Water resistance of recycled cement compressed earth blocks

J. Alexandre Bogas[1], Ricardo Cruz[1], Bruno Azevedo[1], Andrea Balboa[1], Vitor Sousa[1]

[1] CERIS, Department of Civil Engineering, Architecture and Georresources (DECivil), Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, Lisbon, Portugal;

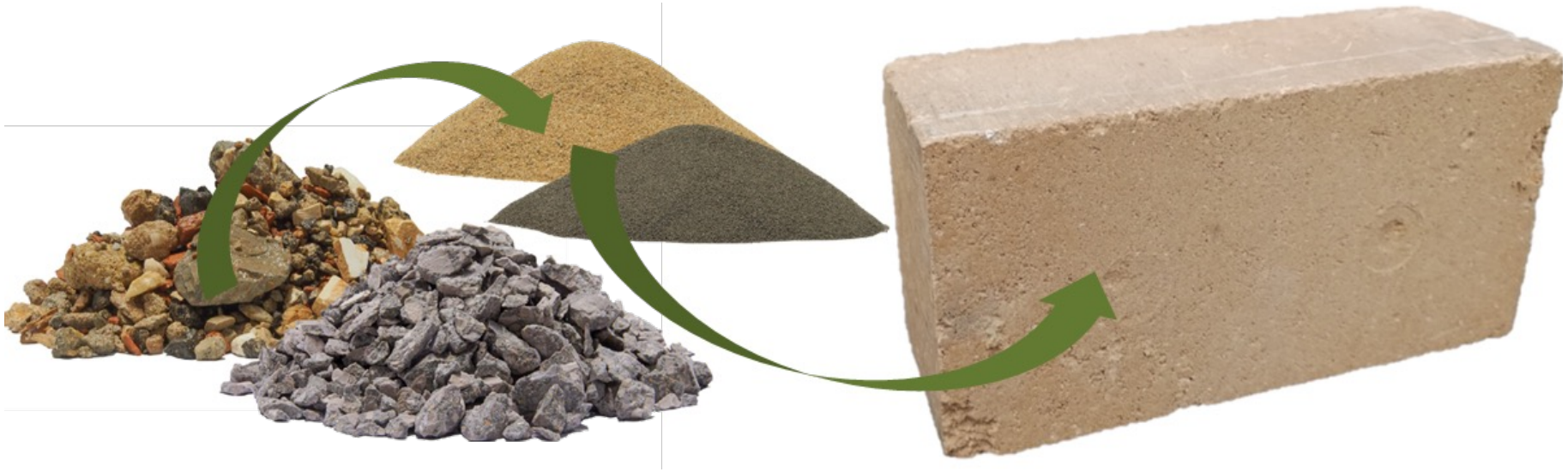
June 2023

TÉCNICO LISBOA CERIS Civil Engineering Research and Innovation for Sustainability fct Fundação para a Ciência e a Tecnologia REPÚBLICA PORTUGUESA

Objectives:

