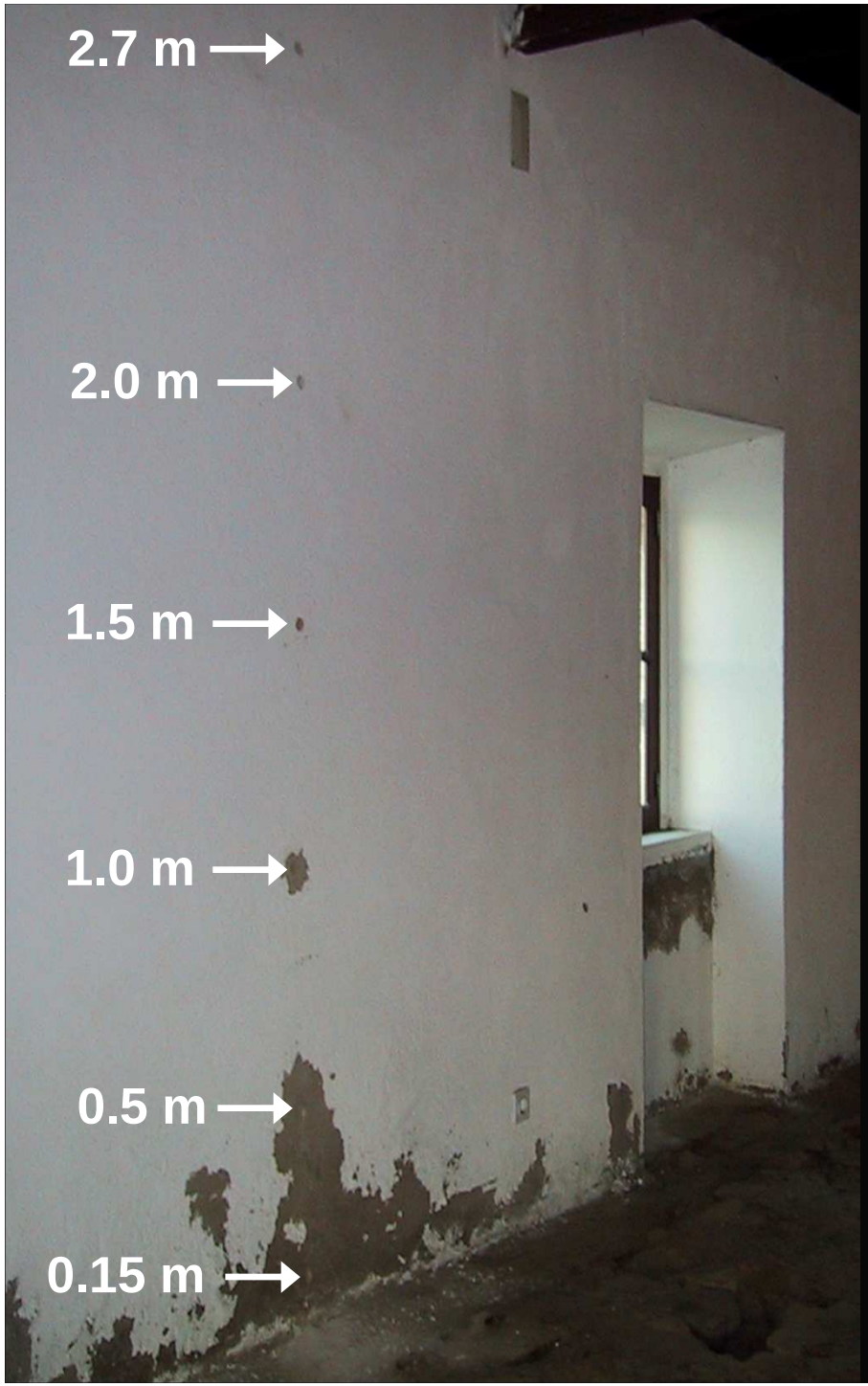
Gaylussite, $Na_2Ca(CO_3)2.5H_2O$

Trona ($Na_2H(CO_3)2.2H_2O$)

Halite (NaCl)

- sodium chloride:
  - probably carried by some capillary rising moisture or by salt mist
- efflorescence mainly composed of alkali-carbonate salts:
  - derive probably from the plaster (artificial hydraulic lime…)


2.7 m
2.0 m
1.5 m
1.0 m
0.5 m
0.15 m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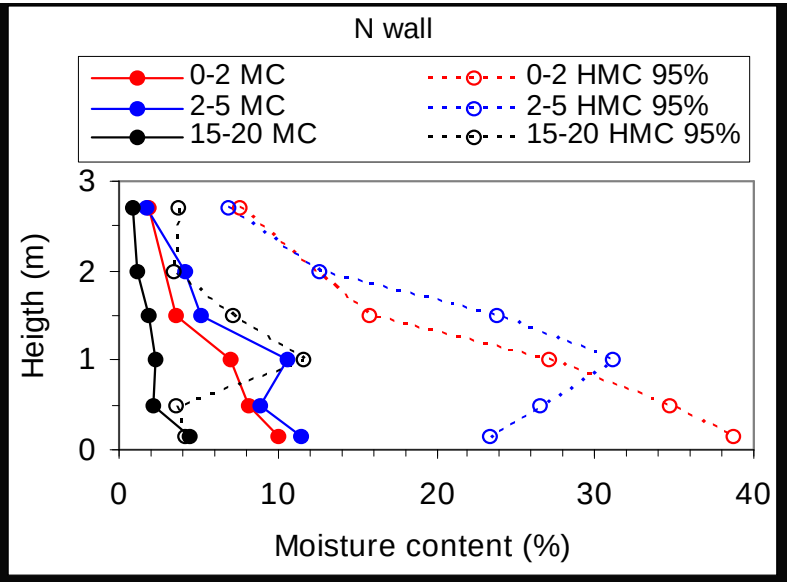
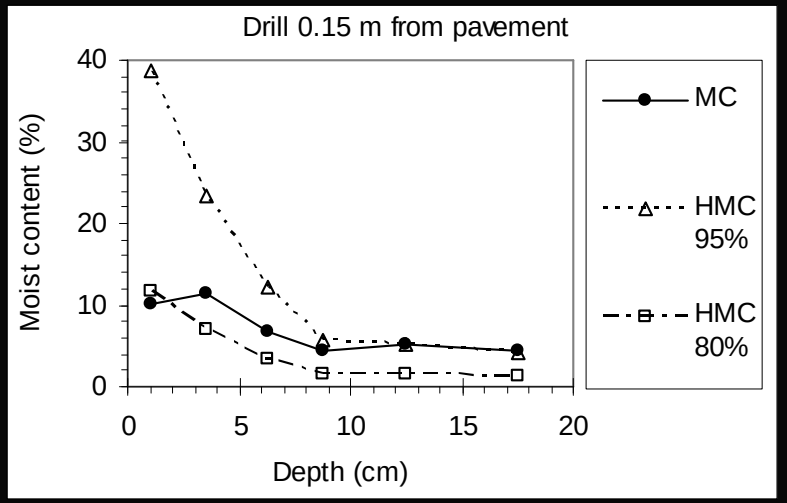
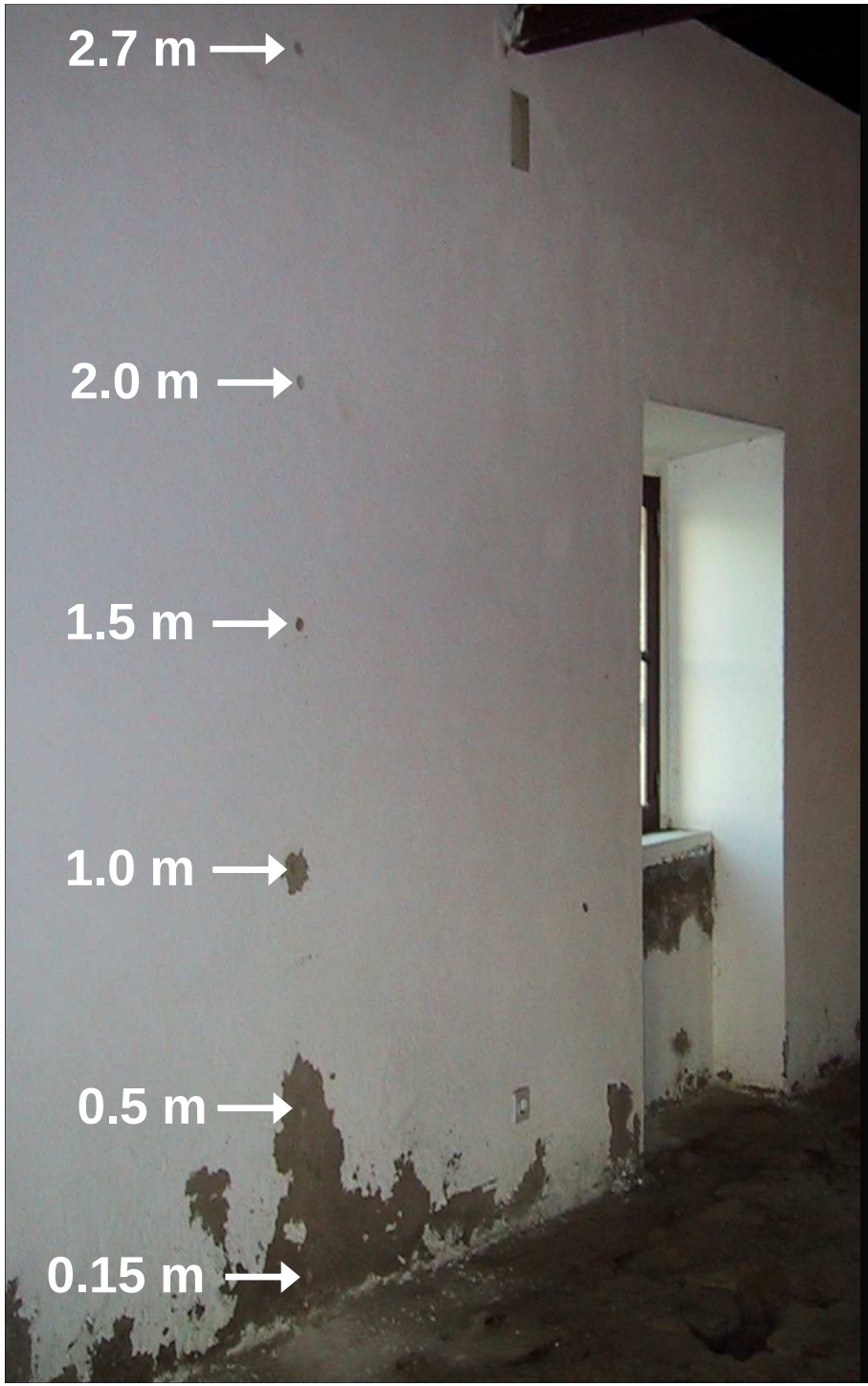
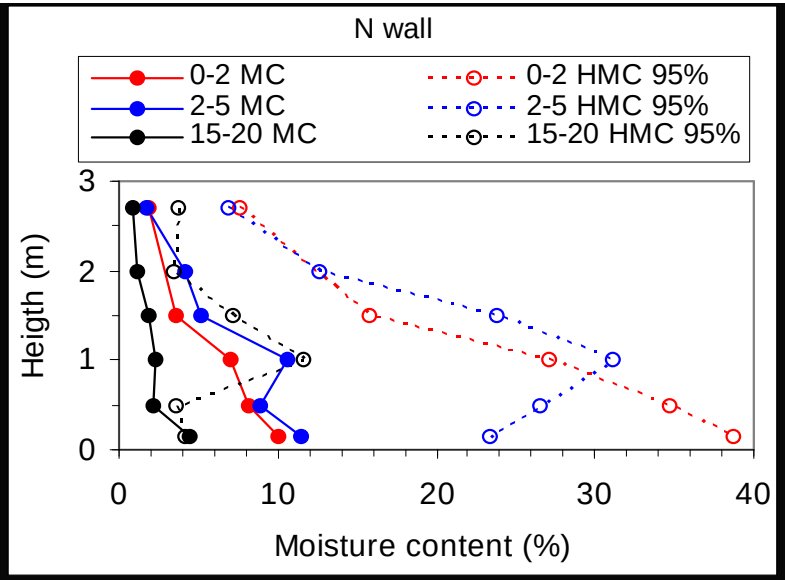
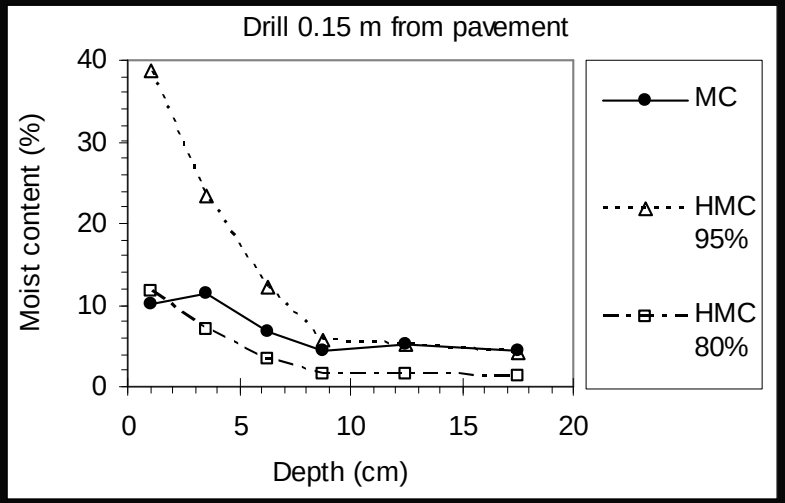

