EU project CHARISMA - ITINERANT COURSE ON STONE CONSERVATION - LNEC, 7-18 May 2012

Repair mortars. Working principles and typical properties.

Teresa Diaz Gonçalves

Untitled graffiti on plaster (unknown author),
Ginjal Dock, Almada, Portugal, 2007

Portrait of Brad Downey – sculpture on plaster (Vhils),
Alcântara, Lisboa, Portugal, 2011 (http://cronolisboa.tk)

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Lecture contents

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Repair mortars. Working principles and typical properties.

Lecture contents

- Introduction: mortars / plasters and renders
- Binders
    - Earth
    - Lime - air lime; hydraulic lime
    - Cement - natural cement; Portland cement
    - Pozzolans - natural; artificial
- Influence of different binders on the properties of the mortar/plaster/render
- Plasters and renders for salt loaded walls
    - Working principles
    - Some influencing factors:
        - The substrate
        - The paint layer
    - How to select / prescribe?

Repair mortars. Working principles and typical properties.

Introduction

Mortar

- workable paste used in construction to coat the walls, bind elements or fill gaps / lacunae
- aggregate + binder + water (+ additives)

Plasters and renders

Bedding / masonry mortars

Pointing mortars

Stone repair mortars

Wall / floor tile mortars
(bedding / grouting)

Salvas church, Sines, Portugal, 2003

Farm-house, Tavira, Portugal, 2002

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Many influencing factors => largely empirical knowledge …

Salvas church, Sines, Portugal, 2003

Farm-house, Tavira, Portugal, 2002

Repair mortars. Working principles and typical properties.

Binders

Repair mortars. Working principles and typical properties.

Binders

Naturally available

Earth

Repair mortars. Working principles and typical properties.

Binders

Naturally available

Earth

Man-made

Air-lime

Hydraulic lime

Natural cement

Portland cement

Note: Gypsum no (decorative finishes, mostly)

Repair mortars. Working principles and typical properties.

Binders

Naturally available

Earth

Man-made

Air-lime → *Air binder*
hardens in the air, through re-absorption of CO_2 (carbonation)

Hydraulic lime
Natural cement
Portland cement

Hydraulic binder
hardens both under water and in air when mixed with water, through hydration of the calcium silicates / aluminates

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Pozzolans → Do not have binding properties - Finely divided amorphous siliceous materials that, when mixed with slaked lime (calcium hydroxide) slowly reacts, forming non-water-soluble (hydraulic…) calcium silicate hydrates

- Natural
- Man-made

Repair mortars. Working principles and typical properties.

Binders: earth

Repair mortars. Working principles and typical properties.

Binders: earth

- building material as old as humanity itself
- vernacular techniques (using local resources)
  - local / regional architecture
  - multiple forms (materials / techniques)

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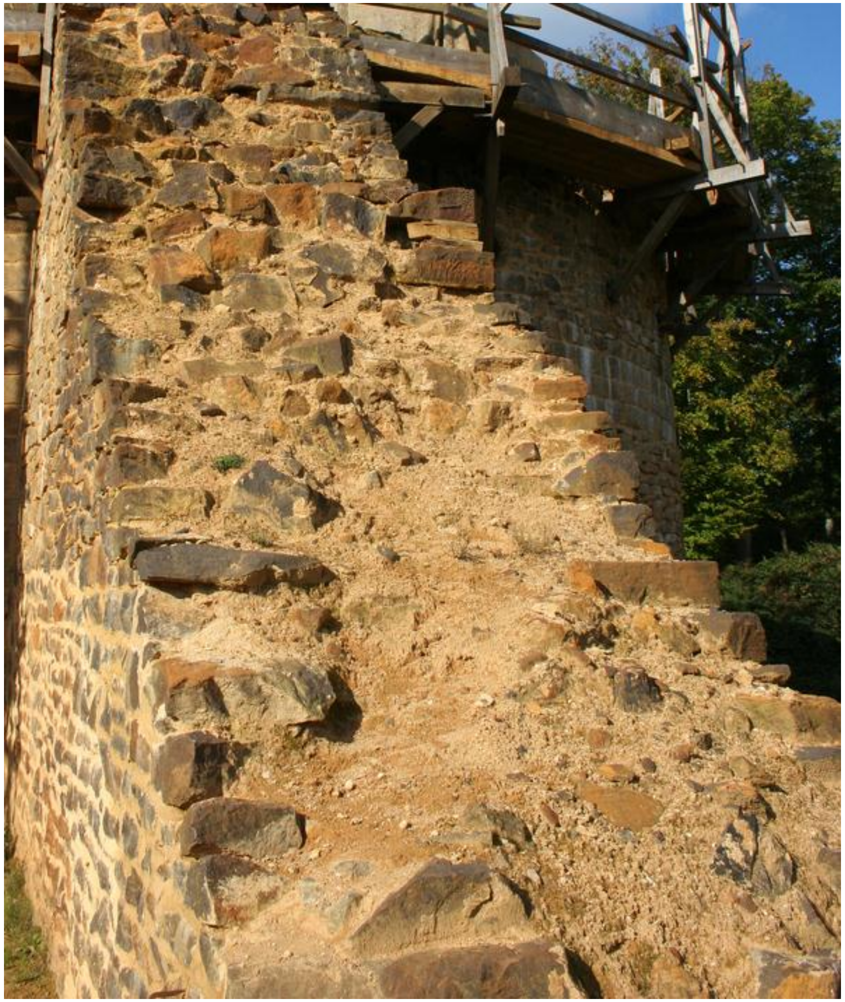
  - multiple forms (materials / techniques)
- often used with stone (also naturally occurring)
- clay => binding properties
  - very small mineral particles (<2 μm)
  - sheets of silicate and aluminate
  - electrostatic forces set up



Earth: bedding mortar

Repair mortars. Working principles and typical properties.

Binders: earth

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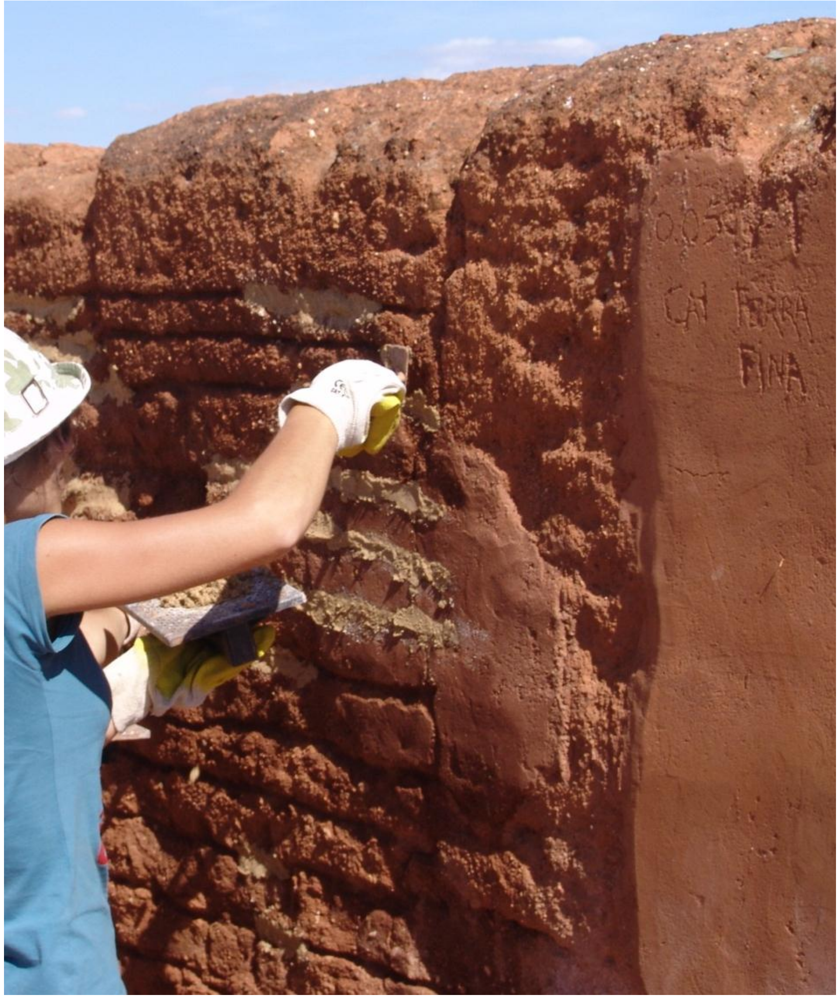
  - electrostatic forces set up
- mortars based on:
  - earth
  - earth + natural fibers (straw,…)
  - lime + earth



Earth: plastering / rendering mortar

Repair mortars. Working principles and typical properties.

Binders: lime

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Types of lime (EN 459-1:2010)

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Air lime

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Air lime - hardens in the air, by re-absorption of CO2

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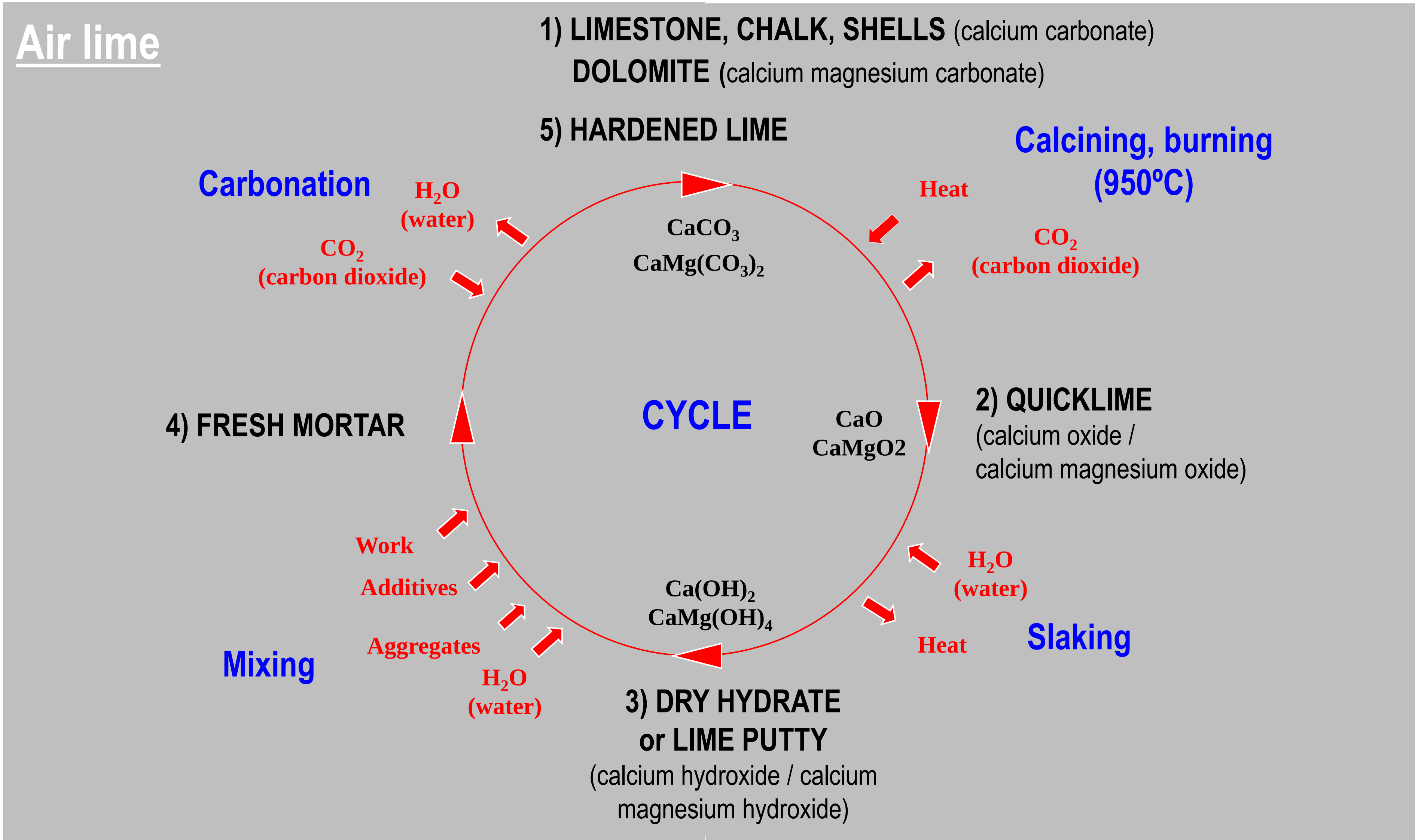
Air lime



