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
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
Methodology for assessment and diagnosis of damage

• Site-inspections
• Sampling / testing
  • Moisture and salt distribution evaluated in selected walls
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
  - Moisture and salt distribution evaluated in selected walls
    - Samples collected by powder-drilling
    - 16 or 20 mm rotary drills
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
  - Moisture and salt distribution evaluated in selected walls
    - Samples collected by powder-drilling
    - 16 or 20 mm rotary drills
    - Several heights and depths
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
  - Moisture and salt distribution evaluated in selected walls
    - Samples collected by powder-drilling
    - 16 or 20 mm rotary drills
    - Several heights and depths
    - MC => mass loss after oven drying at 105°C
    - HMC => mass increase at 20°C and 96% RH
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
  - Moisture and salt distribution evaluated in selected walls
    - Samples collected by powder-drilling
    - 16 or 20 mm rotary drills
    - Several heights and depths
    - MC => mass loss after oven drying at 105°C
    - HMC => mass increase at 20°C and 95% RH
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
  - Moisture and salt distribution evaluated in selected walls
    - Samples collected by powder-drilling
    - 16 or 20 mm rotary drills
    - Several heights and depths
    - MC => mass loss after oven drying at 105ºC
    - HMC => mass increase at 20ºC and 96% RH
  - Soluble salts investigated by means of:
    - Ion chromatography
    - XRD / EDS
Methodology for assessment and diagnosis of damage

- Site-inspections
- Sampling / testing
  - Moisture and salt distribution evaluated in selected walls
    - Samples collected by powder-drilling
    - 16 or 20 mm rotary drills
    - Several heights and depths
    - MC => mass loss after oven drying at 105ºC
    - HMC => mass increase at 20ºC and 96% RH
  - Soluble salts investigated by means of:
    - Ion chromatography => Na⁺, K⁺, Mg²⁺, Cl⁻, NO₃⁻, SO₄²⁻
    - 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
1 - Salvas Church, Sines

- 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

Damage (2004):
- 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

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

• Next to water fountain
 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

Salvas - Back façade

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>MC 0-2 cm</th>
<th>MC 2-5 cm</th>
<th>MC 25-30 cm</th>
<th>HMC 0-2 cm</th>
<th>HMC 2-5 cm</th>
<th>HMC 25-30 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
November 2003

• 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)

November 2003

Salvas - Back façade

Drill 0.2 m from pavement

Moisture content (%) vs. Depth (cm)

MC
HMC 95%RH

NE (rear) façade
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…

November 2003
November 2003

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

<table>
<thead>
<tr>
<th>Material</th>
<th>IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halite (NaCl)</td>
<td>+/++</td>
</tr>
<tr>
<td>Calcite, CaCO₃</td>
<td>+++</td>
</tr>
<tr>
<td>Quartz, SiO₂</td>
<td>++</td>
</tr>
<tr>
<td>Feldspars</td>
<td>vtg/+</td>
</tr>
<tr>
<td>Mica</td>
<td>vtg</td>
</tr>
</tbody>
</table>

Ion content of samples 0-2cm

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>NO₃⁻</th>
<th>SO₄²⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>0.33</td>
<td>0.07</td>
<td>nd</td>
<td>0.60</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>0.5</td>
<td>0.05</td>
<td>0.04</td>
<td>nd</td>
<td>0.16</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

WTA classification for anion content (WTA 1991):

- low content
- medium content
- high content

- DRX/EDS => halite (sea water ... marine fog ...)
- IC => chloride (sea) + some nitrate (ground)
XDR/EDS on the fine fraction
(3 mm thick sample)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Halite (NaCl)</td>
<td>+/++</td>
</tr>
<tr>
<td>Calcite, CaCO₃</td>
<td>+++</td>
</tr>
<tr>
<td>Quartz, SiO₂</td>
<td>++</td>
</tr>
<tr>
<td>Feldspars</td>
<td>vtg/+</td>
</tr>
<tr>
<td>Mica</td>
<td>vtg</td>
</tr>
</tbody>
</table>

Ion content of samples 0-2cm

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>NO₃⁻</th>
<th>SO₄²⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>0.33</td>
<td>0.07</td>
<td>nd</td>
<td>0.60</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>0.5</td>
<td>0.05</td>
<td>0.04</td>
<td>nd</td>
<td>0.16</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

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

- DRX/EDS => halite (sea water ... marine fog ...)
- IC => chloride (sea) + some nitrate (ground)
XDR/EDS on the fine fraction
(3 mm thick sample)

<table>
<thead>
<tr>
<th>Material</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halite (NaCl)</td>
<td>+/-++</td>
</tr>
<tr>
<td>Calcite, CaCO₃</td>
<td>+++</td>
</tr>
<tr>
<td>Quartz, SiO₂</td>
<td>++</td>
</tr>
<tr>
<td>Feldspars</td>
<td>vtg/+</td>
</tr>
<tr>
<td>Mica</td>
<td>vtg</td>
</tr>
</tbody>
</table>