N wall
0-2 MC
2-5 MC
15-20 MC
0-2 HMC 95%
2-5 HMC 95%
15-20 HMC 95%
Heigth (m)
0
1
2
3
0
10
20
30
40
Moisture content (%)


Drill 0.15 m from pavement
Moist content (%)
0
10
20
30
40
0
5
10
15
20
Depth (cm)
MC
HMC 95%
HMC 80%







the MC is low inside the wall:

=> <u>rising damp is not the main problem</u>, despite the direct contact of the mill foundations with the river water

2 - Alhos-Vedros tide-mill

Where does the water come from?

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Where does the water come from?

circumstantial evidence …

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Where does the water come from?
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Salt damage:

- close to the pavement

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Where does the water come from?
circumstantial evidence …

Salt damage:

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- around the NW windows

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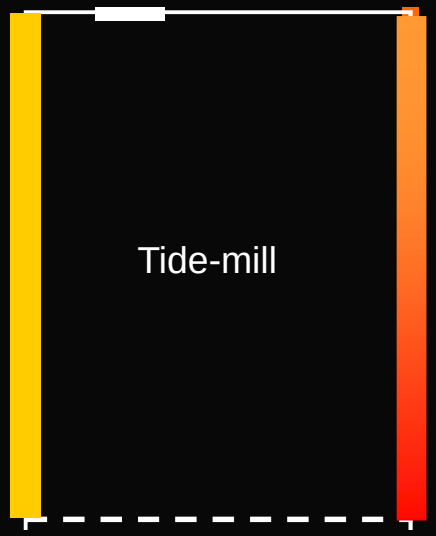

Salt damage:

- close to the pavement
- around the NW windows
- more intense on the NW wall than on the SE wall

Damage intensity

2 - Alhos-Vedros tide-mill

Where does the water come from?
circumstantial evidence …

Salt damage:

- close to the pavement
- around the NW windows
- more intense on the NW wall than on the SE wall
- NW wall: increases towards the N corner

Damage intensity

Hypothesis: damage occurs on colder surfaces where condensation hazard is higher

2 - Alhos-Vedros tide-mill

Where does the water come from?
circumstantial evidence …

Cold /wet day

Sun suddenly appeared

Air temp raised rapidly

Wet spots start appearing (condensation…)

November 2002

2 - Alhos-Vedros tide-mill

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… the main reason for the observed decay seems to lay in the plaster itself:

Key recommendations

- Prevent the a access of chloride => hardly feasible …

⇒ try test plaster of low alkali content (prevents formation of alkali carbonate salts)

2 - Alhos-Vedros tide-mill

Conclusions

- Rising damp is not very significant
- Moisture source: probably dew point condensation
- Salts: alkali carbonate + some sodium chloride (sea)
- Damage affects mostly the (new) hydraulic plaster

… the main reason for the observed decay seems to lay in the plaster itself:

Key recommendations

- Prevent the a access of chloride => hardly feasible …

⇒ try test plaster of low alkali content (prevents formation of alkali carbonate salts)

- will work as a museum => surface free of damage => salt accumulating plaster

3 - House of Despacho

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History

- built early XVIII century
- used as sacristy and mortuary chapel

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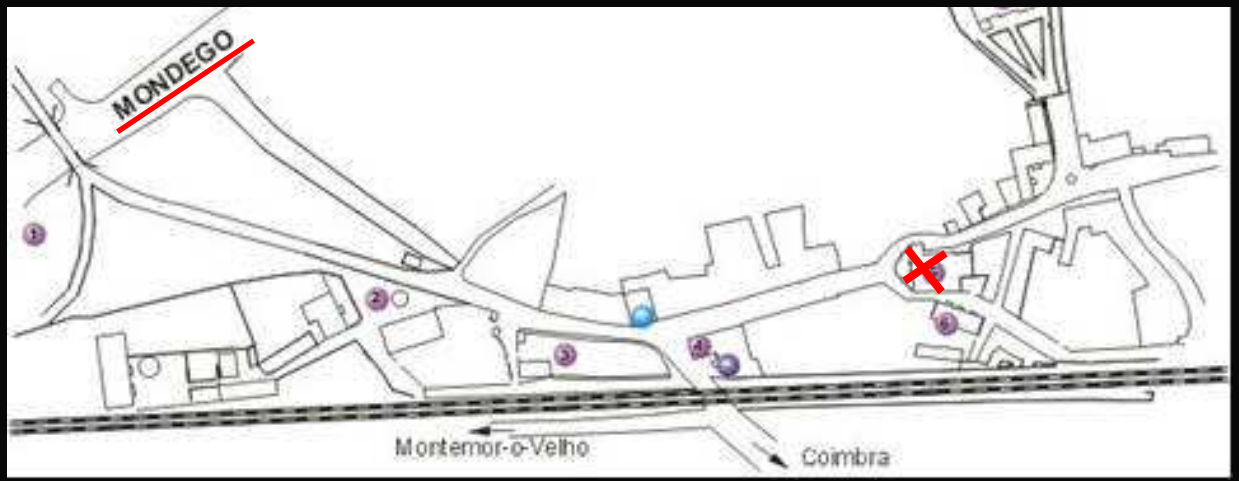