1) LIMESTONE, CHALK, SHELLS (calcium carbonate)

DOLOMITE (calcium magnesium carbonate)

5) HARDENED LIME

Calcining, burning (950ºC)

Heat

CO_2 (carbon dioxide)

2) QUICKLIME (calcium oxide / calcium magnesium oxide)

Slaking

H_2O (water)

Heat

3) DRY HYDRATE or LIME PUTTY (calcium hydroxide / calcium magnesium hydroxide)

Mixing

Work

Additives

Aggregates

H_2O (water)

4) FRESH MORTAR

Carbonation

H_2O (water)

CO_2 (carbon dioxide)

Repair mortars. Working principles and typical properties.

Binders: lime

Types of lime (EN 459-1:2010)

%W

Air lime - hardens in the air, by re-absorption of CO2

Raw material

Delivery conditions

Purity: CO_2 is measure of the degree of burning

Repair mortars. Working principles and typical properties.

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Types of lime (EN 459-1:2010)

%W

Air lime - hardens in the air, by re-absorption of CO2

Raw material:

- Calcium carbonate ($CaCO_3$)
  => CL (calcium lime)
- Calcium magnesium carbonate ($CaMg(CO_3)_2$)
  => DL (dolomitic lime)

Note: dolomitic limestone => 50% or greater content of magnesium replacing calcium

Delivery conditions:

- Oxide (CaO or $CaMgO_2$)
  => Q (quicklime) granular / powder
- Slaked, hydrated ($Ca(OH)_2$ or $CaMg(OH)_4$)
  => S (dry hydrate) free water < 2%
  => S PL (lime putty) 45% < free water < 70%
  => S ML (slurry or milk of lime) suspension or saturated solution of $Ca(OH)_2$ or $CaMg(OH)_4$

Purity: CO_2 is measure of the degree of burning

- Calcium lime - MgO < 5%
  => CL 90 ($CO_2 \leq 4\%$; $CaO+MgO \geq 90\%$)
  => CL 80 ($CO_2 \leq 7\%$; $CaO+MgO \geq 80\%$)
  => CL 70 ($CO_2 \leq 12\%$; $CaO+MgO \geq 70\%$)
- Dolomitic lime - MgO ≥ 5% or ≥ 30%
  => DL 90-30 ($CO_2 \leq 6\%$; $CaO+MgO \geq 90\%$)
  => DL 90-5 ($CO_2 \leq 6\%$; $CaO+MgO \geq 90\%$)
  => DL 90-30 ($CO_2 \leq 9\%$; $CaO+MgO \geq 85\%$)
  => DL 90-5 ($CO_2 \leq 9\%$; $CaO+MgO \geq 80\%$)

Repair mortars. Working principles and typical properties.

Binders: lime

Types of lime (EN 459-1:2010)

Hydraulic lime

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Hydraulic lime - hardens both by reaction with water and with air CO2 => setting + hardening

Calcium hydroxide +calcium silicates and aluminates

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Binders: lime

Types of lime (EN 459-1:2010)

Hydraulic lime - hardens both by reaction with water and with air CO2 => setting + hardening

Calcium hydroxide +calcium silicates and aluminates

Classes (raw material):

- NHL (natural hydraulic lime)
  produced by calcining limestone that contains clay; kiln temperature ≈ 900 to 1100ºC
- FL (formulated lime)
  - includes CL or NHL + hydraulic or pozzolanic additions (cement or clinker, ground-granulated blast-furnace slag, etc.)
  - additions identified by the manufacturer
- HL (hydraulic lime)
  - includes CL or NHL + additions
  - no requirement to identify its composition

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Type

for each class; depending on the clay content of the limestone (=> on the resulting lime content) + on the compressive strength (Rc):

Natural hydraulic lime (NHL)

- NHL 2 – $Ca(OH)_2 \geq 35\%$; $2 \leq Rc \leq 7$ MPa
- NHL 3,5 – $Ca(OH)_2 \geq 25\%$; $3,5 \leq Rc \leq 10$ MPa
- NHL 5 – $Ca(OH)_2 \geq 15\%$; $5 \leq Rc \leq 15$ MPa

Formulated lime (FL)

- FL A – $40\% \leq Ca(OH)_2 \leq 80\%$
- FL B – $25\% \leq Ca(OH)_2 \leq 50\%$
- FL C – $15\% \leq Ca(OH)_2 \leq 40\%$

- FL A/B/C 2 – $2 \leq Rc \leq 7$ MPa
- FL A/B/C 3,5 – $3,5 \leq Rc \leq 10$ MPa
- FL A/B/C 5 – $5 \leq Rc \leq 15$ MPa

Hydraulic lime (HL)

- HL 2 – $Ca(OH)_2 \geq 10\%$; $2 \leq Rc \leq 7$ MPa
- HL 3,5 – $Ca(OH)_2 \geq 8\%$; $3,5 \leq Rc \leq 10$ MPa
- HL 5 – $Ca(OH)_2 \geq 4\%$; $5 \leq Rc \leq 15$ Mpa

Repair mortars. Working principles and typical properties.

Binders: cement

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Types of cement

Natural cement (ASTM C10/C10M-10)

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Natural cement (ASTM C10/C10M-10)

Similarities with lime:

- made from limestone with certain clay content (argillaceous limestone / marl)
- produced by heating to 900 to 1100ºC

Differences to (Natural Hydraulic) Lime:

- NHL contains excess free lime (ex: NHL 5 => $Ca(OH)2 \geq 15\%$)

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A natural cement known as "Roman cement" was patented in 1796 (UK)

Appropriate marls were eventually discovered in other countries (Europe and US)

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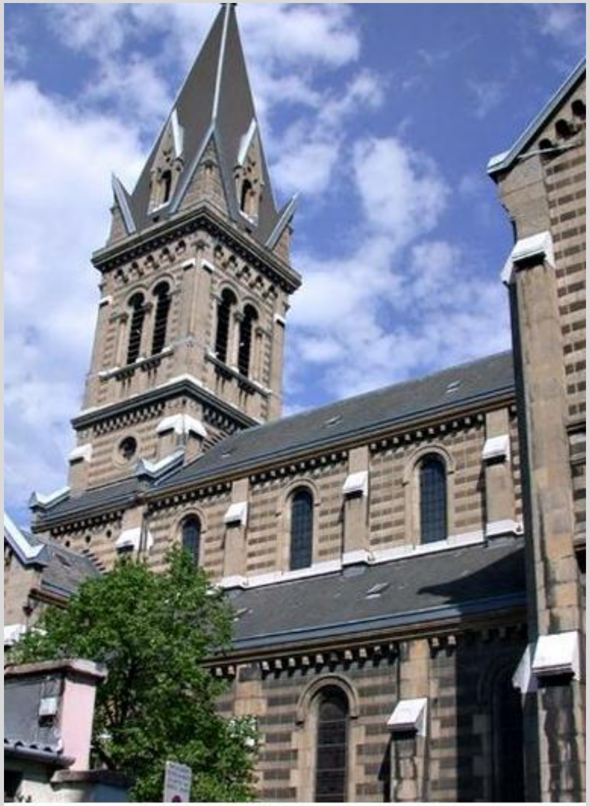

St Bruno, Grenoble, ca. 1870

(http://www.rocare.eu/page/photogallery.php)

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Roman cements were used to decorate façades in central Europe (19th/early 20th centuries)

ROCARE (EU project) – "Roman Cements for Architectural Restoration to New High Standards"

- combine knowledge of the historical binder with modern aspects of cement manufacture, use and marketing

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(http://www.rocare.eu/page/seite,workpackage3.html)

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Artificial cement

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Artificial cement

Common (Portland) cements - EN 197

Main constituent =Portland clinker = precisely specified mixture of raw materials containing CaO, $SiO2$, $Al2O3$, $Fe2O3$ and small amounts of others.

White - essentially the same properties as grey cement, except for colour (selected raw materials)

Masonry cement - EN 413

For masonry works (laying, plastering). Portland cement + additives (ex: plasticisers to make it more workable and suitable for brick and block laying).

Identified by the letters MC, followed by the strength class (5, 12.5 and 22.5 MPa) and, where applicable, the letter X (X => without air entraining additives).

Supersulfated cement - EN 15743

80% GGBFS, 15 % gypsum and a little Portland clinker or lime as an activator. Good resistance to aggressive agents, including sulphates.

Calcium aluminate cement - EN 14647

For use in refractory (high-temperature resistant) concretes.

