3rd Historic Mortars Conference

Artisanal lime coatings
and their influence on moisture transport during drying

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Introduction

Lime coatings are common in historical buildings

aesthetical + sanitary purposes + protection of the substrates

Terena village, Alentejo, south Portugal

Introduction

Lime coatings are common in historical buildings

aesthetical + sanitary purposes + protection of the substrates

- interiors and exteriors
- on lime plasters or directly on stone elements
    - most typical: limewashes (aqueous suspensions of lime)
    - also: thicker coatings (lime pastes)

Monte rural, Tavira, Algarve, south Portugal

Mosteiro de Rendufe, Amares, Braga, north Portugal

Introduction

Lime coatings are common in historical buildings

aesthetical + sanitary purposes + protection of the substrates

Moisture / dampness is also frequent in those buildings

- thick solid walls + porous hydrophilic materials + direct contact with the ground + soluble salts
- coatings control moisture exchanges construction / environment

Mértola, Alentejo, south Portugal

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- when lime coatings are replaced by synthetic coatings
  => drying hindered => often, moisture problems exacerbated

Mértola, Alentejo, south Portugal

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  => drying hindered => often, moisture problems exacerbated

How (and why) do traditional lime coatings affect (or not) the drying of porous building materials?

Mértola, Alentejo, south Portugal

Materials

Substrate: porous materials relevant for cultural heritage

Ref	Designation	Description
A	Lime mortar	dry hydrated lime Lusical H100 : sand (1:3) mortar
CA	Ançã limestone	soft and porous limestone from Portugal
CC	“Grey” limestone	low porosity limestone from Portugal
M	Maastricht limestone	soft and very porous sandstone from the Netherlands
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S. Sebastião Church, Almada, Portugal

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Christ Convent in Tomar, Portugal

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Portuguese pavement

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Basilica of Our Lady, Tongeren, Belgium

http://www.belgium-mapped-out.com/belfries.html

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New Church in Delft, The Netherlands
http://commons.wikimedia.org/

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Cubic specimens with 24 mm edge

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Substrate: porous materials relevant for cultural heritage

Lime coating: maximum porosity; good workability

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PC	Lime paste	dry hydrated lime Lusical H100 W/L=1.4 (by weight)

Cubic specimens with 24 mm edge

coating applied in two crossed coats (24 hour interval)

by brush (on the mortar) or spatula (on the stones)

Materials

Substrate: porous materials relevant for cultural heritage
Lime coating: maximum porosity; good workability

Ref	Designation	Description	Capillary porosity (%)	Modal pore radius (µm)
A	Lime mortar	dry hydrated lime Lusical H100 : sand (1:3 by volume)	20.8	0.59
CA	Ançã limestone	soft and porous limestone from Portugal	22.9	0.35
CC	"Grey" limestone	low porosity limestone from Portugal	9.1	0.13
M	Maastricht limestone	soft and very porous sandstone from the Netherlands	42.7	10 –18 (1)
B	Bentheimer sandstone	porous sandstone from Germany	17.7	20 (2)
PC	Lime paste	dry hydrated lime Lusical H100 W/L=1.4 (by weight)	51.1	0.46

(1) De Clercq, H., De Zanche, S., Biscontin, G. (2007) TEOS and time: the influence of application schedules on the effectiveness of ethyl silicate based consolidants, *Restoration of buildings and monuments an international journal* 13, 305-318.

(2) Dautriat, J., Gland, N., Guelard, J., Dimanov, A., Raphanel, J. L. (2009) Axial and radial permeability evolutions of compressed sandstones: end effects and shear-band induced permeability anisotropy, *Pure and Applied Geophysics* 166 , 1037-1061.

Method: drying kinetics (RILEM test)

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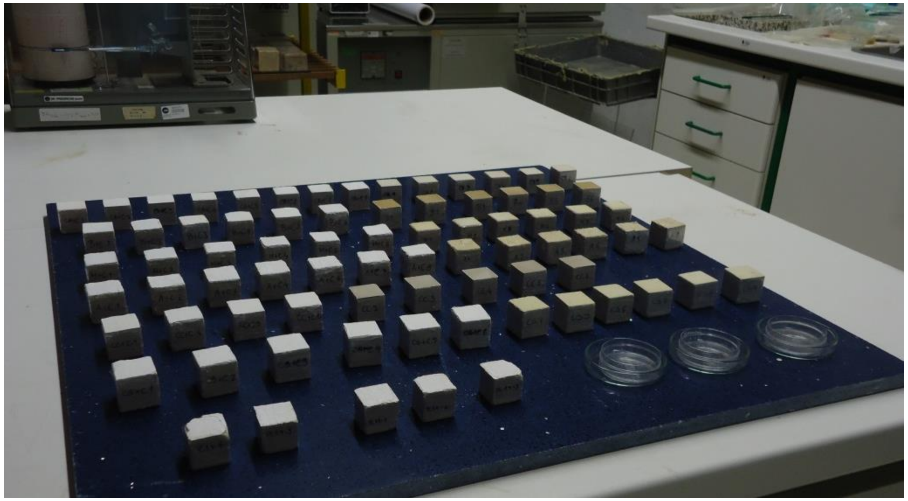
- Laterally sealed specimens (1D moisture transport)
- Partial immersion in water 3 days (capillary saturation)
- Bottom sealed
- Drying at 20ºC and 50% RH
- Free water surfaces (Petri dishes) as reference
- Periodical weighing