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  - cement-based adhesion coat

3 - House of Despacho

http://emiliotorrao.blogspot.pt/2011/02/montemor-o-velho-pode-conhecer-novas.html

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Damage (2003)

- few months after the works ended…
- affects 50% of the plastered area
- cracking + efflorescence
- affects upper part of walls (1.0/1.5 - 2.7 m)

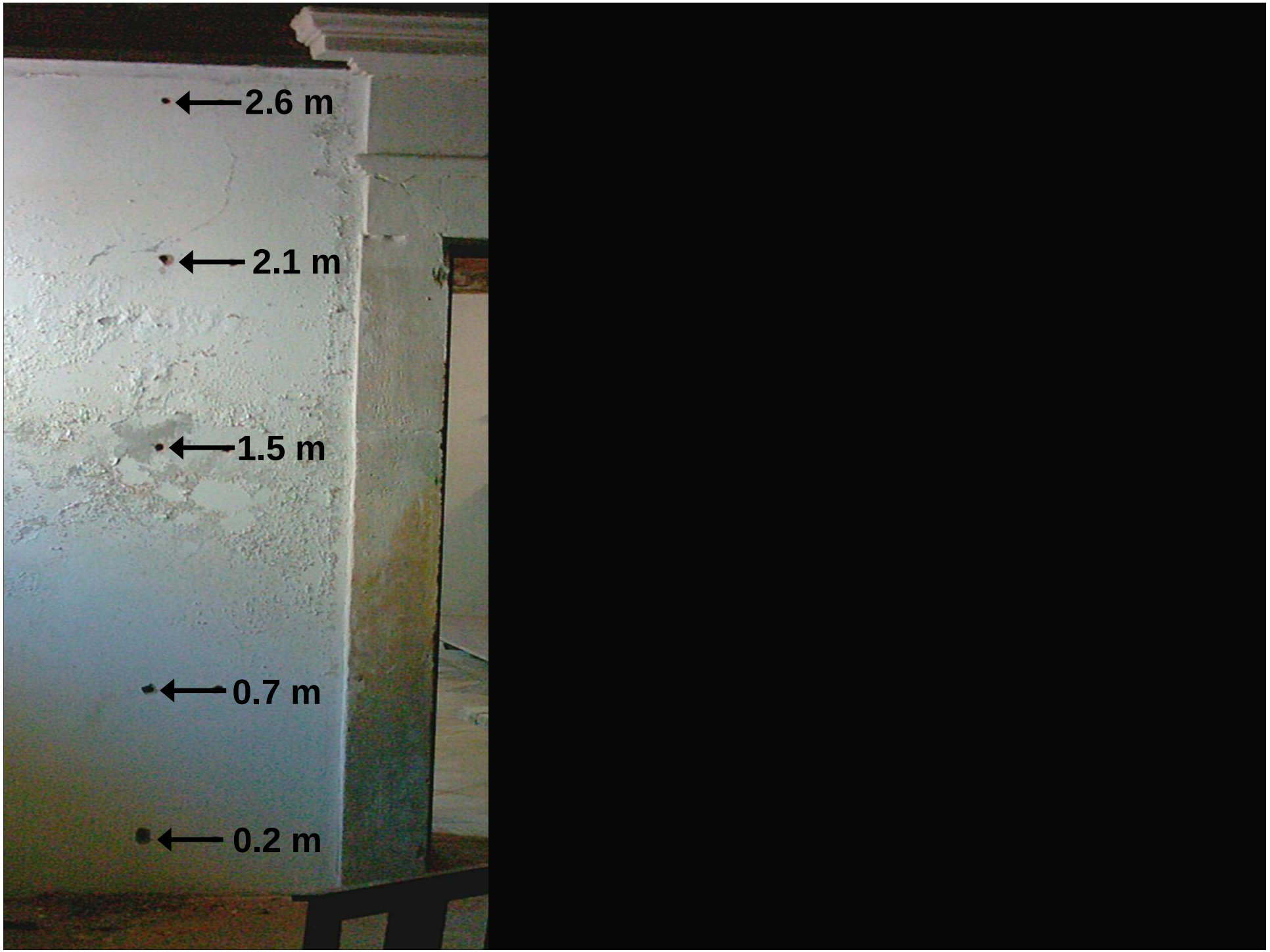
Evolution of damage:

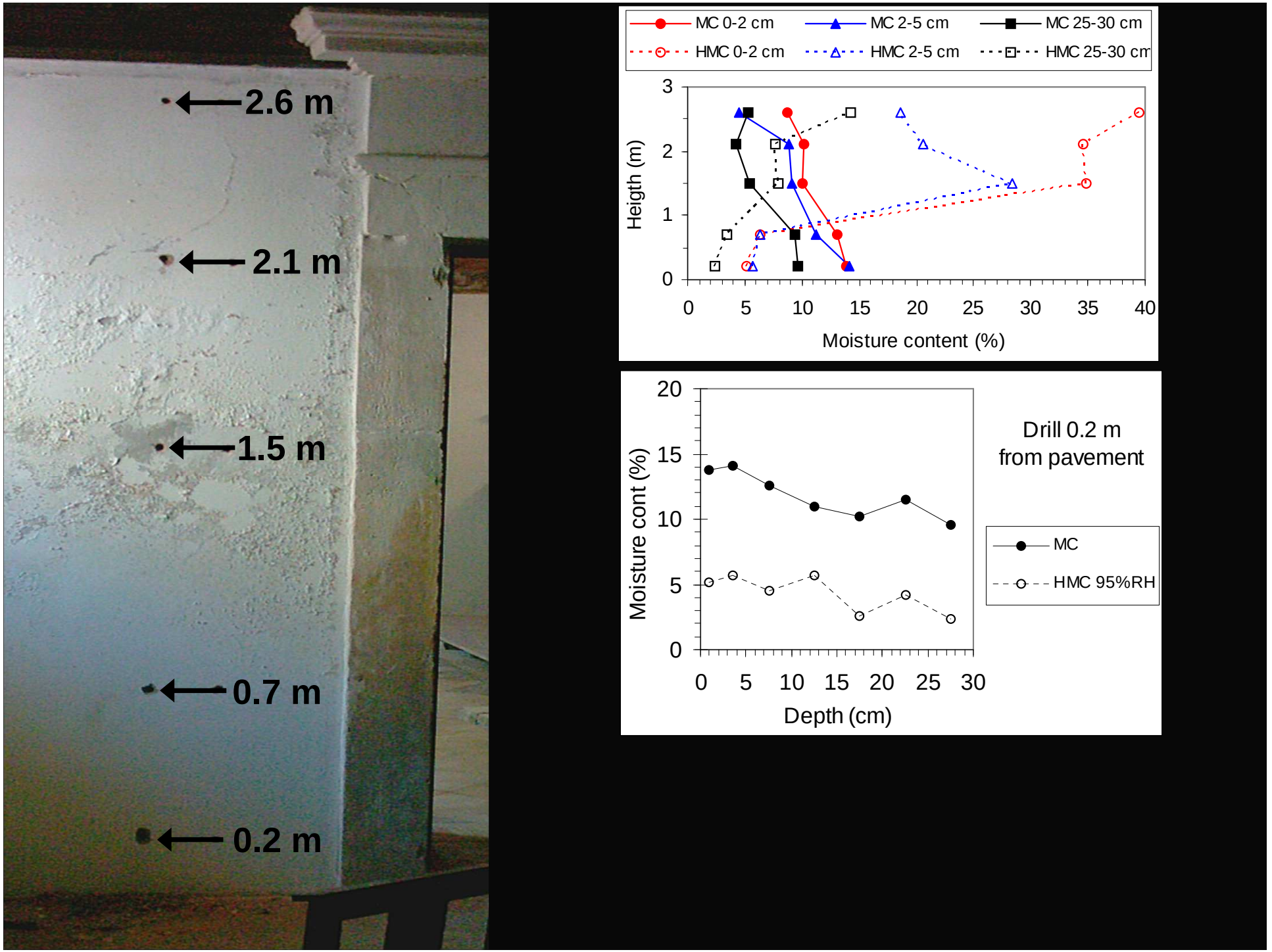
1) efflorescence develops at the interface plaster/paint