November 2003
November 2003

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

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halite (NaCl)</td>
<td>+/++</td>
</tr>
<tr>
<td>Calcite, CaCO$_3$</td>
<td>+++</td>
</tr>
<tr>
<td>Quartz, SiO$_2$</td>
<td>++</td>
</tr>
<tr>
<td>Feldspars</td>
<td>vtg/+</td>
</tr>
<tr>
<td>Mica</td>
<td>vtg</td>
</tr>
</tbody>
</table>

IC: 3.0 m

IC: 0.5 m

DRX: 2.1 m
XDR/EDS on the fine fraction
(3 mm thick sample)

<table>
<thead>
<tr>
<th>Material</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halite (NaCl)</td>
<td>++++</td>
</tr>
<tr>
<td>Calcite, CaCO₃</td>
<td>+++</td>
</tr>
<tr>
<td>Quartz, SiO₂</td>
<td>++</td>
</tr>
<tr>
<td>Feldspars</td>
<td>vtg/+</td>
</tr>
<tr>
<td>Mica</td>
<td>vtg</td>
</tr>
</tbody>
</table>

Ion content of samples 0-2cm

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>NO₃⁻</th>
<th>SO₄²⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>0.33</td>
<td>0.07</td>
<td>nd</td>
<td>0.60</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>0.5</td>
<td>0.05</td>
<td>0.04</td>
<td>nd</td>
<td>0.16</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

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

November 2003
XDR/EDS on the fine fraction (3 mm thick sample)

<table>
<thead>
<tr>
<th></th>
<th>Halite (NaCl)</th>
<th>Calcite, CaCO₃</th>
<th>Quartz, SiO₂</th>
<th>Feldspars</th>
<th>Mica</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>++/++</td>
<td>+++</td>
<td>++</td>
<td>vtg/+</td>
<td>vtg</td>
</tr>
</tbody>
</table>

Ion content of samples 0-2cm

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>NO₃⁻</th>
<th>SO₄²⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>0.33</td>
<td>0.07</td>
<td>nd</td>
<td>0.60</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>0.5</td>
<td>0.05</td>
<td>0.04</td>
<td>nd</td>
<td>0.16</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

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

November 2003
IC: 3.0 m

IC: 0.5 m

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

<table>
<thead>
<tr>
<th>Material</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halite (NaCl)</td>
<td>+/+++</td>
</tr>
<tr>
<td>Calcite, CaCO₃</td>
<td>+++</td>
</tr>
<tr>
<td>Quartz, SiO₂</td>
<td>++</td>
</tr>
<tr>
<td>Feldspars</td>
<td>vtg/+</td>
</tr>
<tr>
<td>Mica</td>
<td>vtg</td>
</tr>
</tbody>
</table>

Ion content of samples 0-2cm

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>NO₃⁻</th>
<th>SO₄²⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>0.33</td>
<td>0.07</td>
<td>nd</td>
<td>0.60</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>0.5</td>
<td>0.05</td>
<td>0.04</td>
<td>nd</td>
<td>0.16</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

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

- DRX/EDS => halite (sea water … marine fog …)
- IC => chloride (sea) + some nitrate (ground)
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
2 - Alhos-Vedros tide-mill

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

NW (front) façade
2 - Alhos-Vedros tide-mill

History
• built beginning of the XVIII century
• inactive since 1940, will work as a museum

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

NW (front) façade
2 - Alhos-Vedros tide-mill

History
• built beginning of the XVIII century
• inactive since 1940, will work as a museum

Situation
• inside a branch of the Tagus estuary
• less than 10 km from the open sea
2 - Alhos-Vedros tide-mill

History
• built beginning of the XVIII century
• inactive since 1940, will work as a museum

Situation
• inside a branch of the Tagus estuary
• less than 10 km from the open sea

Materials (1999):
• plasters were replaced up to:
  - 2.6m in the NW wall
  - 1.4m in the SW wall
  - 1.0m in the SE wall
  - around NW windows
• traditional artificial hydraulic lime mortar
• common emulsion paint (interior + exterior)
2 - Alhos-Vedros tide-mill

History
• built beginning of the XVIII century
• inactive since 1940, will work as a museum

Situation
• inside a branch of the Tagus estuary
• less than 10 km from the open sea

Materials (1999):
• plasters were replaced up to:
  - 2.6m in the NW wall
  - 1.4m in the SW wall
  - 1.0m in the SE wall
  - around NW windows
• traditional artificial hydraulic lime mortar
• common emulsion paint