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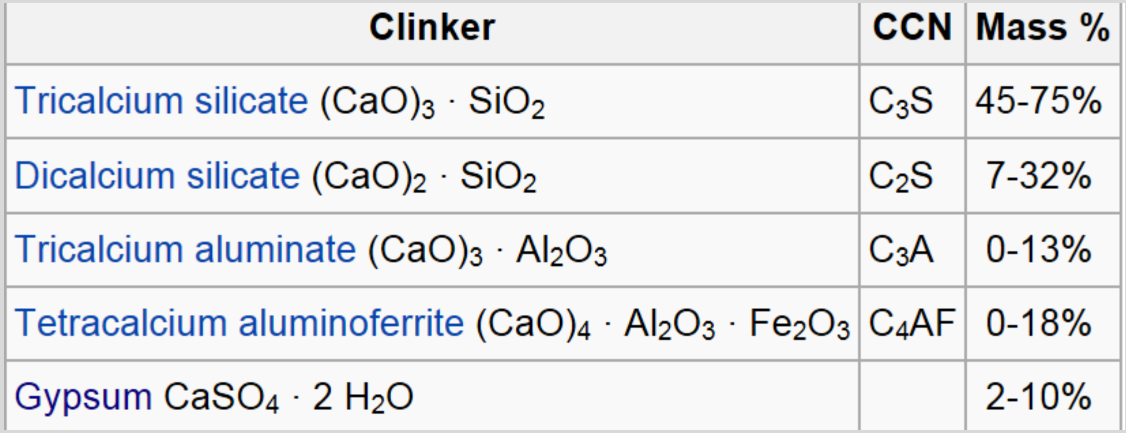
Binders: cement

EN 197-1:2000 - 5 classes of common cement that use Portland clinker as main constituent:



Clinker	CCN	Mass %
Tricalcium silicate $(CaO)_3 \cdot SiO_2$	C_3S	45-75%
Dicalcium silicate $(CaO)_2 \cdot SiO_2$	C_2S	7-32%
Tricalcium aluminate $(CaO)_3 \cdot Al_2O_3$	C_3A	0-13%
Tetracalcium aluminoferrite $(CaO)_4 \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	0-18%
Gypsum $CaSO_4 \cdot 2\ H_2O$		2-10%

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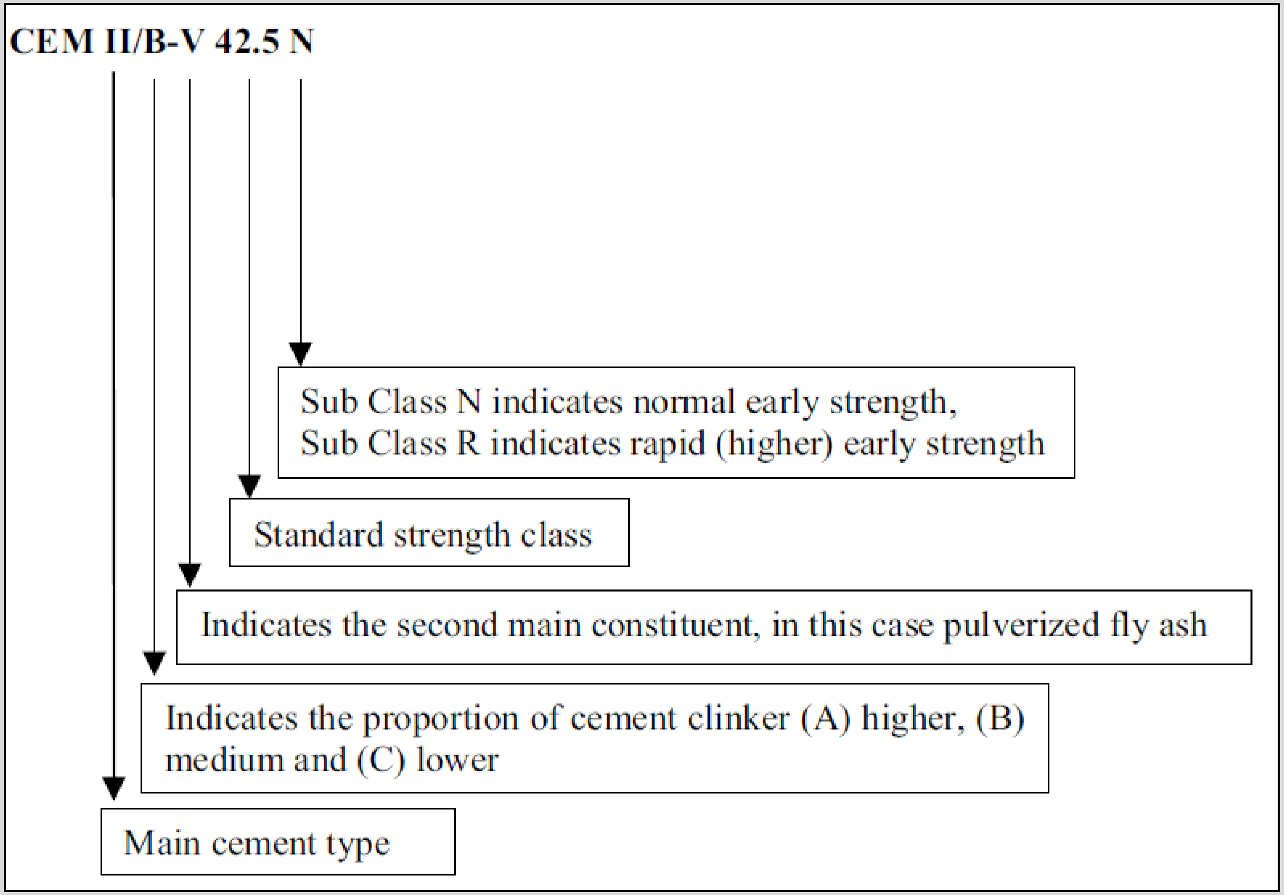

CEM II/B-V 42.5 N

Sub Class N indicates normal early strength,
Sub Class R indicates rapid (higher) early strength

Standard strength class

Indicates the second main constituent, in this case pulverized fly ash

Indicates the proportion of cement clinker (A) higher, (B) medium and (C) lower

Main cement type

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EN 197-1:2000 - 5 classes of common cement that use Portland clinker as main constituent:

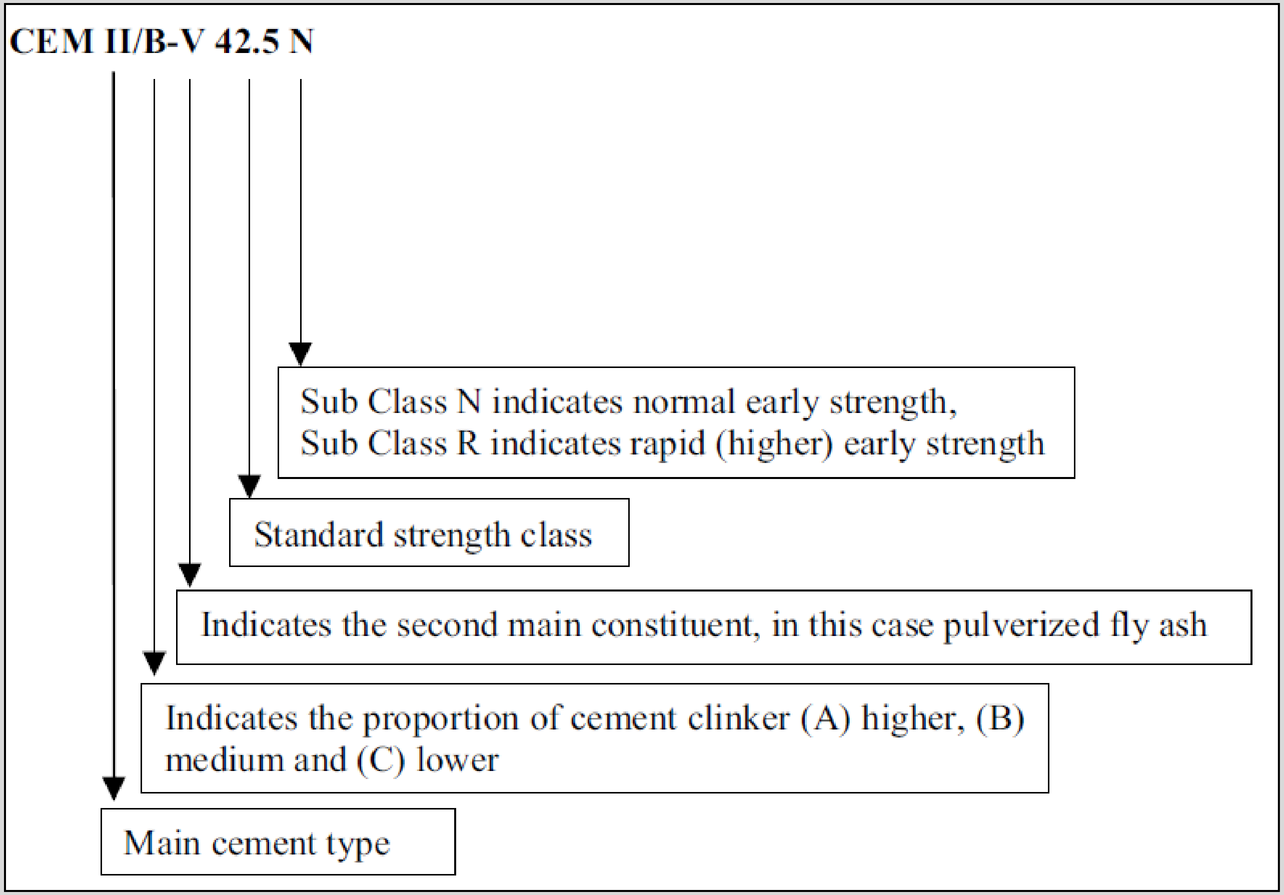
CEM I - Portland cement: up to 5% of other minor constituents

CEM II - Portland-composite cement: up to 35% of other constituents

CEM III - Blastfurnace cement - higher percentage of blastfurnace slag

CEM IV - Pozzolanic cement: up to 55% of pozzolanic constituents

CEM V - Composite cement: blastfurnace slag or fly ash and pozzolana



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CEM III - Blastfurnace cement - higher percentage of blastfurnace slag