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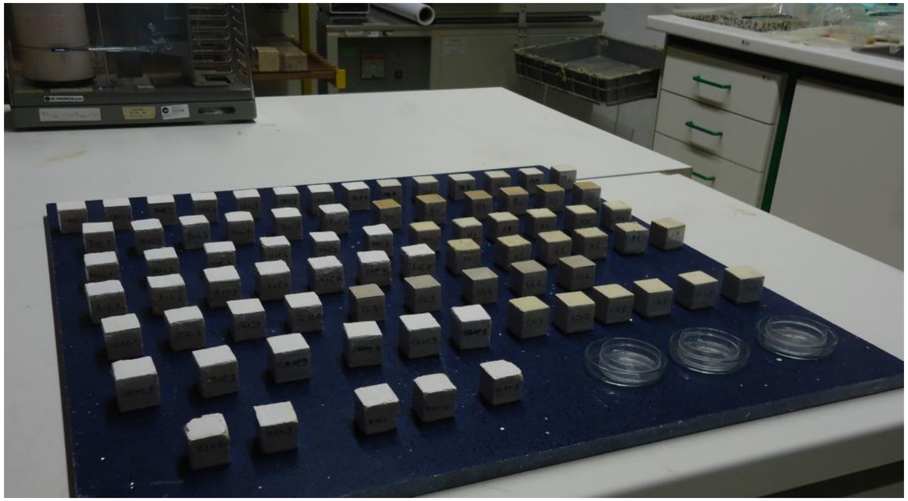
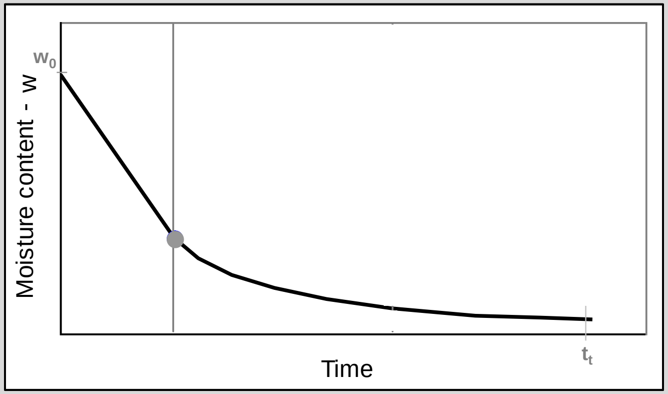
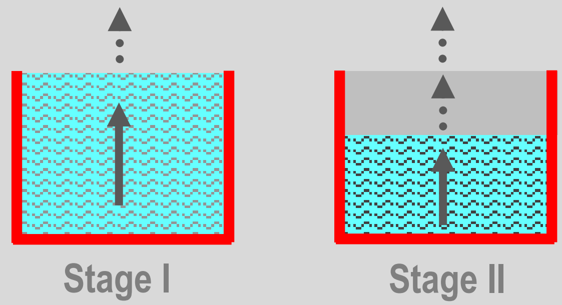




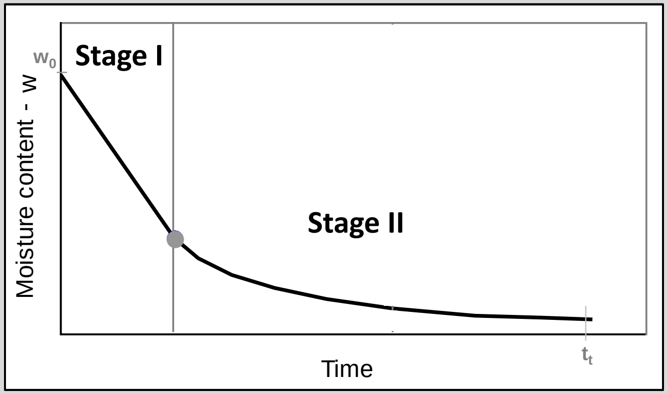
Typical evaporation curve

Method: drying kinetics (RILEM test)



Stage I

- Liquid continuity across the sample
- Evaporation front at the surface
- Drying rate is constant



Typical evaporation curve

Stage I => straight line

Stage II

- Moisture content decreases => lower liquid flow
- Evaporation front recedes into the material
- Drying rate decreases

Sealant

Wet material / liquid continuity

Dry material

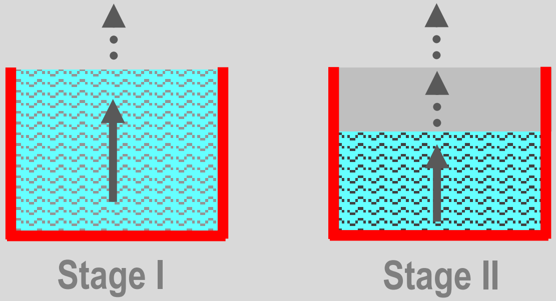
Liquid transport

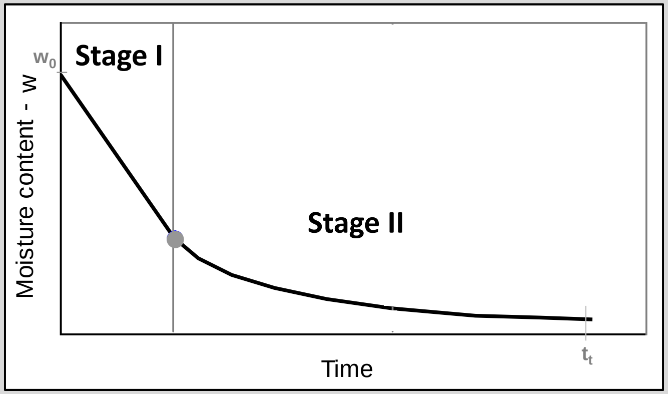
Vapour transport

Method: drying kinetics (RILEM test)