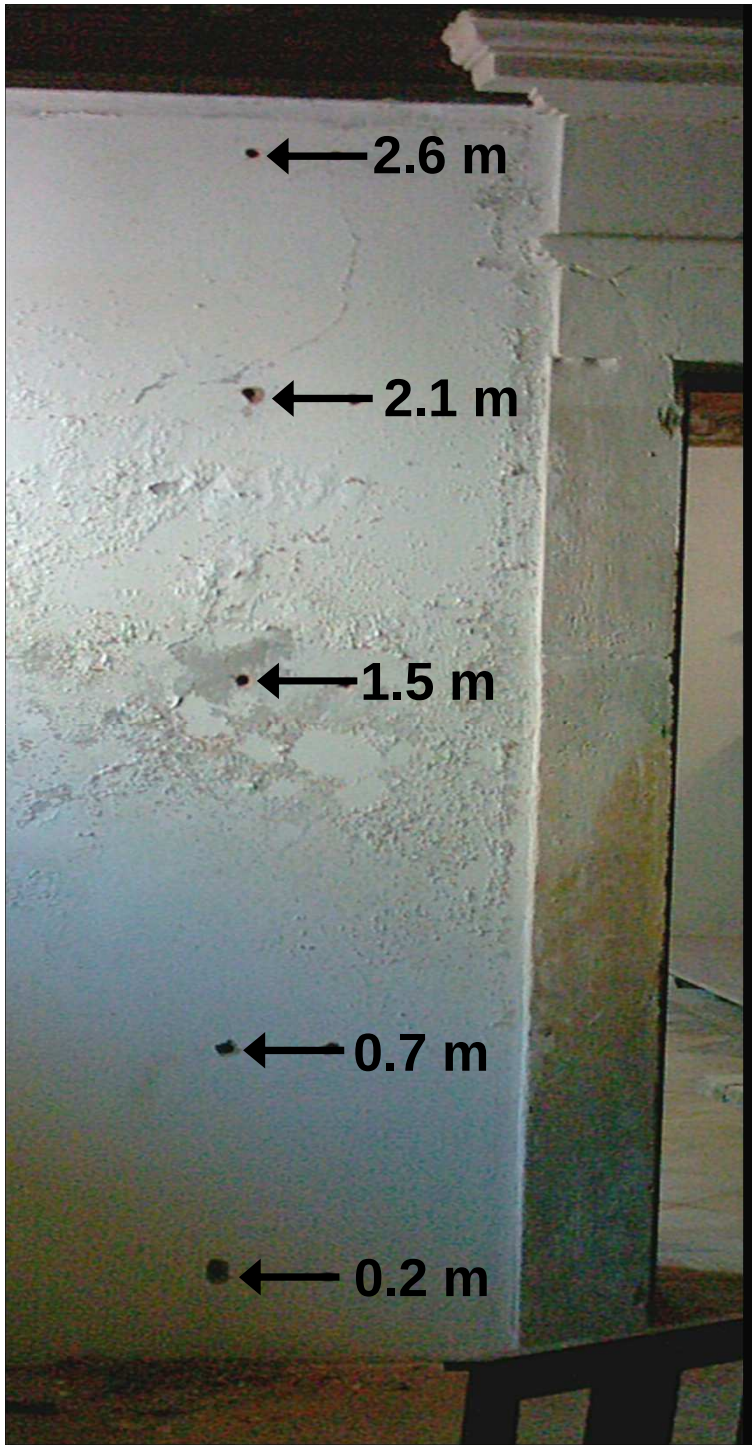
2) the crystals push the paint layer and cause its rupture

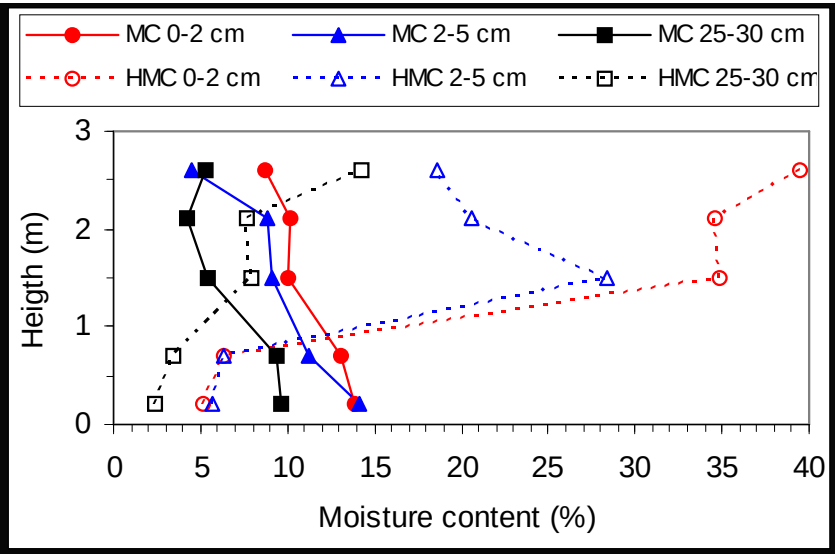
3) long needle-like crystals appear + sanding of the plaster

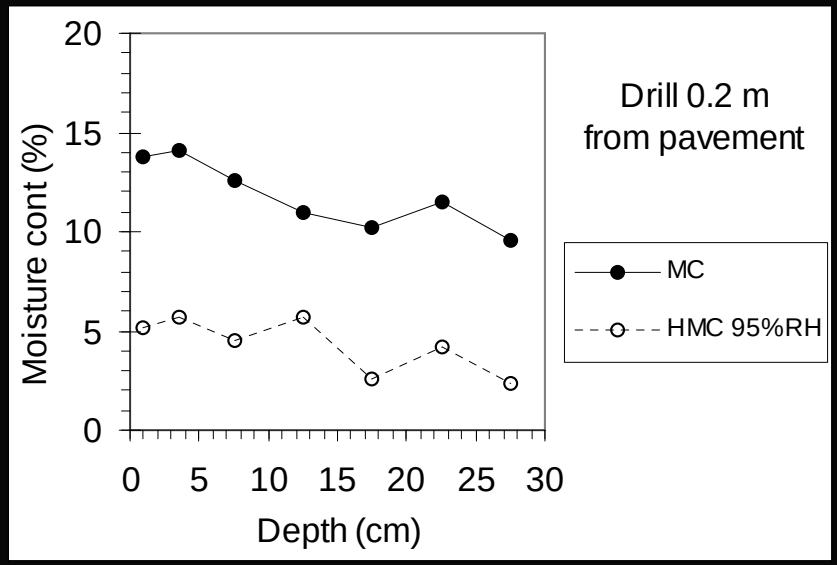
plaster cracks = critical points were the degradation first starts and develops faster


2.6 m
2.1 m
1.5 m
0.7 m
0.2 m

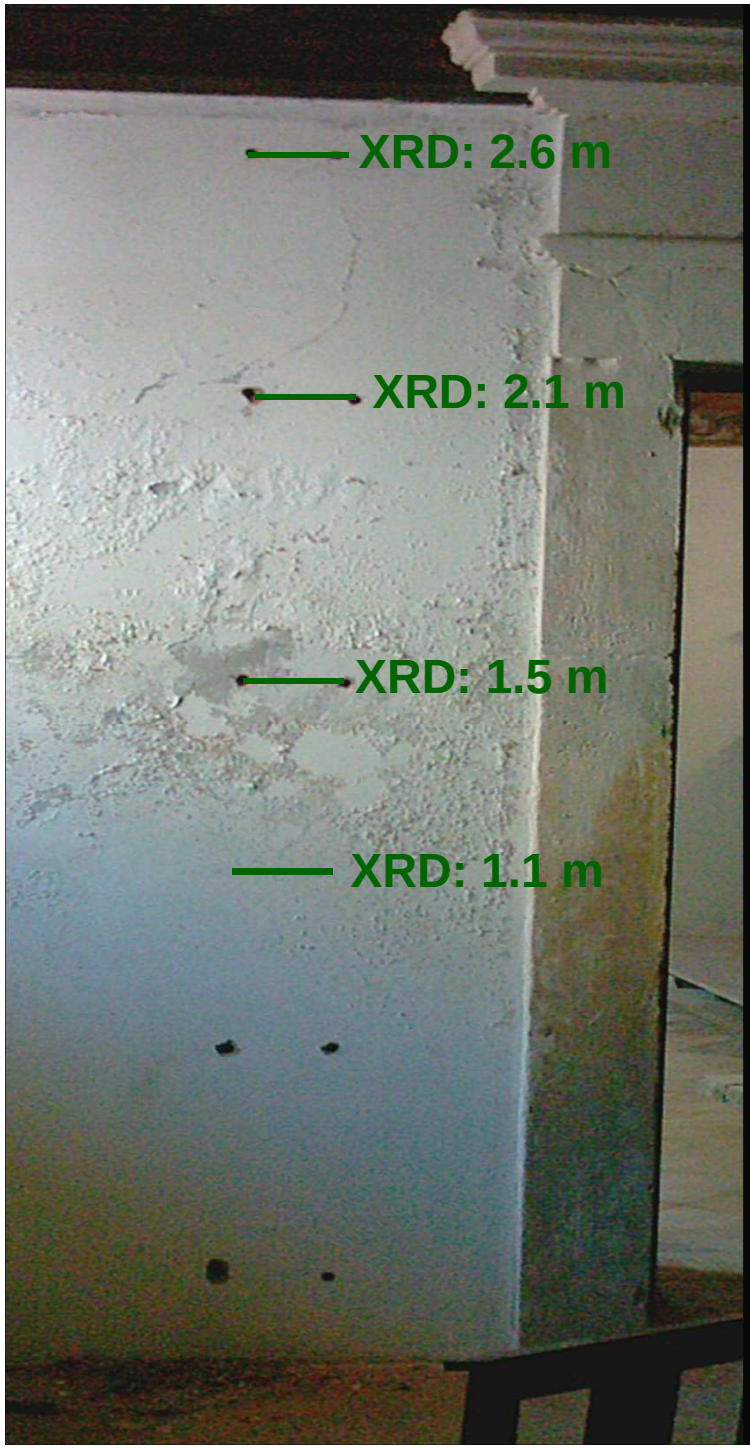

2.6 m
2.1 m
1.5 m
0.7 m
0.2 m
MC 0-2 cm
MC 2-5 cm
MC 25-30 cm
HMC 0-2 cm
HMC 2-5 cm
HMC 25-30 cm
Heigth (m)
Moisture content (%)
Moisture cont (%)
Depth (cm)
Drill 0.2 m
from pavement
MC
HMC 95%RH