CEM IV - Pozzolanic cement: up to 55% of pozzolanic constituents

CEM V - Composite cement: blastfurnace slag or fly ash and pozzolana

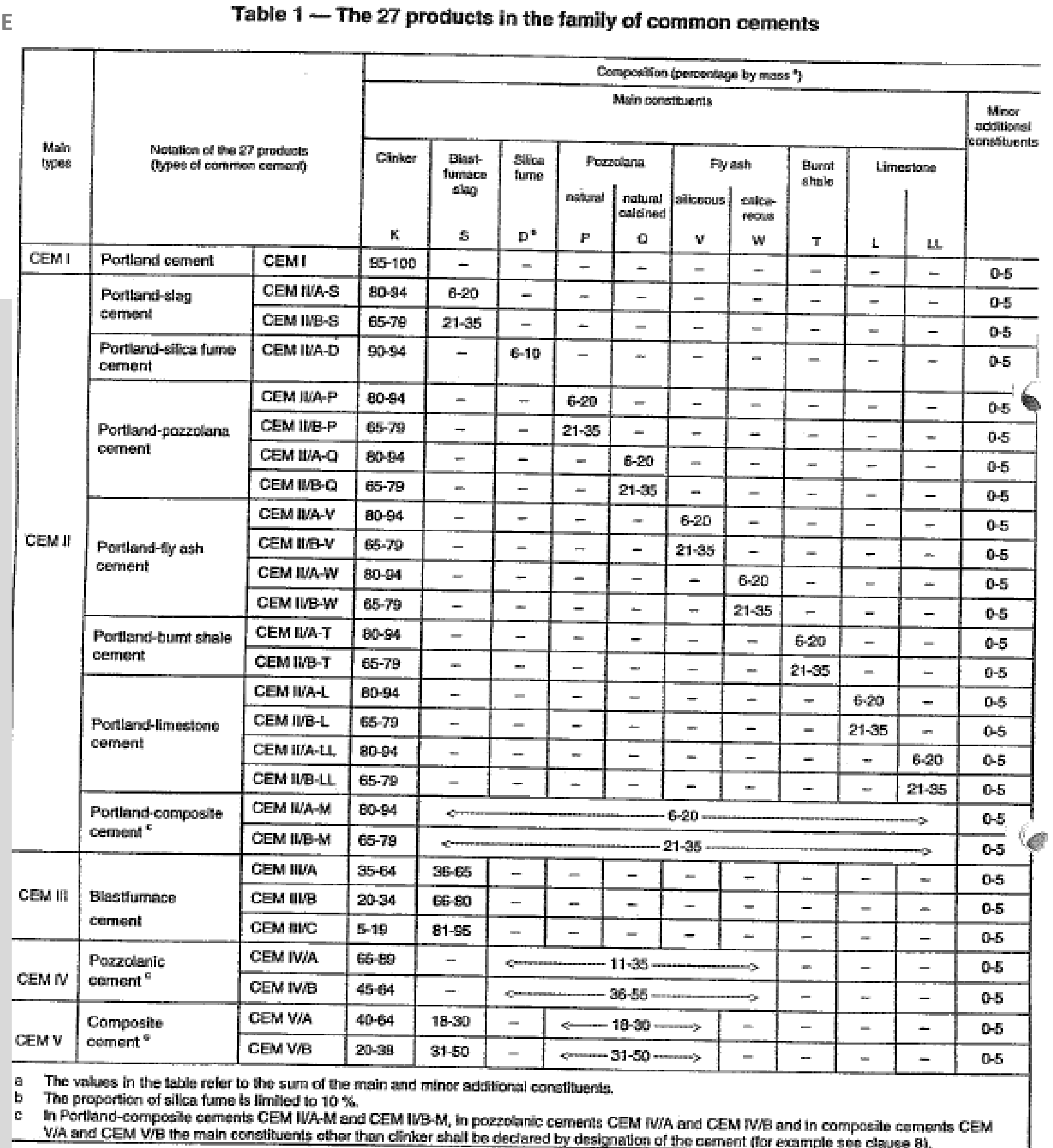

Table 1 — The 27 products in the family of common cements

Main types	Notation of the 27 products (types of common cement)		Composition (percentage by mass [a])										
			Main constituents										Minor additional constituents
			Clinker	Blast-furnace slag	Silica fume	Pozzolana		Fly ash		Burnt shale	Limestone		
						natural	natural calcined	siliceous	calcareous				
			K	S	D [b]	P	Q	V	W	T	L	LL	
CEM I	Portland cement	CEM I	95-100	–	–	–	–	–	–	–	–	–	0-5
CEM II	Portland-slag cement	CEM II/A-S	80-94	6-20	–	–	–	–	–	–	–	–	0-5
		CEM II/B-S	65-79	21-35	–	–	–	–	–	–	–	–	0-5
	Portland-silica fume cement	CEM II/A-D	90-94	–	6-10	–	–	–	–	–	–	–	0-5
	Portland-pozzolana cement	CEM II/A-P	80-94	–	–	6-20	–	–	–	–	–	–	0-5
		CEM II/B-P	65-79	–	–	21-35	–	–	–	–	–	–	0-5
		CEM II/A-Q	80-94	–	–	–	6-20	–	–	–	–	–	0-5
		CEM II/B-Q	65-79	–	–	–	21-35	–	–	–	–	–	0-5
	Portland-fly ash cement	CEM II/A-V	80-94	–	–	–	–	6-20	–	–	–	–	0-5
		CEM II/B-V	65-79	–	–	–	–	21-35	–	–	–	–	0-5
		CEM II/A-W	80-94	–	–	–	–	–	6-20	–	–	–	0-5
		CEM II/B-W	65-79	–	–	–	–	–	21-35	–	–	–	0-5
	Portland-burnt shale cement	CEM II/A-T	80-94	–	–	–	–	–	–	6-20	–	–	0-5
		CEM II/B-T	65-79	–	–	–	–	–	–	21-35	–	–	0-5
	Portland-limestone cement	CEM II/A-L	80-94	–	–	–	–	–	–	–	6-20	–	0-5
		CEM II/B-L	65-79	–	–	–	–	–	–	–	21-35	–	0-5
		CEM II/A-LL	80-94	–	–	–	–	–	–	–	–	6-20	0-5
		CEM II/B-LL	65-79	–	–	–	–	–	–	–	–	21-35	0-5
	Portland-composite cement [c]	CEM II/A-M	80-94	<———— 6-20 ————>									0-5
		CEM II/B-M	65-79	<———— 21-35 ————>									0-5
CEM III	Blastfurnace cement	CEM III/A	35-64	36-65	–	–	–	–	–	–	–	–	0-5
		CEM III/B	20-34	66-80	–	–	–	–	–	–	–	–	0-5
		CEM III/C	5-19	81-95	–	–	–	–	–	–	–	–	0-5
CEM IV	Pozzolanic cement [c]	CEM IV/A	65-89	–	<———— 11-35 ————>					–	–	–	0-5
		CEM IV/B	45-64	–	<———— 36-55 ————>					–	–	–	0-5
CEM V	Composite cement [c]	CEM V/A	40-64	18-30	–	<—— 18-30 ——>			–	–	–	–	0-5
		CEM V/B	20-38	31-50	–	<—— 31-50 ——>			–	–	–	–	0-5

[a] The values in the table refer to the sum of the main and minor additional constituents.

[b] The proportion of silica fume is limited to 10 %.

[c] In Portland-composite cements CEM II/A-M and CEM II/B-M, in pozzolanic cements CEM IV/A and CEM IV/B and in composite cements CEM V/A and CEM V/B the main constituents other than clinker shall be declared by designation of the cement (for example see clause 8).

Repair mortars. Working principles and typical properties.

Binders: cement

Sulphate attack

Suphate can react, in the presence of water, with the calcium aluminates in cement => formation of expansive products (ettringite or thaumasite) which can disrupt the materials => use of cements with low amount of tricalciumaluminate

The development of a prescriptive EN for sulfate resisting cements has been complicated by national differences in the types of cement that are recognised to have sulfate resisting properties

In general, in damp walls (old walls in general…) or structures close to the sea:

- CEM III - Blastfurnace cement
- CEM IV - Pozzolanic cement

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Binders: pozzolans

Repair mortars. Working principles and typical properties.

Binders: pozzolans

- finely divided
- siliceous or siliceous and aluminous material (silica - SiO_2, alumina - Al_2O_3)
- in the presence of moisture
- at ordinary temperature
- reacts slowly with calcium hydroxide (hydrated lime / portlandite)
- forms compounds with hydraulic properties

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- original: roman *pozzolana* (Vitruvius, 25 BC, Ten Books on Architecture) - volcanic deposits, first found in Pozzuoli, Italy, near the Vesuvius
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Natural

- volcanic deposits - ex: Santo Antão (Cabo Verde), São Miguel (Azores, Portugal), Trass (Germany), Canarias (Spain), Santorini (Greece)
- natural rock materials - certain argillaceous sands, diatomaceous earth

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  - used in the roman concrete / *Opus caementicium* (do not confuse with *roman cement*); tipically 1:3 (lime:pozzolana, in volume)

Natural

- volcanic deposits - ex: Santo Antão (Cabo Verde), São Miguel (Azores, Portugal), Trass (Germany), Canarias (Spain), Santorini (Greece)
- natural rock materials - certain argillaceous sands, diatomaceous earth

Artificial

- ceramic brick / tile dust - already used by the Romans (typically crushed materials)
- fly ash - produced during combustion of coal
  EN 450-1:2005+A1:2007 (concrete)
- silica fume - fine powder, by-product of the alloy production
- ground granulated blast furnace slag (GGBFS) - obtained by melting and cooling iron slag (a byproduct of the production of iron and steel); this forms a glassy, granular product which is ground into a fine powder
- high-reactivity metakaolin (HRM) - obtained by calcining and milling certain types of clay; ex: kaolinite/kaolin, by-products from the paper industry

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

Earth

- Drying shrinkage depends on the amount and type of clay => may require stabilization (air-lime, fibers, …)
- Natural => no quality control => low constancy of characteristics
- Environmental benefits:
  - Low carbon footprint (no burning; local materials => no transportation)
  - High recyclability (non-stabilized earth => simple disaggregation + 100% of the material)

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

Earth

Air-lime

- Used in most historical constructions => compatibility advantages

- Good workability (in comparison to cement) => allows reducing the amount of water in the mixing

- Shrinkage may be high (≠ hydraulic binders, where part of the water combines with the material) => more efficient mixers may be helpful…

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

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- Does not set / slow hardening => wait for proper environmental conditions / protection of the façades

- Proper carbonation => not too dry environmental conditions (cure?)

- High deformability after hardening (in comparison to cement)

- Environmental benefits:

  • Carbon footprint lower than for cement

    burning at 950oC (cement 1400ºC)

    hardening => CO_2 reabsorption

Stockholm, historical center, 2004

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

Earth

Air-lime

Hydraulic lime

- Intermediate characteristics between air lime and cement

  Hydraulic => setting => initial resistance

  Free lime => workability, deformability, compatibility with old substrates

- Environmental benefits:
  - Carbon footprint lower than for cement

    burning at 900 - 1100ºC (cement 1400ºC) – mostly for NHL; confirm for each type/brand…

    hardening => (some) CO_2 reabsorption

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

Earth

Air-lime

Hydraulic lime

Natural cement

- Used in building façades (XIX / early XX) in (central) Europe => compatibility advantages in their repair works
- Natural raw material (marls = limestones with 20 to 40% of clay) => lower constancy of characteristics
- No free lime => higher durability (aggressive environments - coastal, cold/ice) ?
- Hardening velocity:
  - fast (few minutes)
  - slower hardening => low clay content (20%); additions (ASTM C10 allows gypsum)
- Environmental benefits:
  - Carbon footprint lower than for Portland cement → burning at 900 - 1100ºC (Portland cement 1400ºC)

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

Earth

Air-lime

Hydraulic lime

Natural cement

Portland cement

- Easily available / well known material / still the most trustable for many users (in the short term…)
- Stone conservation => mostly disadvantages …

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

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- Stone conservation => mostly disadvantages …

- Low deformability + high mechanical resistance => high stresses in the boundary with the substrate

Repair mortars. Working principl

Plasters and renders: influence o

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- Easily available / well known material / still the most trustable for many users (in the short term…)
- Stone conservation => mostly disadvantages …
- Low deformability + high mechanical resistance => high stresses in the boundary with the substrate
- High alkali content:

  the alkali combine with air CO2 (dissolved in the water in damp walls)
  → soluble alkali-carbonate/bicarbonate salts
- Relevant sulphate content

Repair mortars. Working principl

Plasters and renders: influence o

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- Stone conservation => mostly disadvantages …
- Low deformability + high mechanical resistance => high stresses in the boundary with the substrate
- High alkali content:

  the alkali combine with air CO2 (dissolved in the water in damp walls)
  → soluble alkali-carbonate/bicarbonate salts
- Relevant sulphate content
- Environmentally less interesting:
  - Higher carbon footprint lower than limes and natural cement → burning at 1400ºC

Note: cement industry produces about 5% of global man-made CO_2 emissions, of which 50% is from the chemical process, and 40% from burning fuel.

Repair mortars. Working principles and typical properties.