Results

- drying rate (stage I)
- drying kinetics => drying index (NORMAL 28/88)





Typical evaporation curve
Stage I => straight line

Method: drying kinetics (RILEM test)

Results

- drying rate (stage I)
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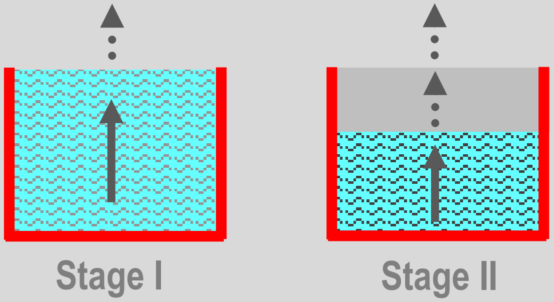
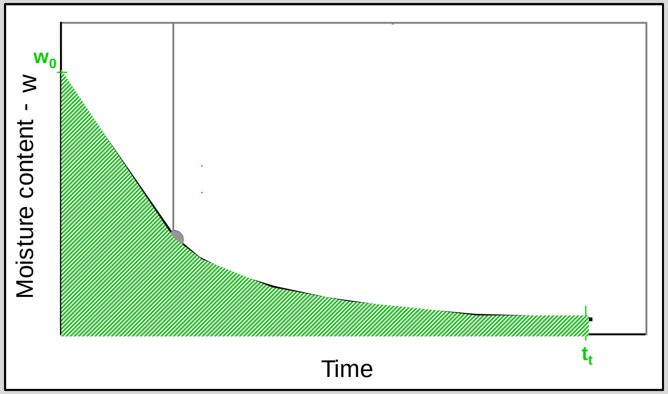
$$DI = \frac{\int_{t_0}^{t_i} f(w_i)dt}{w_0 t_i}$$

Note: the lower DI the faster the drying





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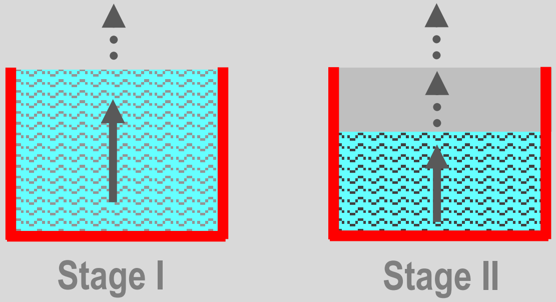

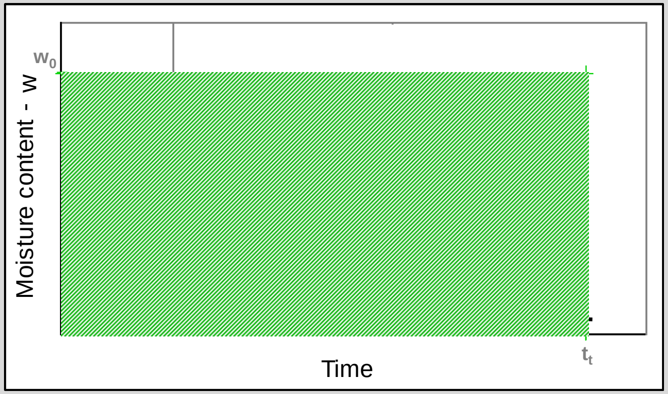

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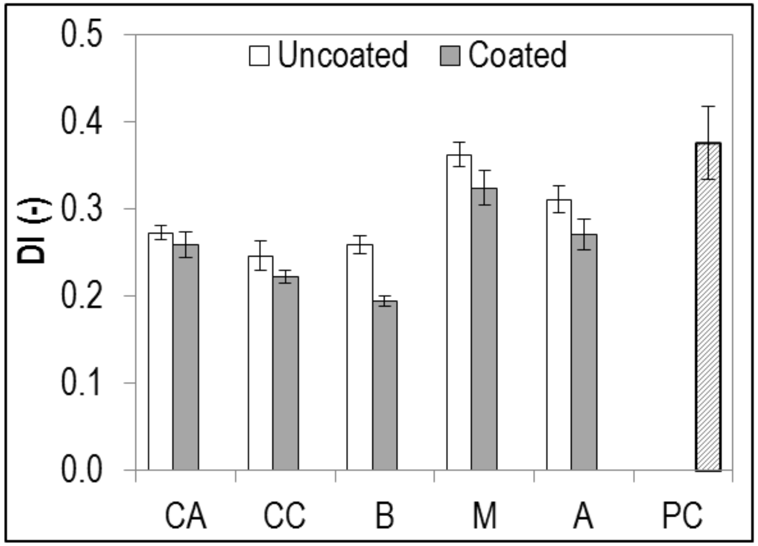
Results and Discussion