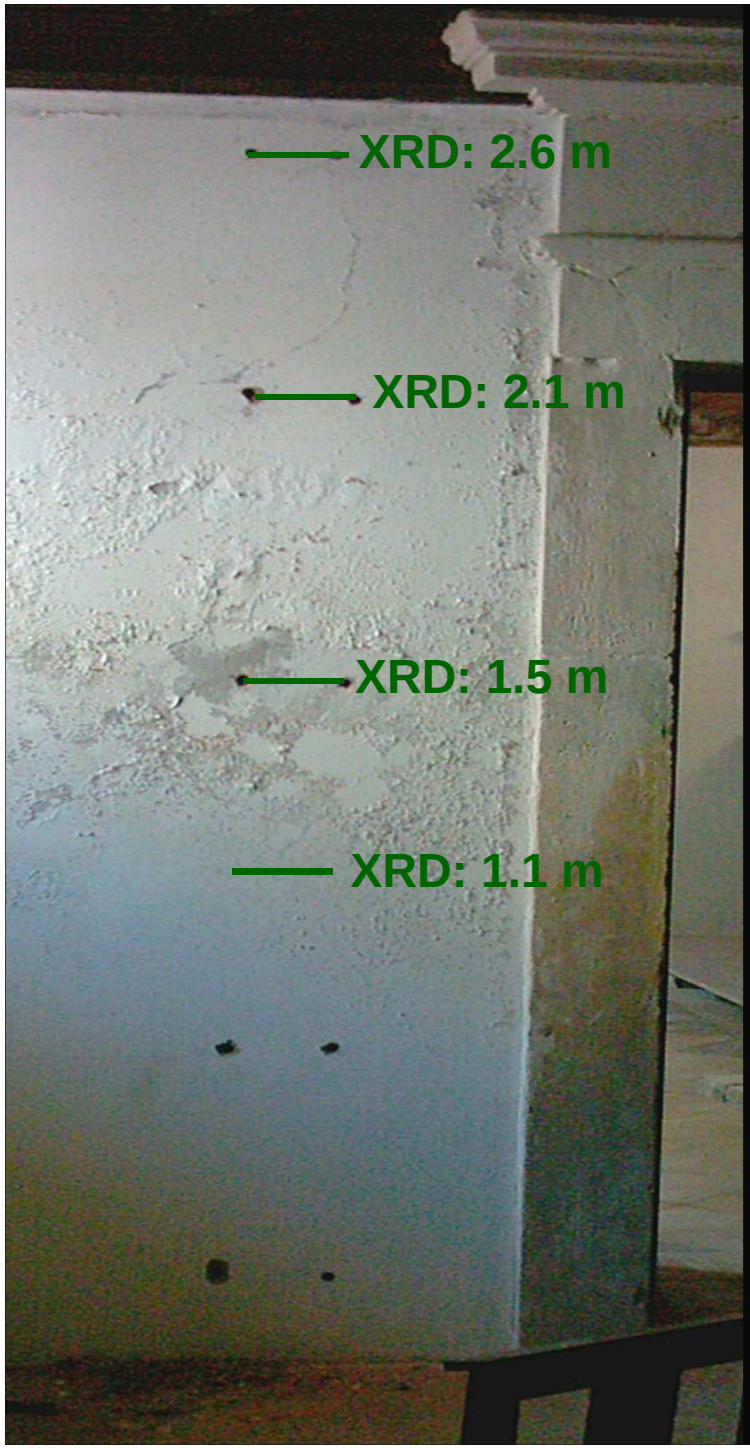




Significant amount of moisture exists inside the walls



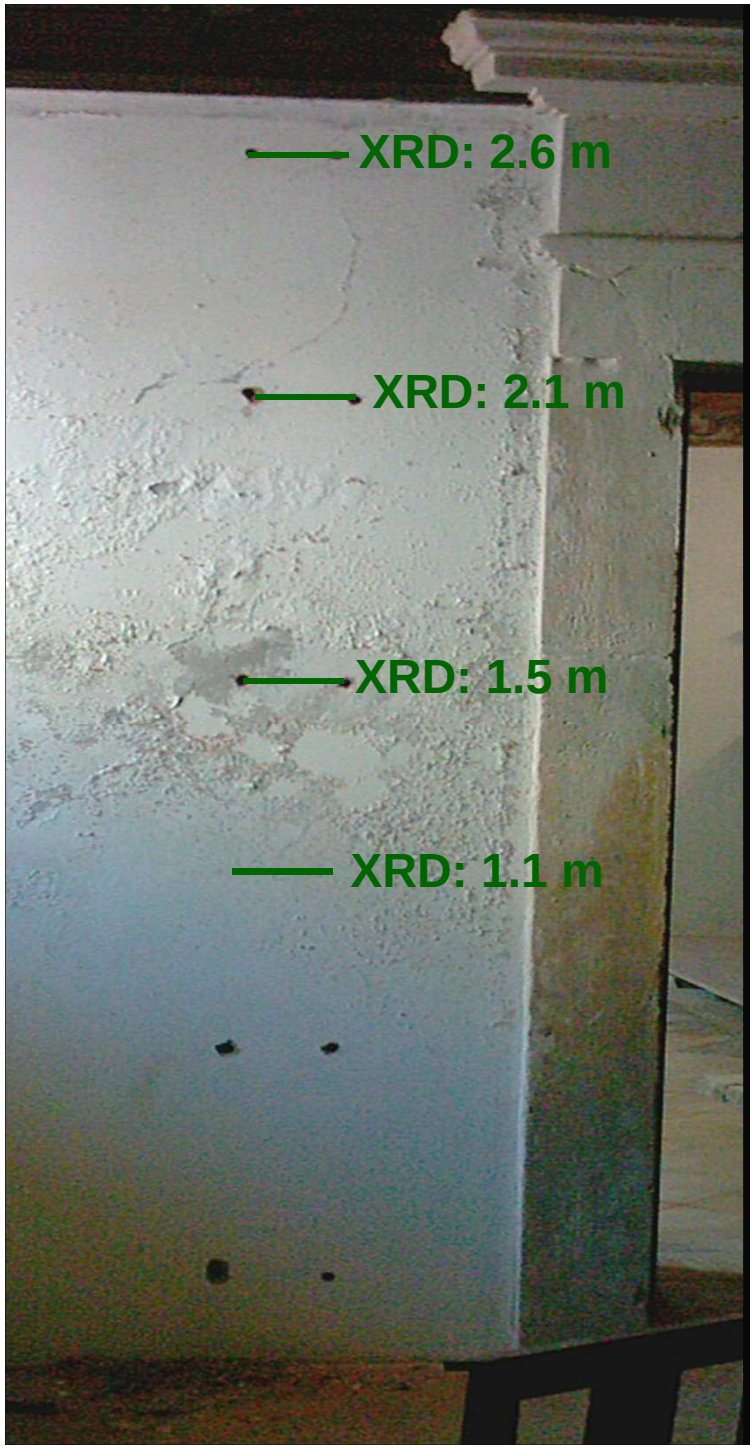
3 - House of Despacho



3 - House of Despacho

XDR on efflorescence

Crystalline compounds	Sampling height (m)			
	1.1	1.5	2.1	2.6
Hydrous sodium carbonate, $Na_2CO_3.7H_2O$	++	+	-	-
Natron, $Na_2CO_3.10H2O$	+	++	-	-
Gaylussite, $Na_2Ca(CO_3)_2.5H_2O$	-	+	+	++
Quartz, SiO_2	-	-	vtg	-
Cristobalite, SiO_2	?	?	+	+
Calcite, $CaCO_3$	+	+	++	+/++
Rutile, TiO_2	+	+	++	++



3 - House of Despacho

Hydrous sodium carbonate, $Na_2CO_3.7H_2O$

Natron, $Na_2CO_3.10H2O$

Gaylussite, $Na_2Ca(CO_3)_2.5H_2O$

3 - House of Despacho

Conclusions

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High moisture content inside the walls

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High moisture content inside the walls:

- rising damp?
- accumulation during the flood?

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=> repeat MC/HMC measurements => know evolution…

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Key recommendations

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High moisture content inside the walls:

- rising damp?
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=> repeat MC/HMC measurements => know evolution…

Key recommendations

- plaster of low alkali content (no cement-based adhesion layer…)

3 - House of Despacho

Conclusions

High moisture content inside the walls:

- rising damp?
- accumulation during the flood?