Plasters and renders: influence of different types of binder

Earth

Air-lime

Hydraulic lime

Natural cement

Portland cement

Pozzolans

- Some reasons for using:
  1) achieve better long term durability (than with pure lime), without the disadvantages of hydraulic binders
     (the slow pozzolanic reaction => take advantage of the workability, deformability of lime)
  2) compatibility advantages in the repair works to plasters/renders where pozzolans were originally used
- Knowledge still very casuistic / experience-based / incomplete
  => ex: Research Project *METACAL - Study of lime-metakaolin mortars for building conservation*
  (http://meta.web.ua.pt/default.html)
- Environmental impact – depends on whether they are natural or artificial + production method

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls

Roles of the plaster/render

- aesthetical
- functional
  - sanitary role
  - sacrificial (replaceable) layers

  protection of the substrate and the adjacent elements

  their own preservation should not superimpose to this function

  (except when the plaster/render itself has historic value…)

Cloister of the Monastery of Jesus , Setubal , 2001

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls

Dampness and soluble salts are common in old buildings (default situation…)

Roles of the plaster/render

- aesthetical
- functional
  - sanitary role
  - sacrificial (replaceable) layers

    protection of the substrate and the adjacent elements

    their own preservation should not superimpose to this function

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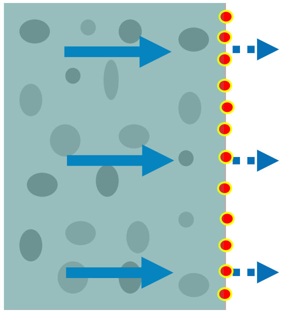
Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles

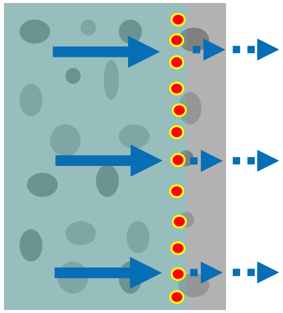
Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles

- Are related to the depth at which the salts crystallize
- Conditions the type of decay



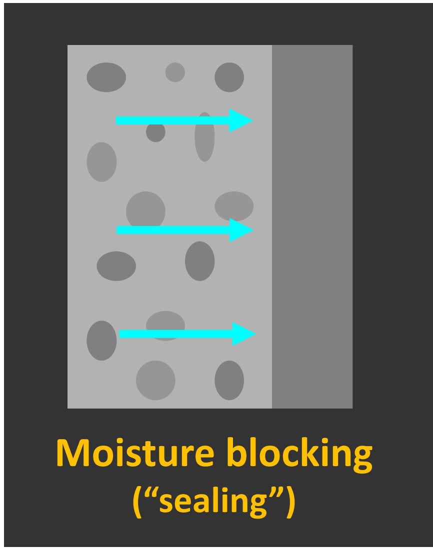
Stage I



Stage II

Repair mortars. Working principles and typical properties.

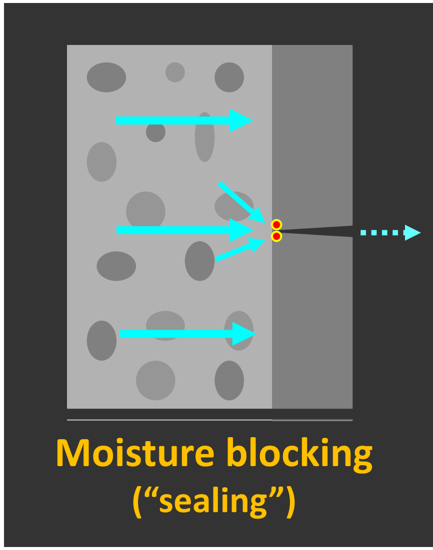
Plasters and renders for salt loaded walls: working principles



- There is no moisture transfer through the plaster
- Theoretically, there is neither evaporation, nor crystallization

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles

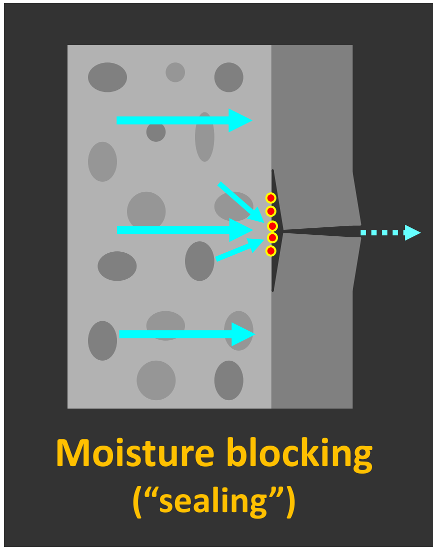


Moisture blocking (“sealing”)

- There is no moisture transfer through the plaster
- Theoretically, there is neither evaporation, nor crystallization
- In practice, however, fissures are “points of escape”

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles

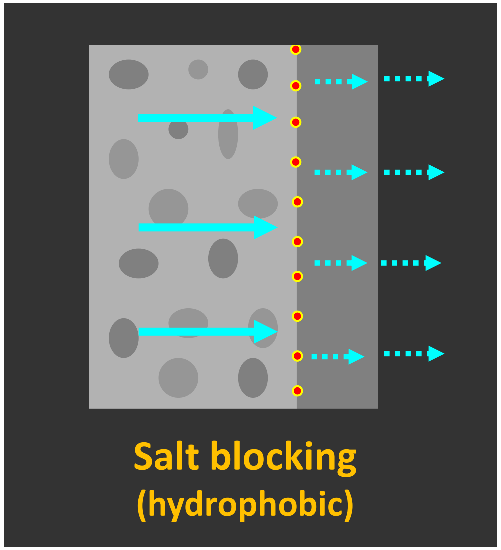


Moisture blocking
("sealing")

- There is no moisture transfer through the plaster
- Theoretically, there is neither evaporation, nor crystallization
- In practice, however, fissures are "points of escape"
- Crystallization at the masonry

Repair mortars. Working principles and typical properties.

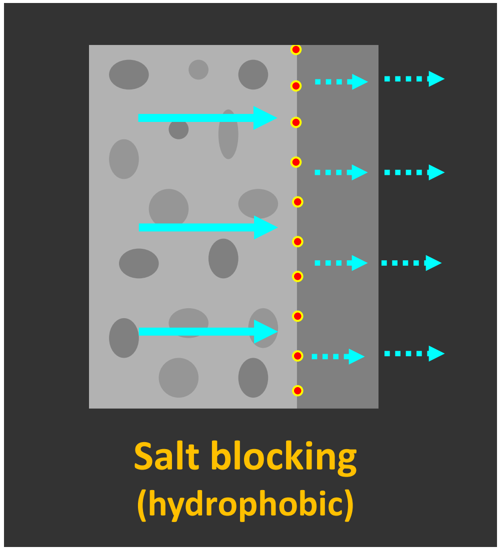
Plasters and renders for salt loaded walls: working principles



- Plasters with very low (or null) capillary absorption
- Liquid migration very reduced or null through the plaster

Repair mortars. Working principles and typical properties.

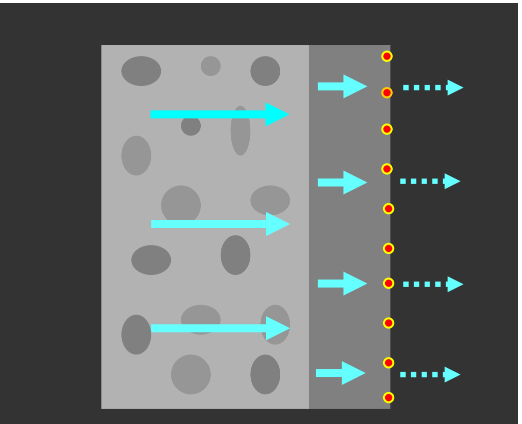
Plasters and renders for salt loaded walls: working principles



- Plasters with very low (or null) capillary absorption
- Liquid migration very reduced or null through the plaster
- Evaporation front has to be located behind the plaster
- Crystallization at the interface plaster/substrate

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles

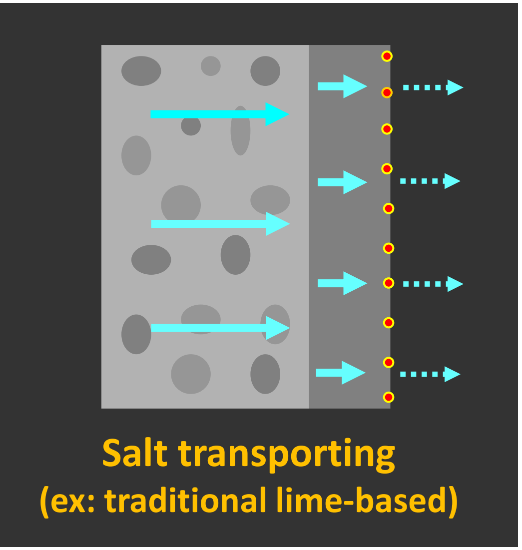


Salt transporting
(ex: traditional lime-based)

- Plasters with very high capillary absorption
- Solutions very quickly transported through the plaster

Repair mortars. Working principles and typical properties.

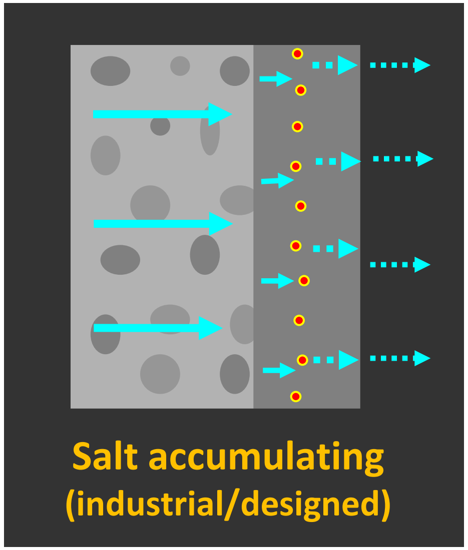
Plasters and renders for salt loaded walls: working principles



- Plasters with very high capillary absorption
- Solutions very quickly transported through the plaster
- Crystallization at (or close to) the surface
- Efflorescence

Repair mortars. Working principles and typical properties.