Drying index (global drying kinetics)



- Coated materials => lower DI

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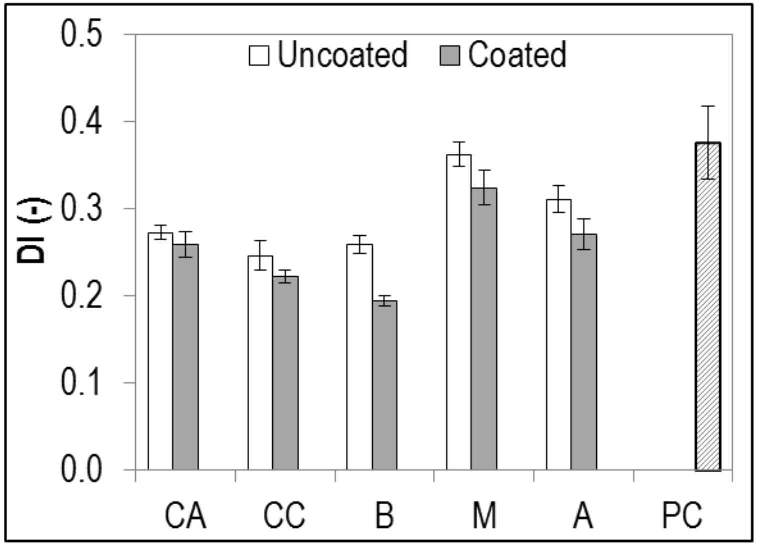

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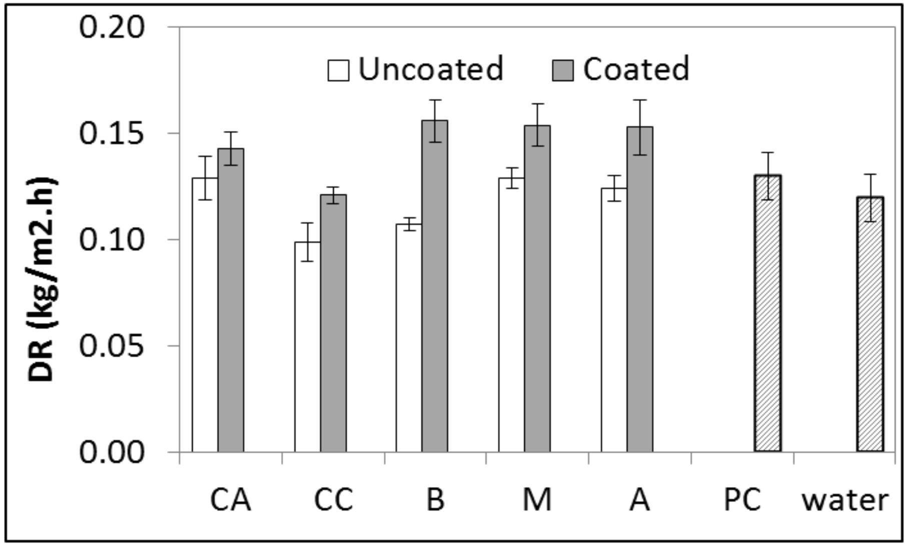

- Coated materials => lower DI + higher DR

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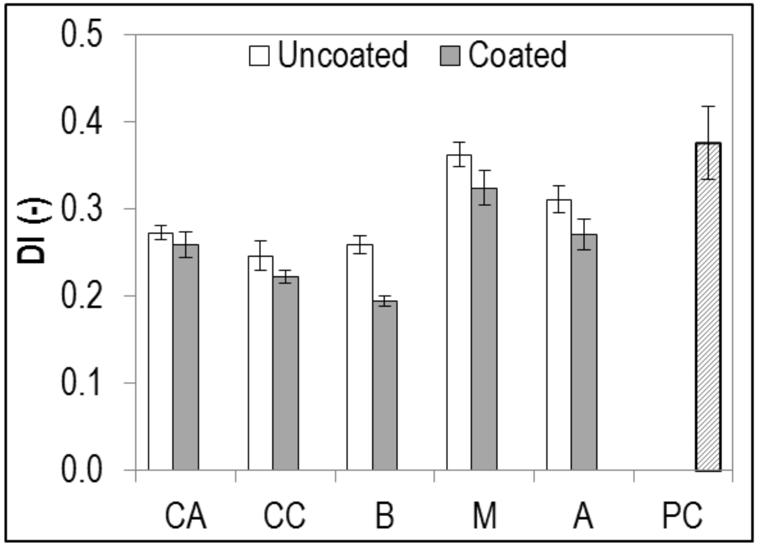