Damage (2002):
• efflorescence, peeling of the paint, sanding of the plaster – in the interior
• affects mostly the (new) plaster
Termonatrite (Na₂CO₃·H₂O) +
Gaylussite, Na₂Ca(CO₃)₂·5H₂O +
Trona (Na₂H(CO₃)₂·2·H₂O) +
Halite (NaCl) +
Calcium hydroxide (Ca(OH)₂) +
Calcite, CaCO₃ +
Quartz, SiO₂ ++
Feldspars / mica / caulinite +
Termonatrite \((\text{Na}_2\text{CO}_3\cdot\text{H}_2\text{O})\)  
Gaylussite, \(\text{Na}_2\text{Ca(\text{CO}_3)}\cdot2.5\text{H}_2\text{O}\)  
Trona \((\text{Na}_2\text{H}\text{(CO}_3\text{)}\cdot2.2\text{H}_2\text{O})\)  
Halite \((\text{NaCl})\)
Termonatrite (Na$_2$CO$_3$·H$_2$O)
Gaylussite, Na$_2$Ca(CO$_3$)$_2$·5H$_2$O
Trona (Na$_2$H(CO$_3$)$_2$·2H$_2$O)
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 →

N wall

Drill 0.15 m from pavement

MC
HMC 95%
HMC 80%
the MC is low inside the wall:

=> rising damp is not the main problem, despite the direct contact of the mill foundations with the river water
Where does the water come from?
Where does the water come from?
circumstantial evidence ...
Salt damage:

• close to the pavement
2 - Alhos-Vedros tide-mill

Where does the water come from?  
circumstantial evidence …

Salt damage:

• close to the pavement
• around the NW windows
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
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

Hypothesis: damage occurs on colder surfaces where condensation hazard is higher
Where does the water come from? 
circumstantial evidence ...

Cold /wet day
Sun suddenly appeared
Air temp raised rapidly
Wet spots start appearing
(condensation…)
Conclusions

• Rising damp is not very significant

• Moisture source: probably dew point condensation
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
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:
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
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 access of chloride => hardly feasible ...
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)
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
3 - House of Despacho

History
- built early XVIII century
- used as sacristy and mortuary chapel
3 - House of Despacho

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

**Situation**
- next to the Mondego (river)
- 20 km from the Atlantic
3 - House of Despacho

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

Situation
- next to the Mondego (river)
- 20 km from the Atlantic

Materials
- 2001:
  - new lime-sand plasters and renders
  - cement-based adhesion coat
3 - House of Despacho

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

Situation
- next to the Mondego (river)
- 20 km from the Atlantic

Materials
- 2001:
  - new lime-sand plasters and renders
  - cement-based adhesion coat
  - a flood (rupture in Mondego dikes) submerged the church up to 2.5 m

3 - House of Despacho

History
• built early XVIII century
• used as sacristy and mortuary chapel

Situation
• next to the Mondego (river)
• 20 km from the Atlantic

Materials
• 2001:
  - new lime-sand plasters and renders
  - cement-based adhesion coat
  a flood (rupture in Mondego dikes) submerged the church up to 2.5 m
• 2003:
  - commercial potassium-silicate paint (with hydrofuge additives) applied at the interior and exterior

3 - House of Despacho

History
• built early XVIII century
• used as sacristy and mortuary chapel

Situation
• next to the Mondego (river)
• 20 km from the Atlantic

Materials
• 2001:
  - new lime-sand plasters and renders
  - cement-based adhesion coat
    a flood (rupture in Mondego dikes) submerged the church up to 2.5 m
• 2003:
  - commercial potassium-silicate paint
    (with hydrofuge additives) applied at the interior and exterior

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
Significant amount of moisture exists inside the walls.
3 - House of Despacho

- XRD: 2.6 m
- XRD: 2.1 m
- XRD: 1.5 m
- XRD: 1.1 m
XDR on efflorescence

<table>
<thead>
<tr>
<th>Crystalline compounds</th>
<th>Sampling height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>Hydrous sodium carbonate, Na$_2$CO$_3$·7H$_2$O</td>
<td>++</td>
</tr>
<tr>
<td>Natron, Na$_2$CO$_3$·10H$_2$O</td>
<td>+</td>
</tr>
<tr>
<td>Gaylussite, Na$_2$Ca(CO$_3$)$_2$·5H$_2$O</td>
<td>-</td>
</tr>
<tr>
<td>Quartz, SiO$_2$</td>
<td>-</td>
</tr>
<tr>
<td>Cristobalite, SiO$_2$</td>
<td>?</td>
</tr>
<tr>
<td>Calcite, CaCO$_3$</td>
<td>+</td>
</tr>
<tr>
<td>Rutile, TiO$_2$</td>
<td>+</td>
</tr>
</tbody>
</table>
3 - House of Despacho

Hydrous sodium carbonate, $\text{Na}_2\text{CO}_3\cdot 7\text{H}_2\text{O}$

Natron, $\text{Na}_2\text{CO}_3\cdot 10\text{H}_2\text{O}$

Gaylussite, $\text{Na}_2\text{Ca(CO}_3)_2\cdot 5\text{H}_2\text{O}$
Conclusions
Conclusions

High moisture content inside the walls
Conclusions

High moisture content inside the walls:
  • rising damp?
  • accumulation during the flood?
Conclusions

High moisture content inside the walls:

- rising damp?
- accumulation during the flood?