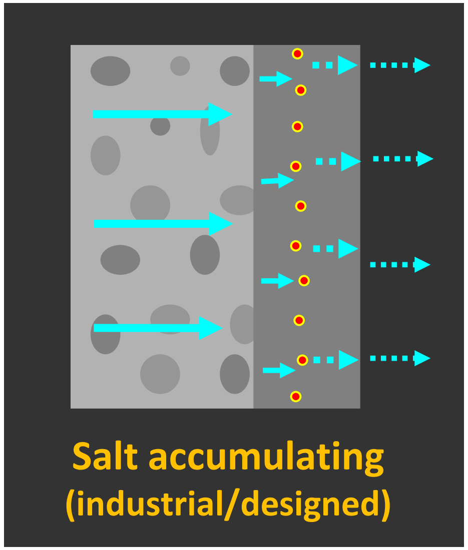
Plasters and renders for salt loaded walls: working principles



- Balance between liquid and vapour flows such that the evaporation front is located inside the plaster (for a wide range of situations)
- Include mass hydrophobic additives + (usually) lightweight aggregates
- Crystallization happens inside the pores of the plaster

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles



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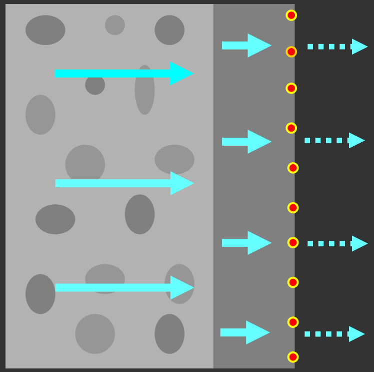
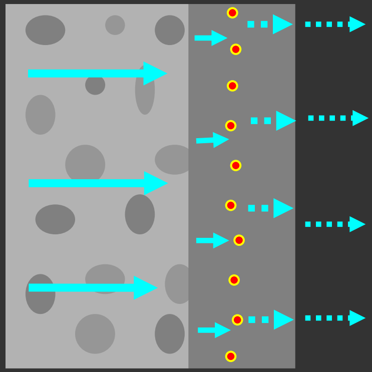
Repair mortars. Working principles and typical properties.

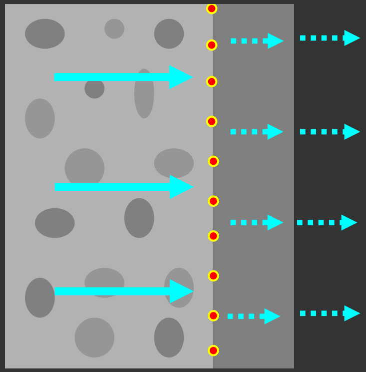
Plasters and renders for salt loaded walls: working principles



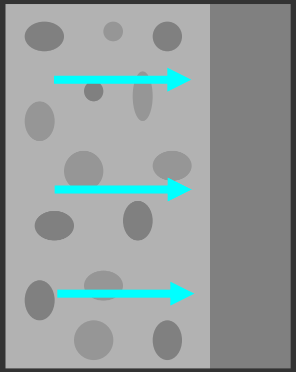
Salt transporting
(ex: traditional lime-based)



Salt accumulating
(industrial/designed)



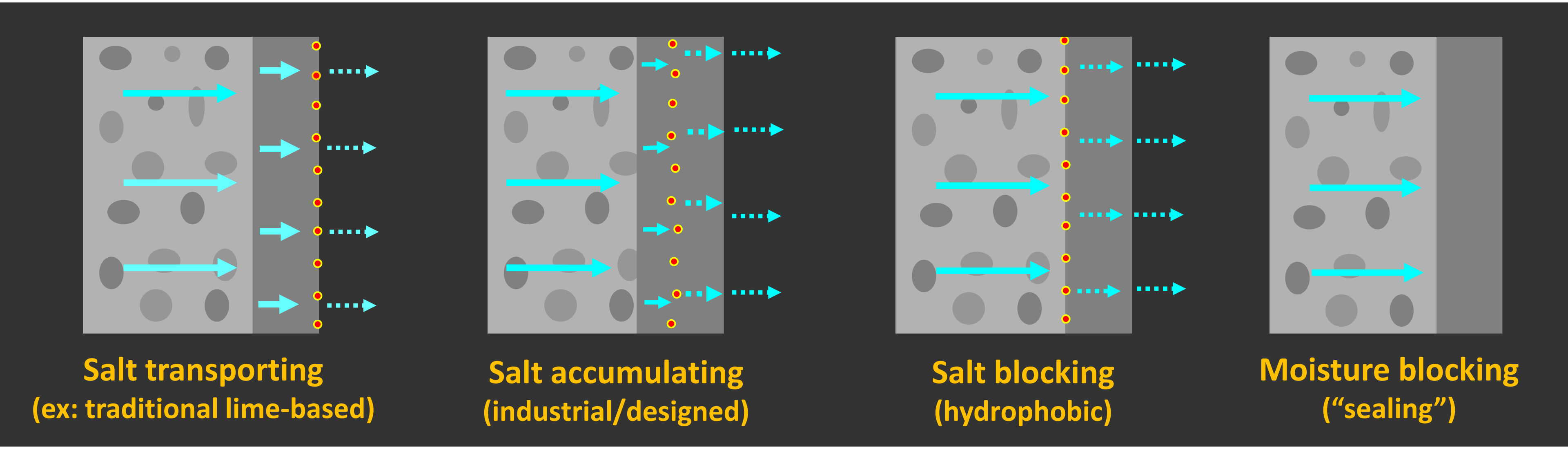
Salt blocking
(hydrophobic)

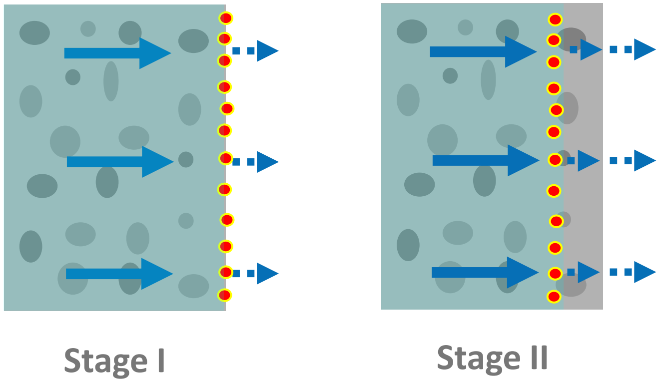


Moisture blocking
("sealing")

Repair mortars. Working principles and typical properties.

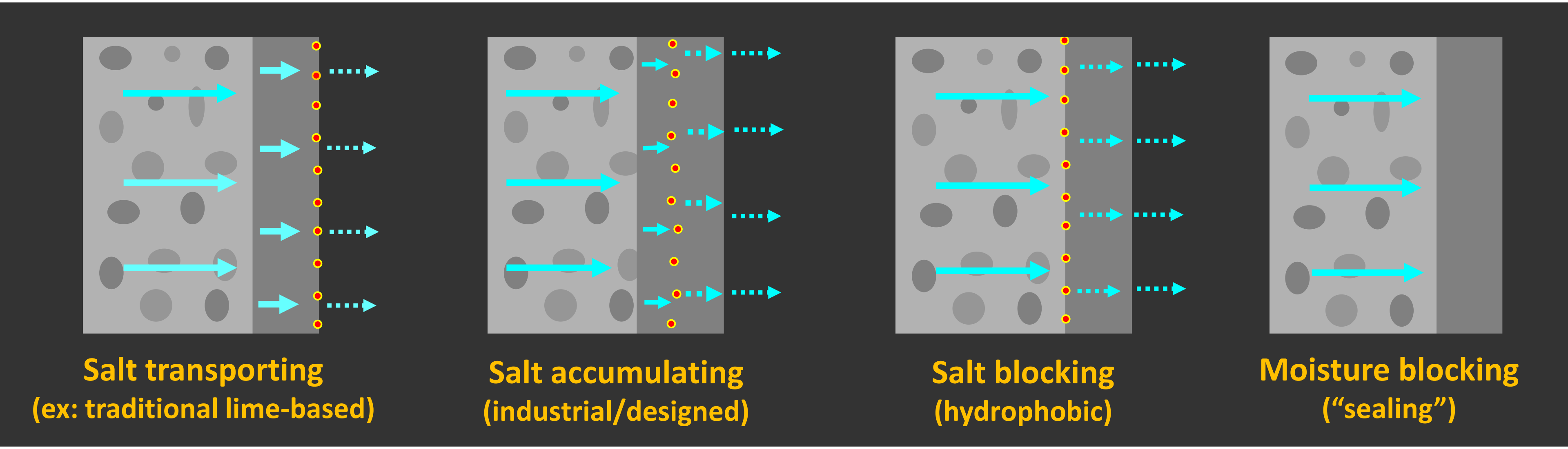
Plasters and renders for salt loaded walls: working principles



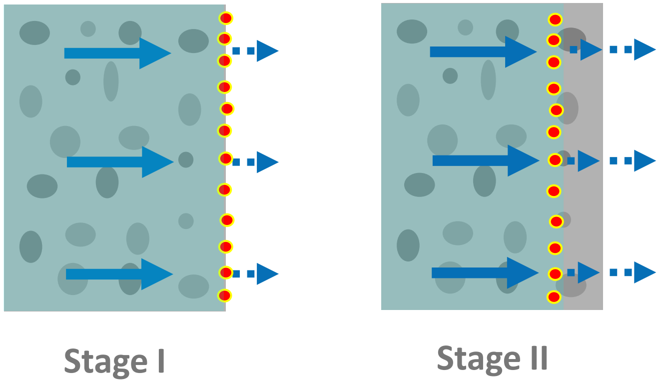


Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles

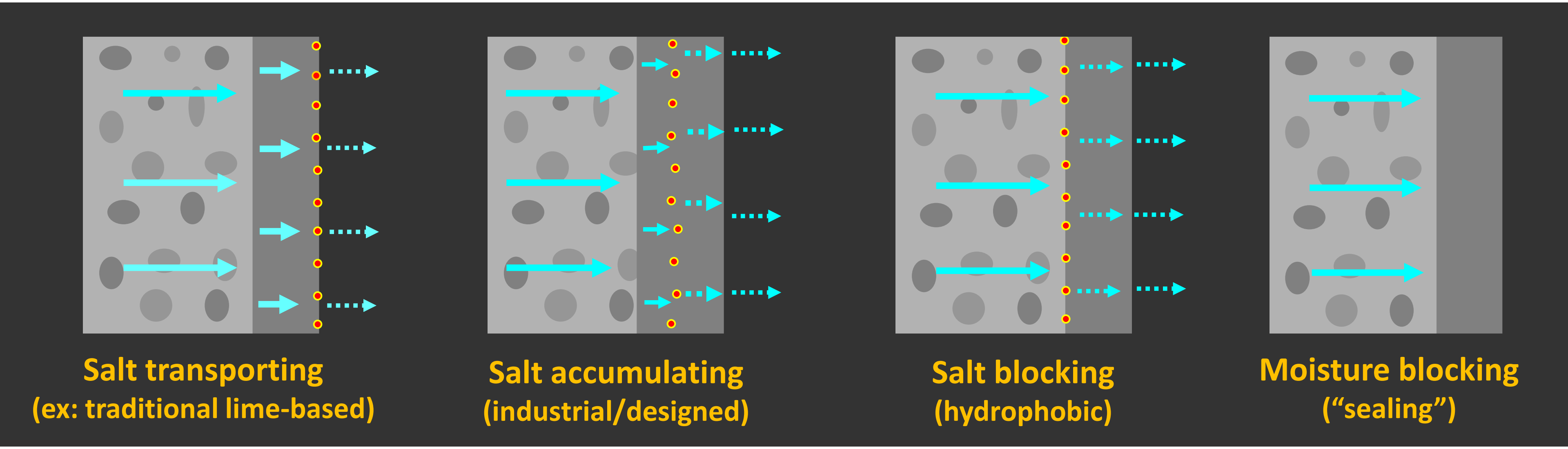


Behaviour of plasters and renders depends on all factors that influence the liquid or the vapour flow