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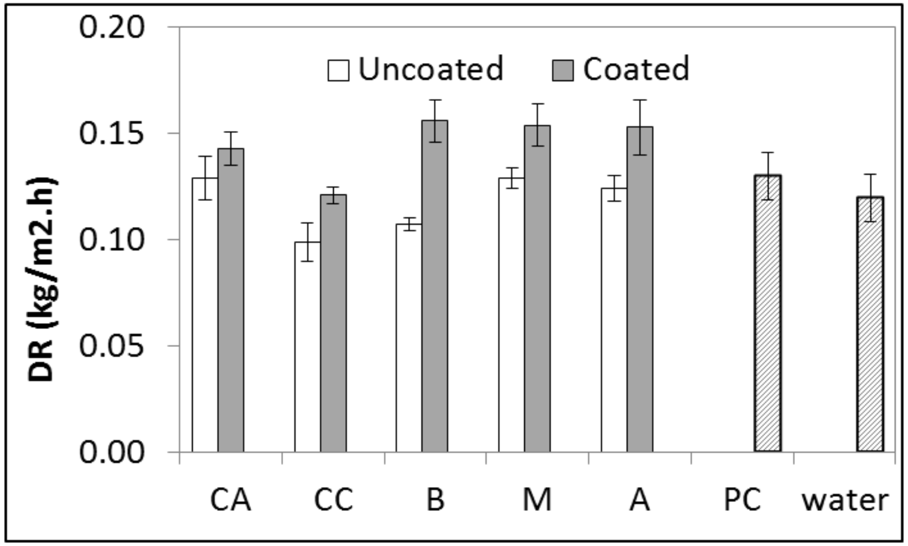

- Coated materials => lower DI + higher DR => the lime coating accelerates the drying

Greatest differences occur for the Bentheimer sandstone (B):
the DI was reduced by 25% and the DR increased by 46%

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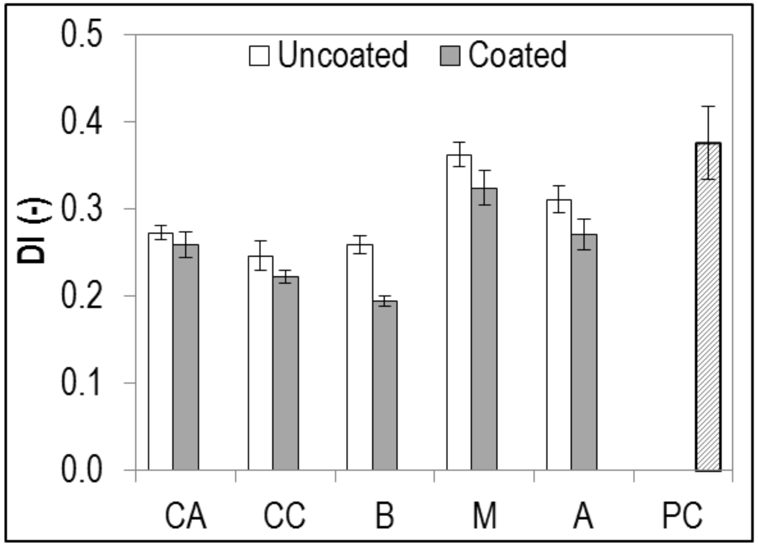

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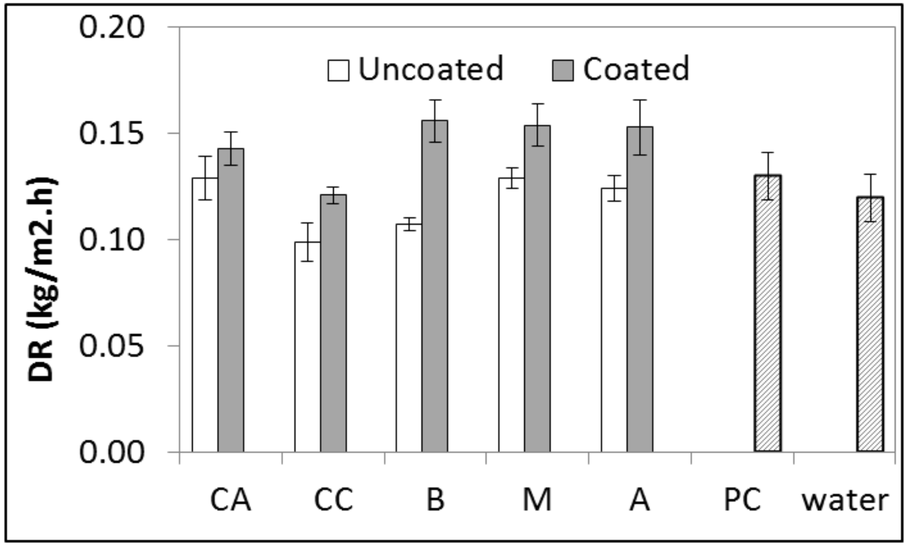

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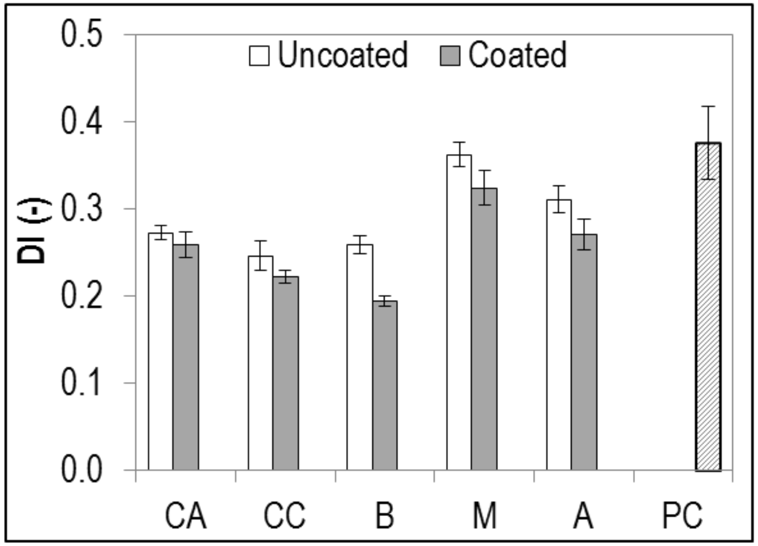