=> repeat MC/HMC measurements => know evolution…

Key recommendations

- plaster of low alkali content (no cement-based adhesion layer…)
- do not use hydrophobic paint
  - hydrophobic surface layer => lower evaporation rate (stage II conditions)
  - subflorescence disrupts the paint layer (rather, let the salt go out…)

4 - Sta Clara Monastery

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- located in Coimbra (20 km from the coast)
- study: ground floor of the cloister gallery
- built in the first half of the XVIII century

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- study: ground floor of the cloister gallery
- built in the first half of the XVIII century
- traditional cement plaster + acrylic emulsion paint
- applied in 1987

4 - Sta Clara Monastery

Damage:

- either upper on the walls, next to stone elements

4 - Sta Clara Monastery

Damage:

- either upper on the walls, next to stone elements
- or close to the pavement

Damage close to the pavement

XDR on sanded surface material (NE wall)

Damage close to the pavement

XDR on sanded surface material (NE wall)

Damage up on the wall

Damage close to the pavement

XDR on sanded surface material (NE wall)

Damage up on the wall

XDR on efflorescence (NW wall)

Damage close to the pavement

Damage up on the wall

XDR on sanded surface material (NE wall)

Trona, $Na_3H(CO3)_2.2H_2O$	?/vtg
Gaylussite, $Na_2Ca(CO_3)_2.5H_2O$	+
Niter,KNO_3	?/vtg
Calcite, $CaCO_3$	+++
Dolomite, $CaMg(CO_3)_2$	+
Quartz, SiO_2	+

XDR on efflorescence (NW wall)

Trona, $Na_3H(CO3)_2.2H_2O$	++/+++
Gaylussite, $Na_2Ca(CO_3)_2.5H_2O$	-
Niter,KNO_3	-
Calcite, $CaCO_3$	++/+++
Dolomite, $CaMg(CO_3)_2$	-
Quartz, SiO_2	vtg