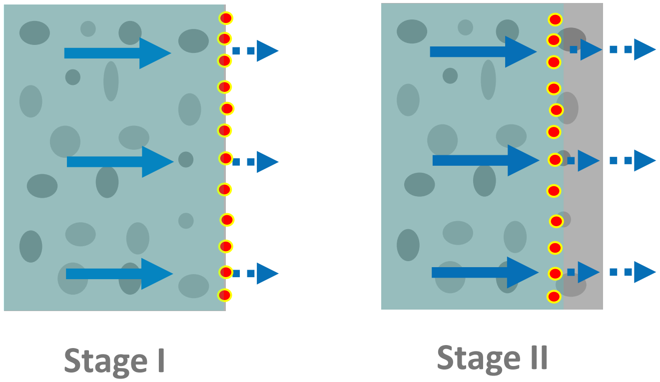
Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: working principles



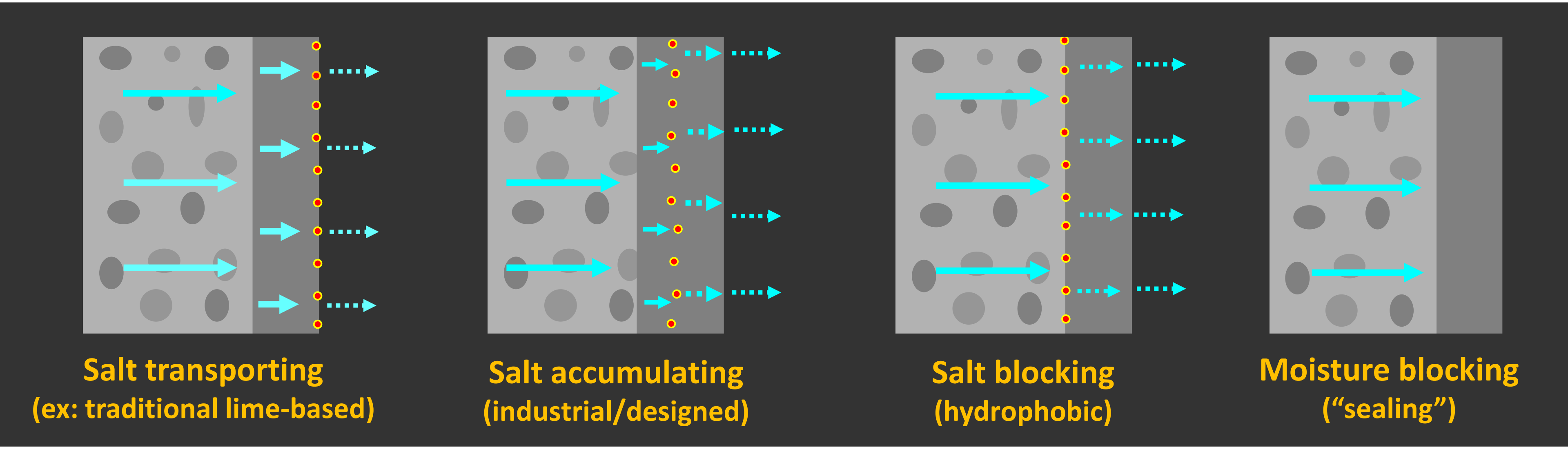
Behaviour of plasters and renders depends on all factors that influence the liquid or the vapour flow:

- Environmental conditions
- Salt solution (type of salt, concentration)
- Paint layer
- Substrate



Repair mortars. Working principles and typical properties.

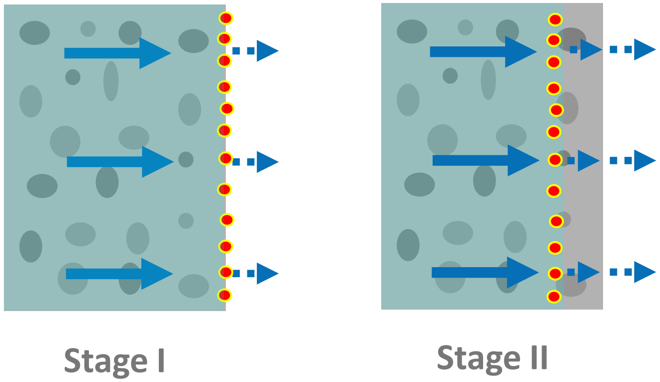
Plasters and renders for salt loaded walls: working principles



Behaviour of plasters and renders depends on all factors that influence the liquid or the vapour flow:

- Environmental conditions
- Salt solution (type of salt, concentration)
- Paint layer
- Substrate

… this influence may be distinct for different materials



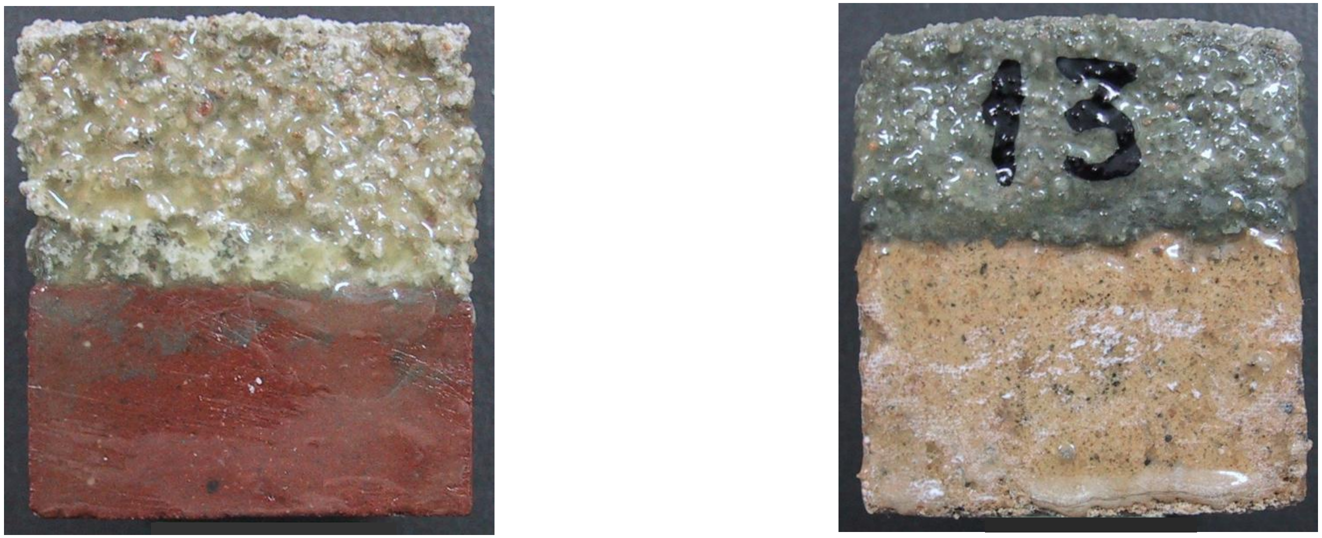
Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the substrate

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the substrate

Salt crystallization test … on plaster/substrate specimens…



Traditional CEM IV-lime plaster

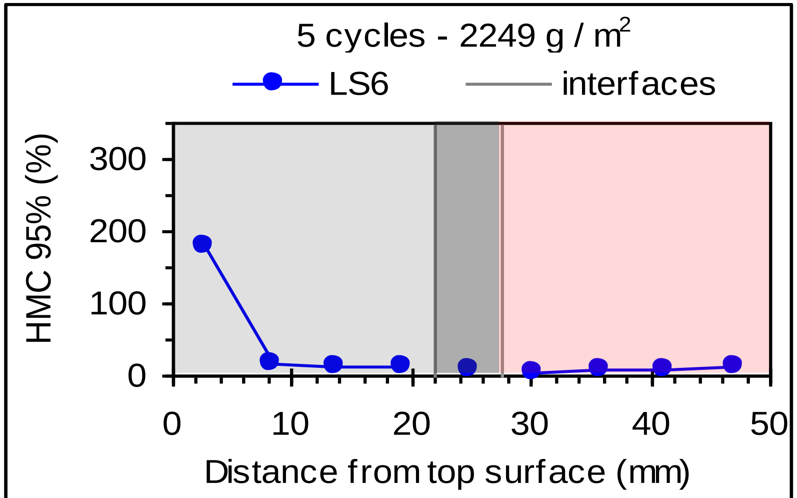
Brick substrate

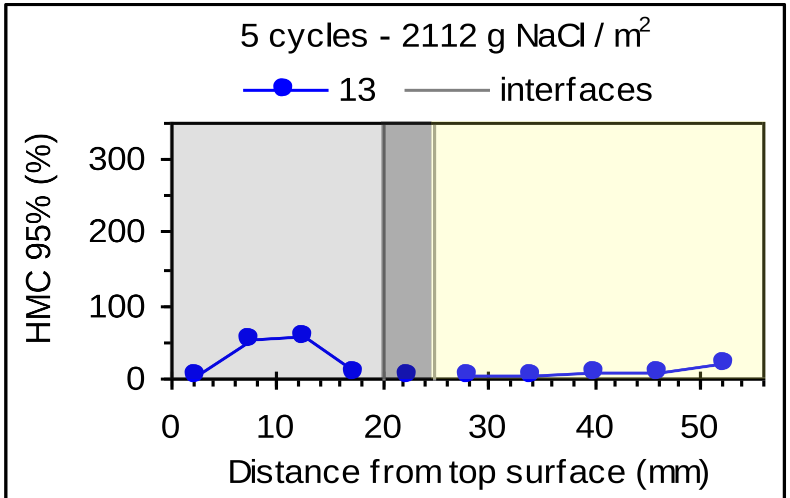
Lime mortar substrate

Sodium chloride crystalization

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the substrate





Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the substrate

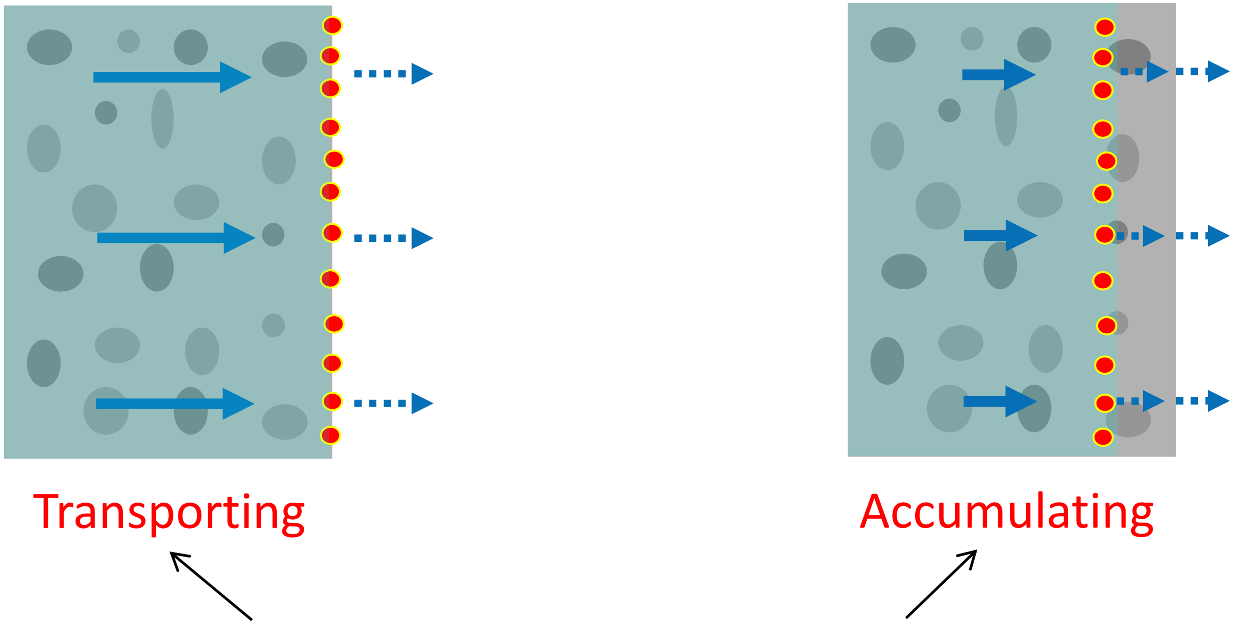
Transporting

Accumulating

Relative suction properties of plaster and substrate condition the liquid flow into the plaster