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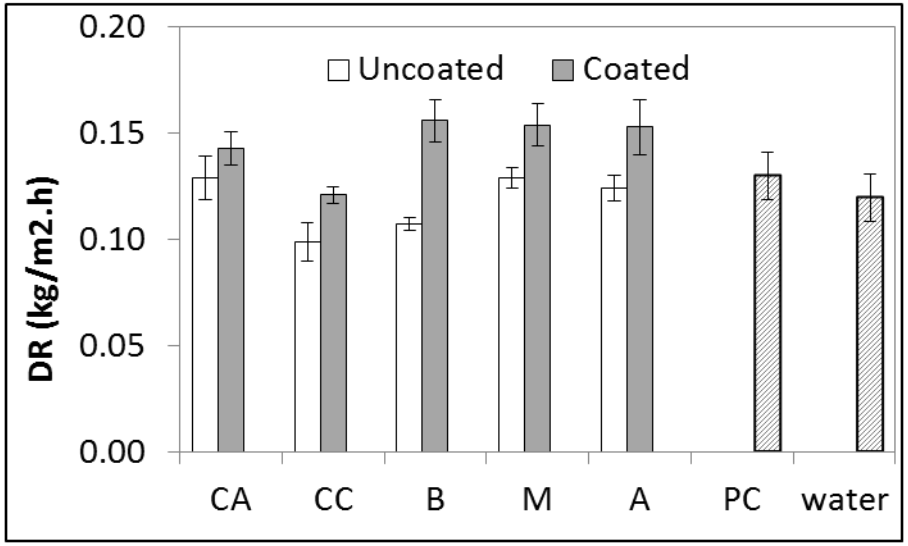

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Why?

Hip.1: High vapour permeability of the lime coating

- could justify, at the maximum, DI equal to that of the uncoated substrate
- wouldn't affect DR as in Stage I the evaporation front is at the surface (no vapour transport across the material)

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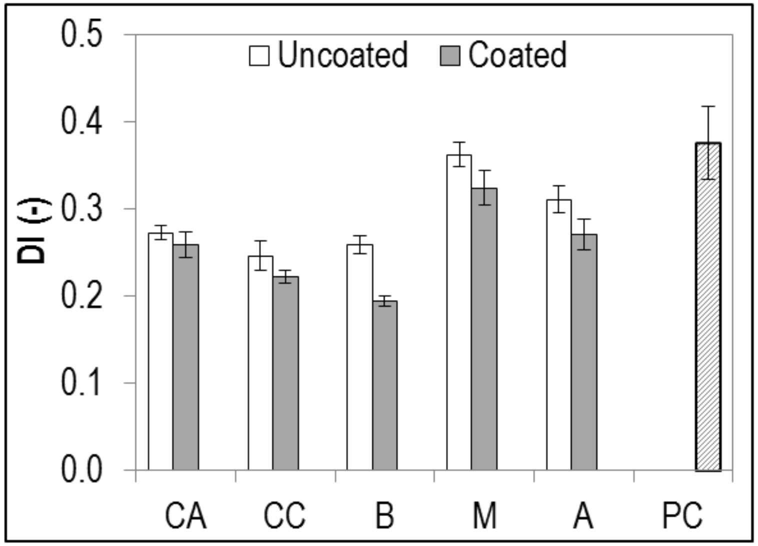

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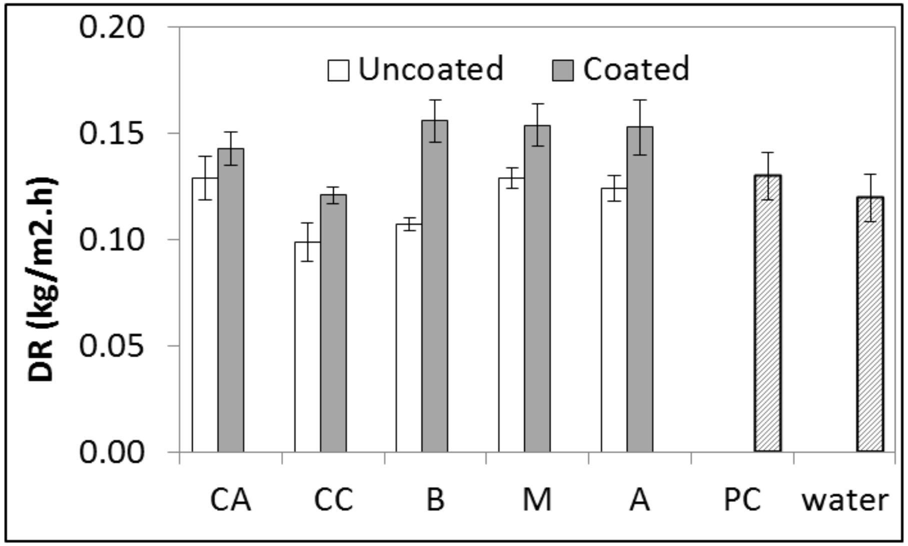