Damage close to the pavement

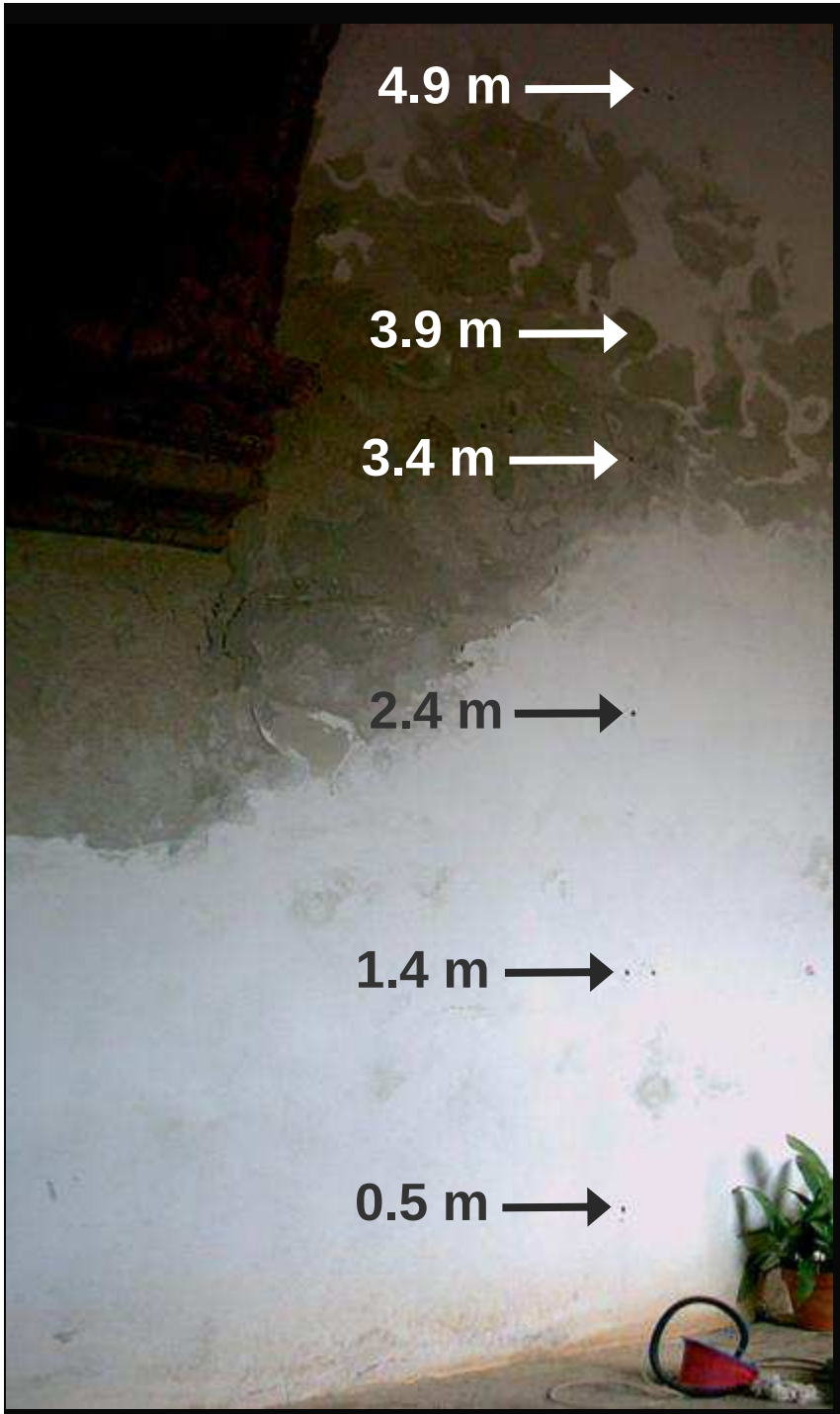
Trona, $Na_3H(CO3)_2.2H_2O$

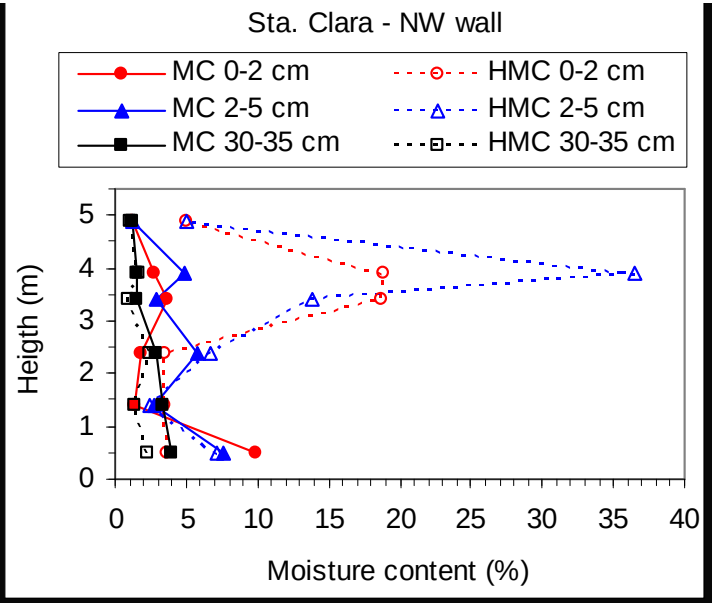
Gaylussite, $Na_2Ca(CO_3)_2.5H_2O$

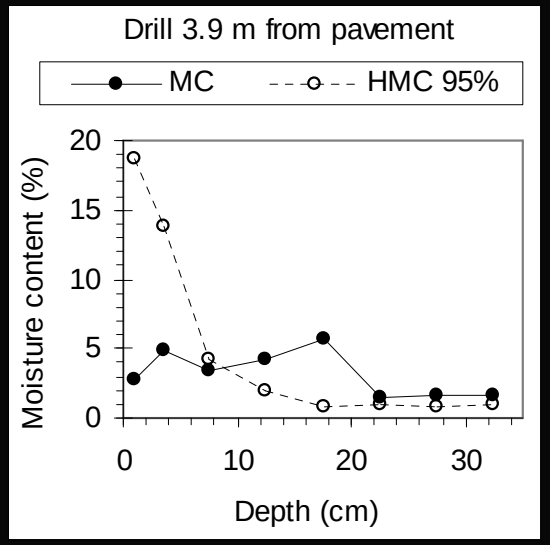
Niter,KNO_3

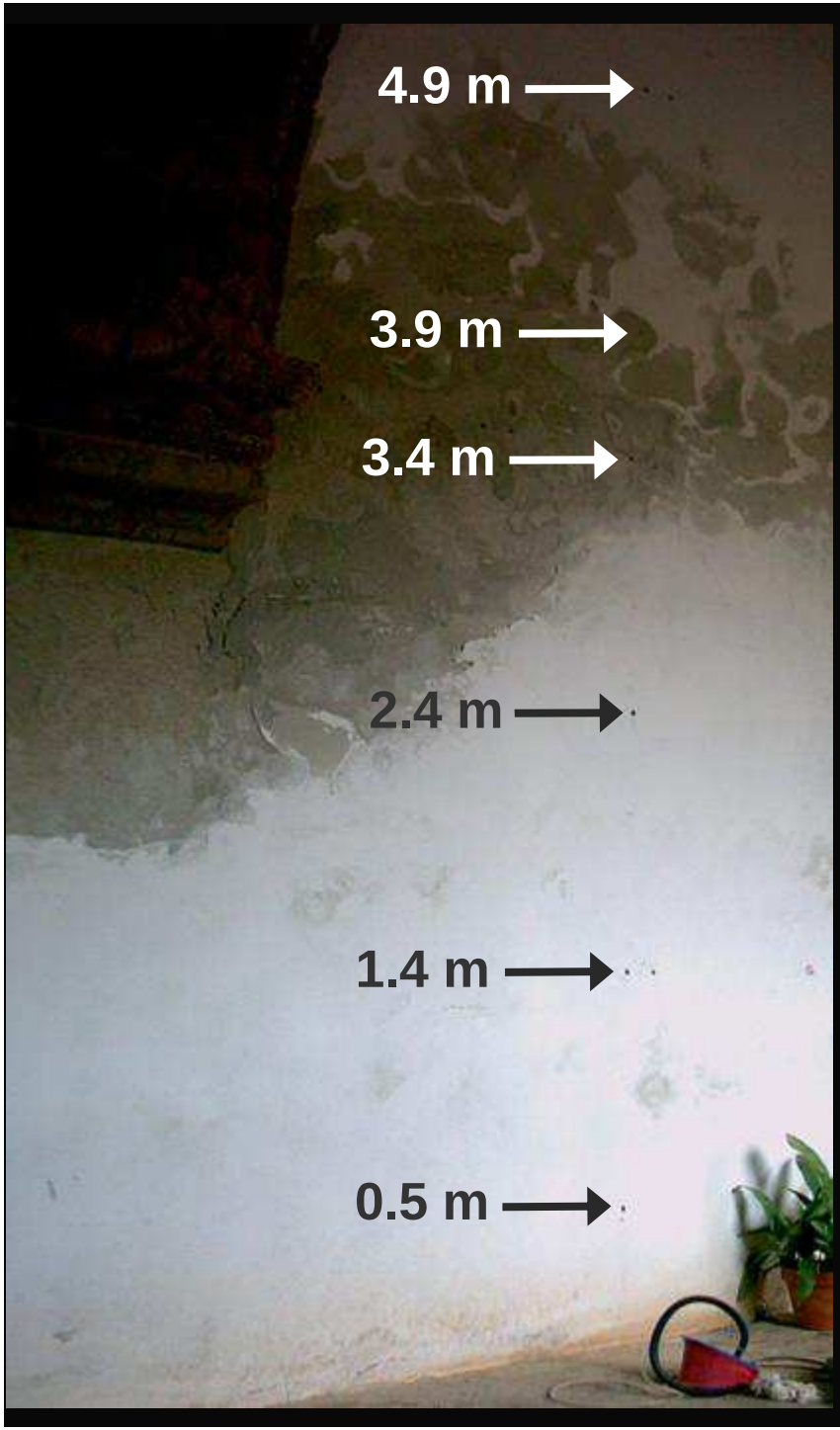
Damage up on the wall

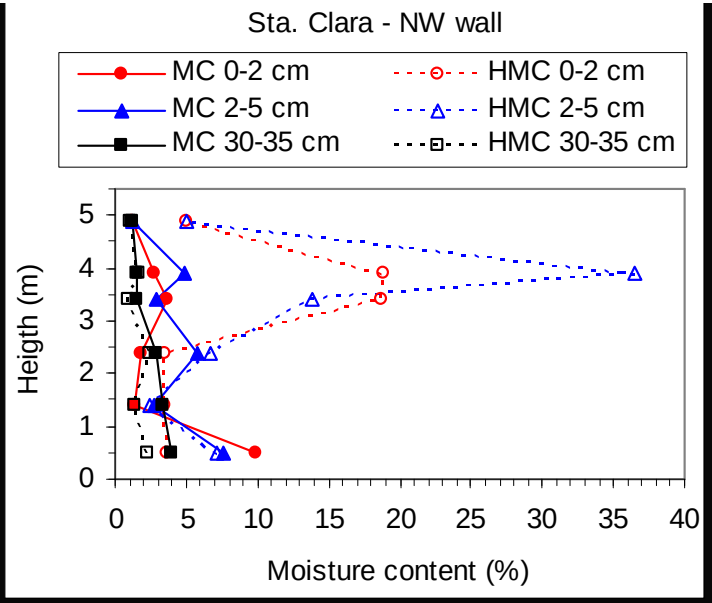
Trona, $Na_3H(CO3)_2.2H_2O$

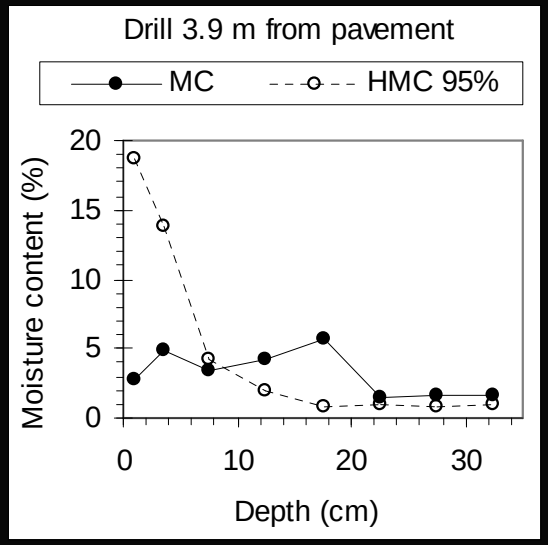

4.9 m
3.9 m
3.4 m
2.4 m
1.4 m
0.5 m


Sta. Clara - NW wall
MC 0-2 cm
MC 2-5 cm
MC 30-35 cm
HMC 0-2 cm
HMC 2-5 cm
HMC 30-35 cm
Heigth (m)
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
Moisture content (%)


Drill 3.9 m from pavement
MC
HMC 95%
Moisture content (%)
0
5
10
15
20
0
10
20
30
Depth (cm)