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

High moisture content inside the walls:
  • rising damp?
  • accumulation during the flood?

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

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

Damage up on the wall

XDR on sanded surface material (NE wall)
XDR on sanded surface material (NE wall)

XDR on efflorescence (NW wall)
<table>
<thead>
<tr>
<th></th>
<th>XDR on sanded surface material (NE wall)</th>
<th>XDR on efflorescence (NW wall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trona, $\text{Na}_3\text{H(CO}_3\text{)}_2\cdot 2\text{H}_2\text{O}$</td>
<td>?/vtg</td>
<td>$\text{Na}_3\text{H(CO}_3\text{)}_2\cdot 2\text{H}_2\text{O}$ ++/+++</td>
</tr>
<tr>
<td>Gaylussite, $\text{Na}_2\text{Ca(CO}_3\text{)}_2\cdot 5\text{H}_2\text{O}$</td>
<td>+</td>
<td>$\text{Na}_2\text{Ca(CO}_3\text{)}_2\cdot 5\text{H}_2\text{O}$ -</td>
</tr>
<tr>
<td>Niter, $\text{KNO}_3$</td>
<td>?/vtg</td>
<td>$\text{KNO}_3$</td>
</tr>
<tr>
<td>Calcite, $\text{CaCO}_3$</td>
<td>+++</td>
<td>$\text{CaCO}_3$</td>
</tr>
<tr>
<td>Dolomite, $\text{CaMg(CO}_3\text{)}_2$</td>
<td>+</td>
<td>$\text{CaMg(CO}_3\text{)}_2$</td>
</tr>
<tr>
<td>Quartz, $\text{SiO}_2$</td>
<td>+</td>
<td>$\text{SiO}_2$</td>
</tr>
</tbody>
</table>
Damage close to the pavement

Damage up on the wall

Trona, Na$_3$H(CO$_3$)$_2$.2H$_2$O
Gaylussite, Na$_2$Ca(CO$_3$)$_2$.5H$_2$O
Niter,KNO$_3$

Trona, Na$_3$H(CO$_3$)$_2$.2H$_2$O
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
Possible moisture sources
Possible moisture sources

Soil surface water (cloister garden)?
Hygroscopic water (stone) ?
Condensation (mainly on the stone) ?
Conclusions
Conclusions

Moisture source? superficial source is likely …
Conclusions

Moisture source? superficial source is likely ...

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

Moisture source? *superficial source is likely* ...

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

Moisture source? **superficial source is likely** …

- 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)
Conclusions

Moisture source? *superficial source is likely* ...

- 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
Conclusions

Moisture source? *superficial source is likely* ...

- 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
## Ficha de Inspeção de Obra

### Informações Gerais
- Data e Horário:
- Marcas presentes:
- Corrosão:

#### Descrição Geral
- Usinas e equipamentos:
  - Usinas:
  - Equipamentos:
  - Instalação para usinas:
  - Sistema estacionário, painel, etc.

#### Volume e Capacidade
- Usina:
- Volume:
- Vida útil:
- Direção e gasto:
- Viabilidade:
- Reforço:

#### Ambiente e Condições
- Zonas de trabalho:
- Zonas de risco:
- Condições operacionais:
  - Clareidade:
  - Temperatura:

#### Efeitos Gerais
- Efeitos visíveis:
  - Gastos:
  - Efeitos visuais:
  - Efeitos estéticos:
  - Efeitos estéticos:
  - Efeitos estéticos:

#### Marcas e Manchas
- Marcas:
- Manchas:
- Doença de usina:
- Manchas de usina:
- Manchas de usina:
- Manchas de usina:

#### Observações
- Observações:
- Observações:
- Observações:
- Observações:
- Observações:
- Observações:
- Observações:
- Observações:
- Observações:

### Anomalias
- Tipos de anomalias:
  - Tensões:
  - Furos:
  - Riscos:
  - Riscos:
  - Riscos:
  - Riscos:

#### Localizações
- Localizações:
  - Furos:
  - Riscos:
  - Riscos:
  - Riscos:

#### Medidas Preventivas
- Medidas preventivas:
  - Medidas preventivas:
  - Medidas preventivas:
  - Medidas preventivas:
  - Medidas preventivas:

## Inspeção Form
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