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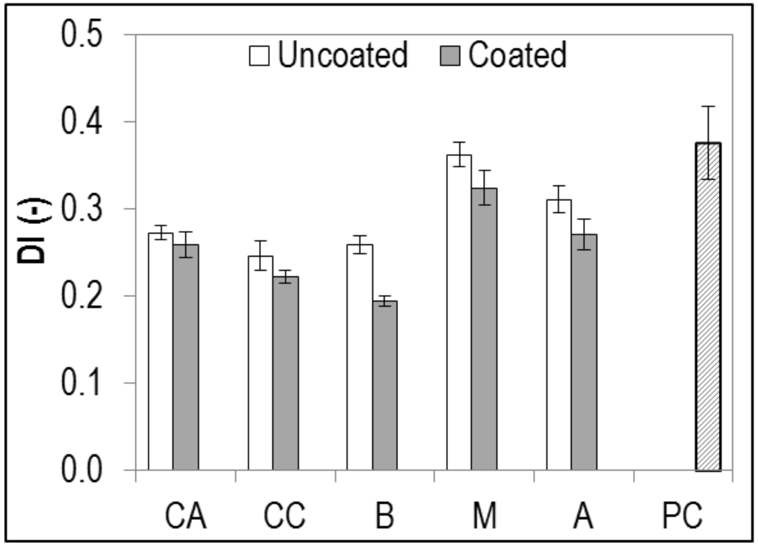

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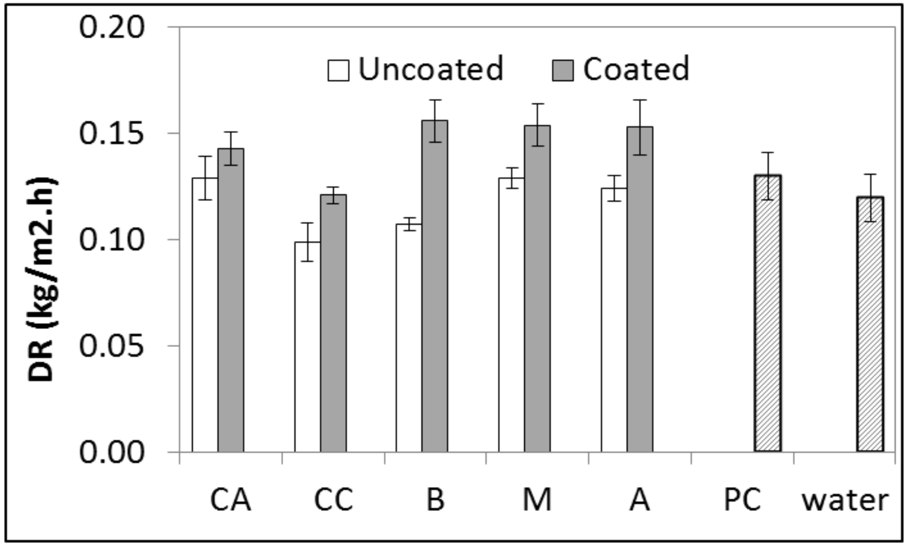

- Coated materials => lower DI + higher DR => the lime coating <u>accelerates</u> the drying

Why?

<u>Hip.2</u>: Larger effective surface of evaporation for the lime coating

- complex pore networks => evaporating surfaces with irregular morphology =>
  => surface area may exceed that of the projected surface
- consistent with the fact that the DR is higher for some materials than for the water surface

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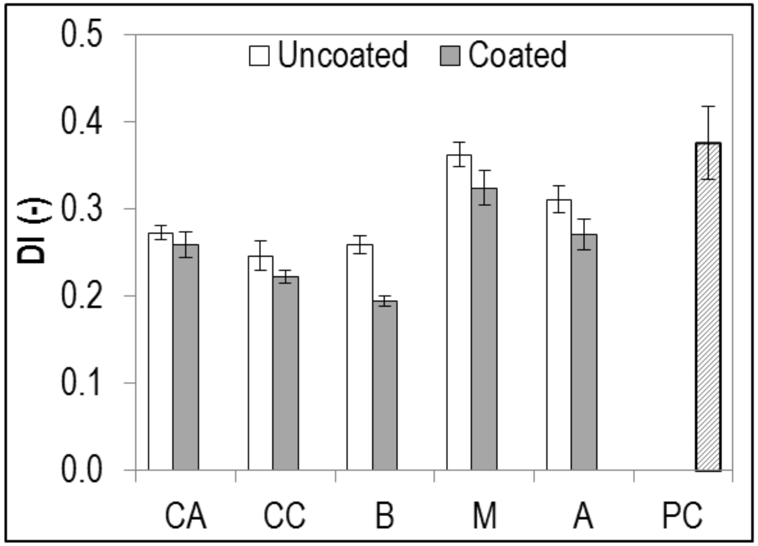