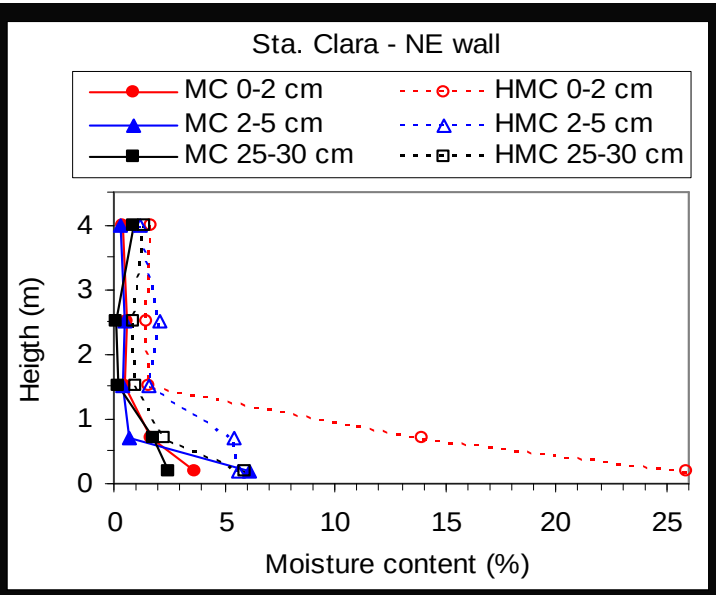


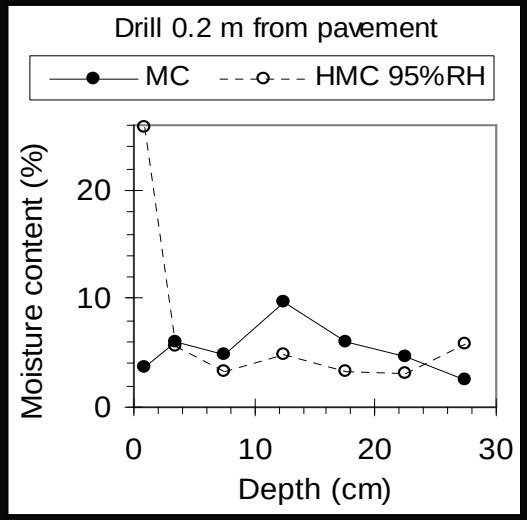


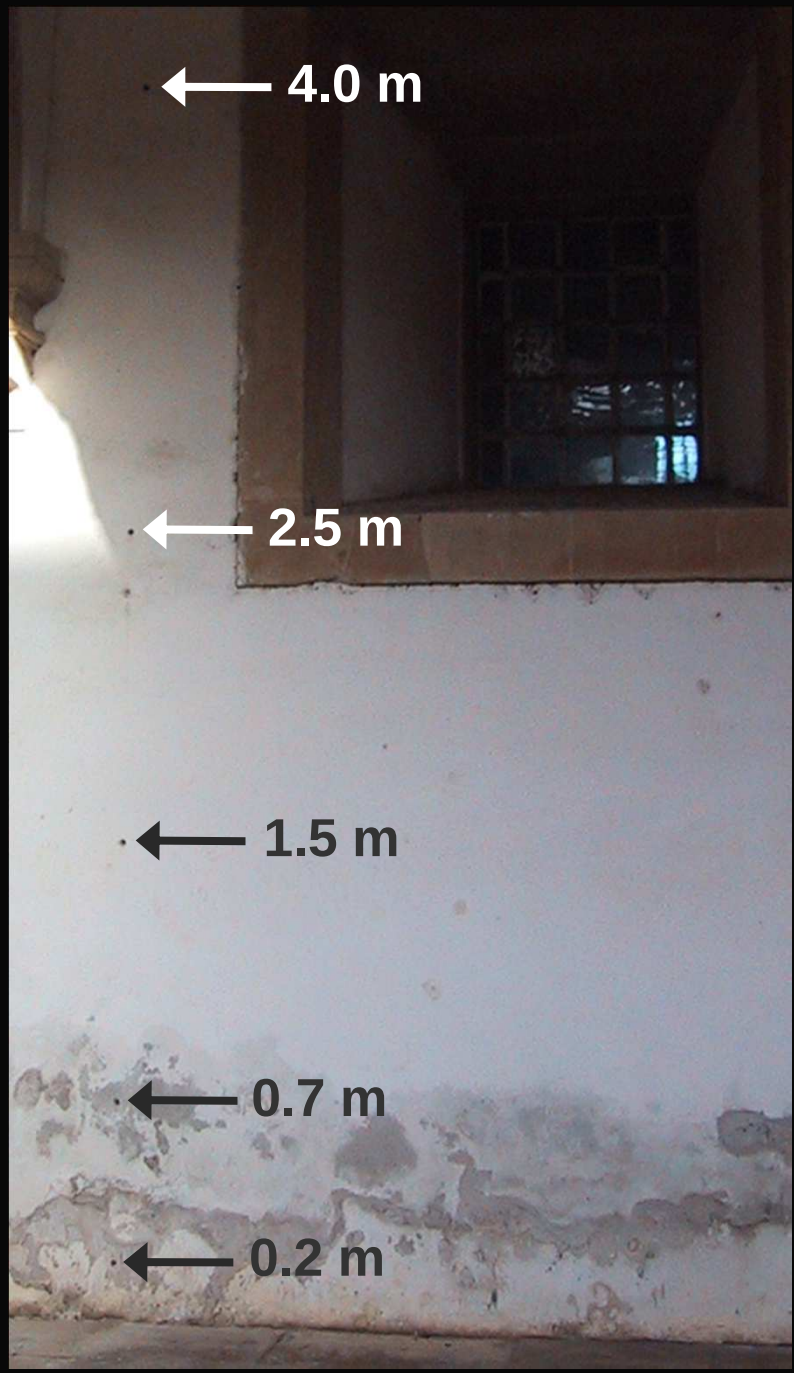


- Rising damp seems limited (< 5% inside)
- In-depth MC/HMC profile at the level of maximum damage => MC decreases towards the interior of the wall (at the deepest points, MC ≈ HMC)

=> superficial source of liquid moisture is likely







- Rising damp seems low also here
- In-depth MC/HMC at the bottom of the wall => MC decreases towards the interior of the wall (at the deepest point, the MC is lower than the HMC)

=> superficial source of liquid moisture is likely also here

February 2004

January 2004

Possible moisture sources

February 2004

January 2004

Possible moisture sources

Soil surface water (cloister garden)?

Hygroscopic water (stone) ?

Condensation (mainly on the stone) ?

4 - Sta Clara Monastery

Conclusions

4 - Sta Clara Monastery

Conclusions

Moisture source? superficial source is likely …

4 - Sta Clara Monastery

Conclusions

Moisture source? superficial source is likely …

- rising damp is low => soil surface water (cloister garden)?

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Salts = carbonate (plaster) + nitrate close to the pavement (some rising damp)

4 - Sta Clara Monastery

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Key recommendations

4 - Sta Clara Monastery

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- rising damp is low => soil surface water (cloister garden)?
- hygroscopic water (stone) ?
- condensation (mainly on the stone) ?

Salts = carbonate (plaster) + nitrate close to the pavement (some rising damp)

Key recommendations

- correct drainage of rain water in the cloister garden
- analyse the stone (hygroscopic features … salts? => dessalination?)
- plaster of low alkali content

Inspection form

Inspection form

FICHA DE INSPECÇAO DE OBRA

INFORMAÇÃO GERAL		
Data e hora da visita:	Técnicos presentes:	Condições meteorológicas:
Nome do edifício:	Morada/localidade:	
Entidade responsável/dono:	Interesse patrimonial (classificação):	
Descrição genérica:		
Uso (actual e anteriores): - Ocupado em permanência? - Ligação/ao - Armazenamento bens soltos - Animais domésticos, portões, etc.		
Volumetria e orientação: - Norte (seguem) - Nº de corpos - Dimensões em planta - Nº de pisos - Pé-direito		
Ambiente envolvente: - Zona costeira / marítima - Zona urbana / rural / industrial - Características particulares		
Tipologia construtiva (incluindo revestimentos): - Fundações - Paredes - Pisos - Coberturas - Caixilharias		
Estado geral de conservação:	Envolvente exterior	- Coberturas: - Paredes: - Vãos:
	Estrutura:	
	Interior	- Paredes: - Pavimentos: - Tectos:
Fases de construção e datas:		
Eventos/anomalias relevantes (cheias, incêndios, colapsos/assentamentos, demolições, etc) e datas:		
Intervenções construtivas conhecidas, consolidação, reparação (datas que relevantes): - Data - Objectivo - Elementos intervencionados - Soluções utilizadas - Empreiteiro/executor		
Observações:		

FICHA DE INSPECÇAO DE OBRA

ANOMALIAS
Tipo de degradação (terminologia Damage Atlas):
Elementos afectados (discriminar estado de conservação): - Fachadas ou paramentos interiores - Paredes exteriores ou interiores - Paredes estruturais, caves - Zonas húmidas - Pavimentos / tectos
Tipologia construtiva e constituição dos elementos afectados: - Tipo de alvenaria, reboco, pintura - Piso térreo sobre impermeabilização / arrefecimento? - Cota de capilaridade na base das paredes?
Extensão (% da área total dos elementos afectados) e profundidade (mm) da degradação:
Localização das zonas degradadas: - Focos dispersos / degradação extensiva - Piso térreo / elevados / último piso - Base da parede / topo / outras zonas - Junto vãos ou outros elementos? - Sistematicamente sobre ou junto a reboços orgânicos? - Orientação das paredes degradadas
História da anomalia - informações precisas (pe: - Primeiros sinais (tipo e data) - Ocorrência sistemática em determinada época do ano? - Lipás obras? - Evolução dos danos: - Medidas tomadas (limpeza paramentos, reparações, etc)
Colheita de amostras - Destino e identificação das amostras: - Localização (esquema + fotos) - Profundidade - Dimensões - Espessura do elemento (parede) - Materiais constituintes
Testes realizados e resultados: - HR e temperatura - Percussão / som oco - Etc.
Hipóteses (diagnóstico):
Observações (condições particulares de exposição, presença de líquenes, etc):

GENERAL INFORMATION

Inspection
- date / time
- weather conditions
- performed by

Identification of the building
- building name / address / location
- responsible entity / owner
- heritage interest / classification

Use(s) of the building (current and previous)
- Use(s)
- Heating
- Storage of salted goods
- Domestic animals, pigeons, etc.

Building dimensions and orientation
- plan / diagram (indicate North)
- dimensions
- different floors / bodies

Surrounding environment
• coastal / interior
• urban / rural / industrial
• particular features …

Constructive typology (materials + functions)
- structure
- foundations
- walls (ex: cavity walls? filled with what?)
- doors/windows
- roof
- pavements
- surrounding terrain / pavement - impermeable or diverting rain water to the base of the walls?

Water supply / drainage systems
location of the pipes + state of conservation

Perceived ventilation

Construction
phases and dates

State of conservation
envelope, structure, interiors

Events / disasters
floods, fires, partial collapses, landslides, demolitions, etc. - dates

Past, present or planned interventions
dates, objectives
elements addressed, constructive solutions
contractor / restorer

ANOMALIES

Type of degradation
describe (may use some classification, but also describe with your own words + fotos)

Elements affected
facades / internal coverings
exterior / interior walls
semi-buried walls, basements
other…

Typology of the affected elements
type of masonry, plaster/render, paint
damp proof courses?

Extension of the damage
area (% of the total area)
depth

Degraded areas
disperse spots / extensive degradation
ground floor / high floor
wall base / top / middle height of the wall
next to specific elements
exposition of the affected walls (N, S, W, E)

History of the anomaly
who provided this information
early signs (type and date)
systematic occurrence at certain time of the year?
how long after the works?
evolution of the damage => several observations or indirect information from users (specify):

- winter / summer
- rain / dry weather

measures taken (cleaning, repairs, etc.)

Sampling
clear identification of the samples
purpose (tests to carry out)
location (+ foto)
depth
dimensions
thickness of the element (wall)
constituent materials

Site tests / quantitative data
RH / air temp / solar radiation (at least qualitatively)
percussion: hollow sound => detached layers

Hypothesis (diagnosis)

Case-studies in plastering and rendering mortars. Sampling and testing for salts

Thank you