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the substrate



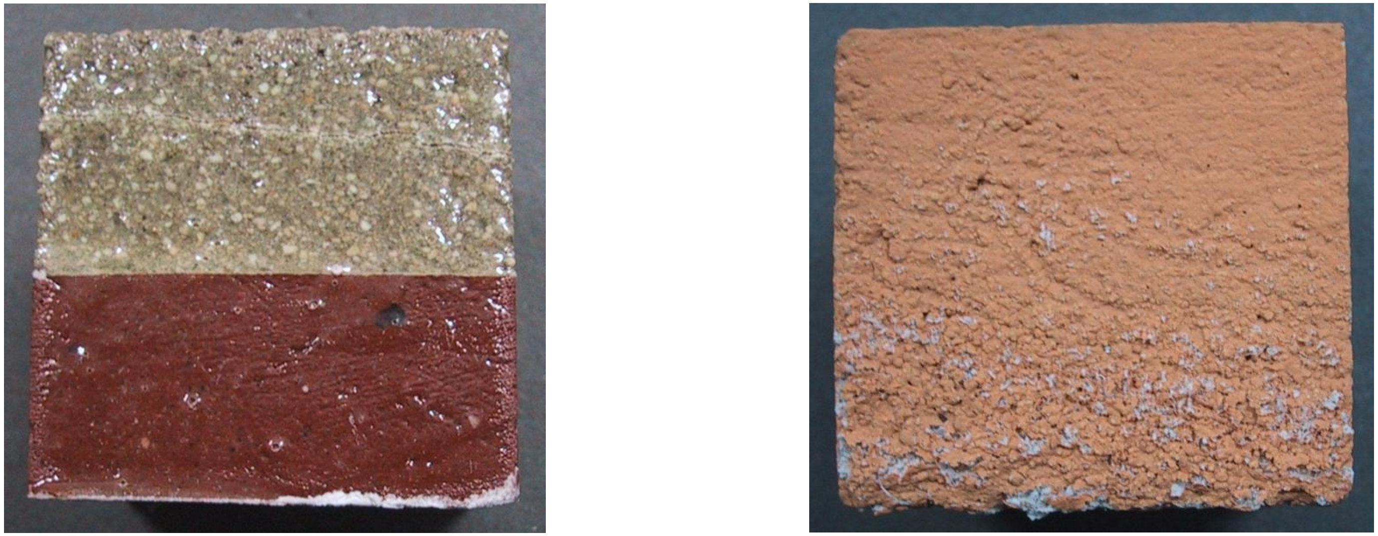
Relative suction properties of plaster and substrate condition the liquid flow into the plaster

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the paint layer

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the paint layer



Industrial (accumulating) plaster

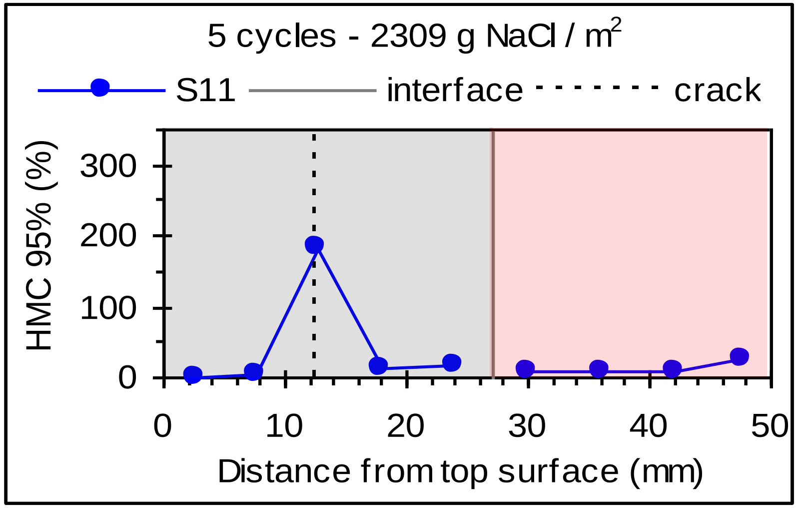
Unpainted

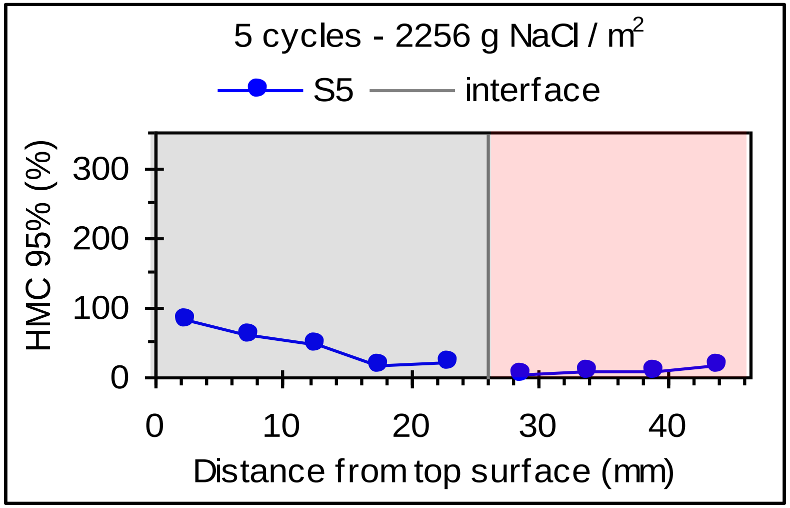
Painted (silicone paint)

Sodium chloride crystalization

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the paint layer





Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: influence of the paint layer

Accumulating

Transporting

Paint conditions the outgoing vapour flow

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

1) Laboratory (salt crystallization) tests

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

1) Laboratory (salt crystallization) tests

- comparison of different plasters/renders
    - under different environmental condition
    - before and after treatment
    - with or without paint
    - on different substrates, etc.

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

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  - before and after treatment
  - with or without paint
  - on different substrates, etc.
- salt crystallization tests cannot serve as general performance tests
  - contradictory aims (simulating reality + speeding up damage) :
    - damage accelerated (more concentrated solutions, lower RH, higher temperature) => ≠ crystallization pressure; ≠ salt distribution => distinct decay features can arise
    - influence of the experimental conditions may vary for different materials and conditions

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

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    - damage accelerated (more concentrated solutions, lower RH, higher temperature) => ≠ crystallization pressure; ≠ salt distribution => distinct decay features can arise
    - influence of the experimental conditions may vary for different materials and conditions
- more important to use realistic conditions (ex: environmental conditions, solution concentration) than to achieve damage in a very short period of time.
- useful to have a reference plaster/ render with known behaviour on site conditions

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

1) Laboratory (salt crystallization) tests

2) Numerical computational models

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

1) Laboratory (salt crystallization) tests

2) Numerical computational models

- powerful tool for simulating the behaviour of plasters and renders under different conditions
- simultaneously considering the numerous complex and dynamically interrelated factors involved
- effective tools not yet available

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

1) Laboratory (salt crystallization) tests

2) Numerical computational models

3) Site testing

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

How to predict the behaviour of a certain plaster/render?

1) Laboratory (salt crystallization) tests

2) Numerical computational models

3) Site testing

- test panels
- best means of evaluating the true behaviour of a given plaster/render under real conditions
- allow considering factors related to the application technique

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

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- best means of evaluating the true behaviour of a given plaster/render under real conditions
- allow considering factors related to the application technique
- may take considerable time and effort (prepare the substrate + make the test panels + evaluation)
- slow (possibly) => measure salt distribution profiles (accumulation tendency)
- carefully choose critical areas <= moisture and salts are often heterogeneously distributed

Repair mortars. Working principles and typical properties.

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… use whenever possible

Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

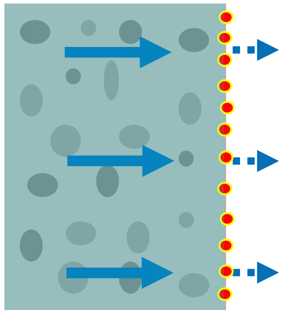
Functional requirements

Health requirements

- for living spaces, museums, rooms where perishable goods are stored (paper, food, ...)
- surface damage not acceptable
- salt accumulating or moisture blocking plasters/renders

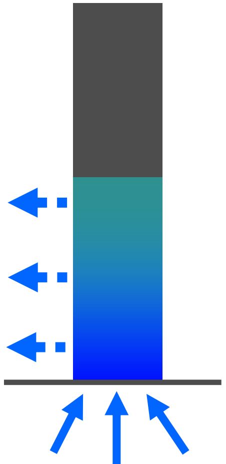
Protection of nearby elements

- paintings, sculptures, stone elements
- avoid that salt solutions are diverted into them
- salt transporting plasters/renders



Stage I

stage I conditions =>
highest evaporation rate =>
lowest evaporating surface area
needed to equilibrate the inflowing moisture



Repair mortars. Working principles and typical properties.

Plasters and renders for salt loaded walls: How to select / prescribe?

Some additional tips …

- Designed (industrial) plasters/renders often have very specific application conditions

  - application by the supplier
  - else, let the plasterers gain practical experience with each specific product

- Avoid plaster/render cracking + ensure a good adherence to the substrate

  - wetting of the substrate + protection against solar radiation in the early days

- Repaintings: always remove the old paint

  - successive layers =>
  - progressively reduction of the evaporation rate =>
  - aggravation of salt damp and efflorescence

Repair mortars. Working principles and typical properties.

Lecture contents

- Introduction
- Binders
  - Earth
  - Lime - air lime; hydraulic lime
  - Cement - natural cement; Portland cement
  - Pozzolans - natural; artificial
- Influence of different binders on the properties of the mortar/plaster/render
- Plasters and renders for salt loaded walls
  - Working principles
  - Some influencing factors:
    - The substrate
    - The paint layer
  - How to select / prescribe?

Repair mortars. Working principles and typical properties.

Thank you