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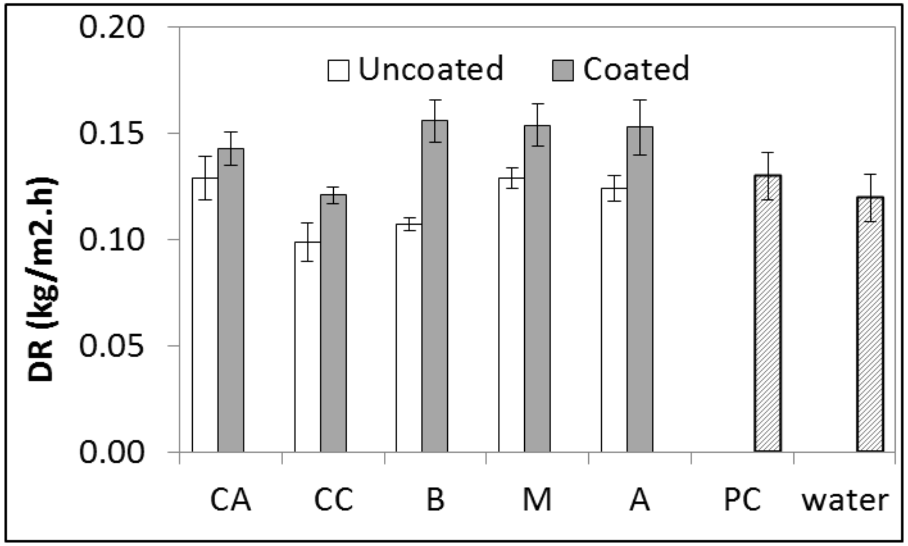


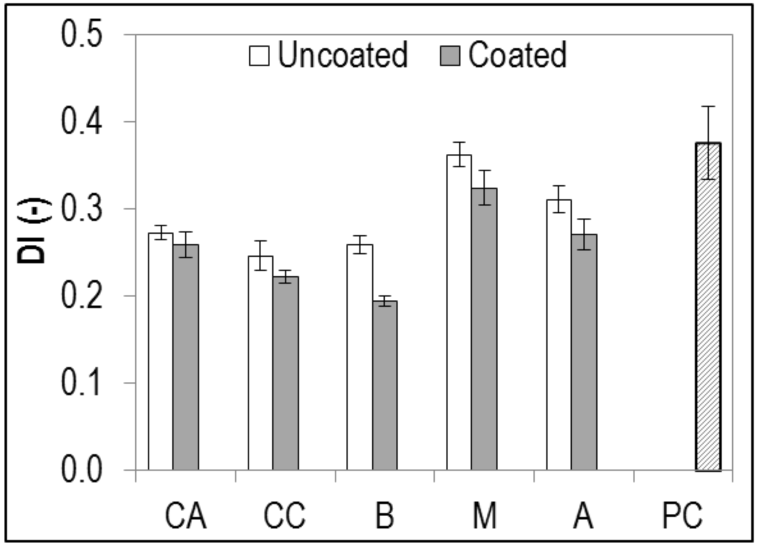
- Coated materials => lower DI + higher DR => the lime coating accelerates the drying
- DR not identical among the coated materials (nor between those and the lime paste)

… contrary to what would be expected because:

- in Stage I the evaporation front is at the surface
- these surfaces are all covered with the same coating

Results and Discussion

Drying index (global drying kinetics)



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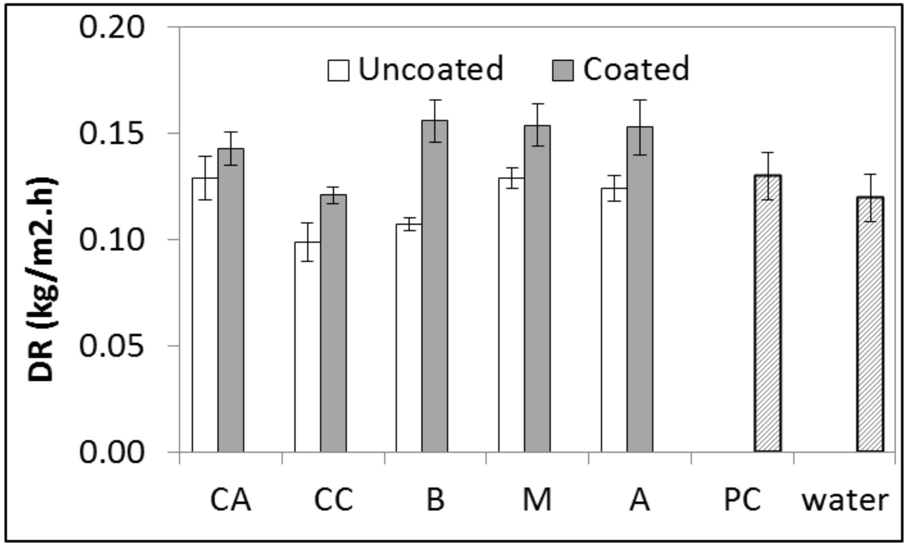

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Why?

Hip.1: The suction of the substrate on the fresh coating changes its physical properties

Hip.2: Influence of the transitional layer, where the coating interpenetrates the substrate

- the menisci recede into the material to generate the capillary pressure gradient
- the coating is thin => the transitional layer could be reached by the wet front

Conclusions

The pure lime coating not only does not hinder drying … but can even accelerate it for a wide range of substrate materials

The acceleration in drying rate:

- is particularly significant for stage I conditions, i.e., when the wet front is at the surface
- is not due to a high vapour permeability of the lime coating
- it is probably due to a larger effective surface of evaporation
- has a magnitude that depends on the type of substrate

Acknowledgements

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We are thankful to Veerle Cnudde and Timo G. Nijland for providing the Bentheimer sandstone.

Thank you!