- **Water resistance assessment of CEB with RC**

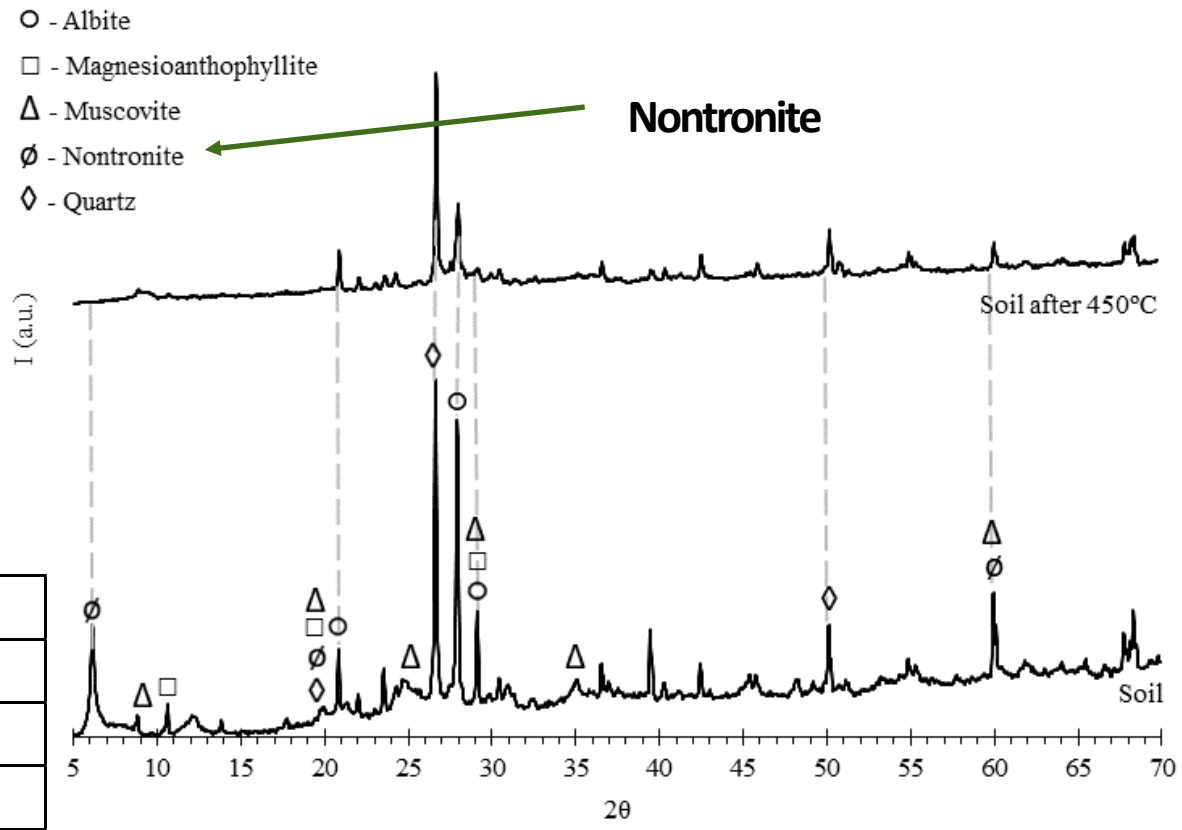
  - 5-10 % Stabiliser
  - 20 to 100% replacent of OPC with RC



Experimental Program

Soil:

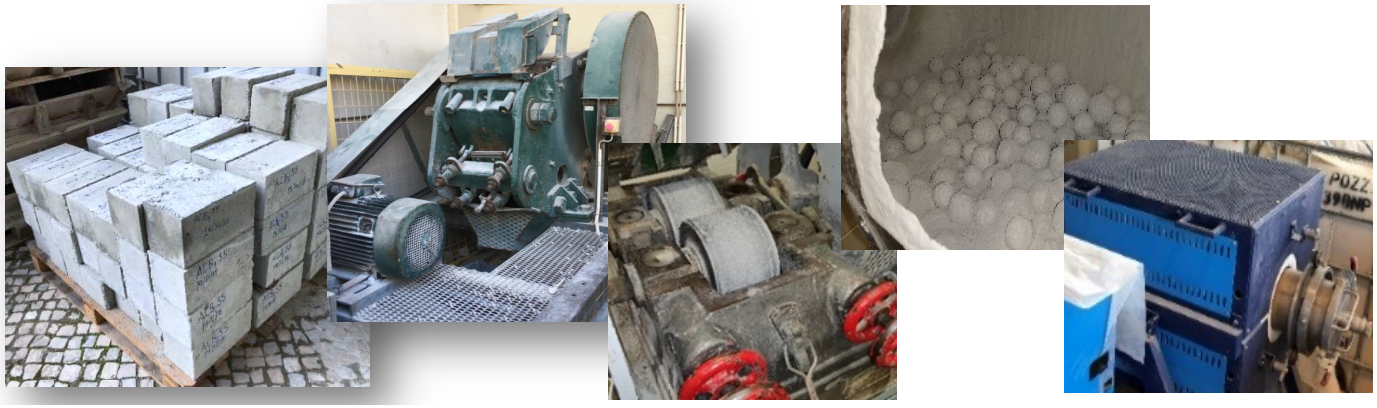
- Unfavourable expansive clay minerals

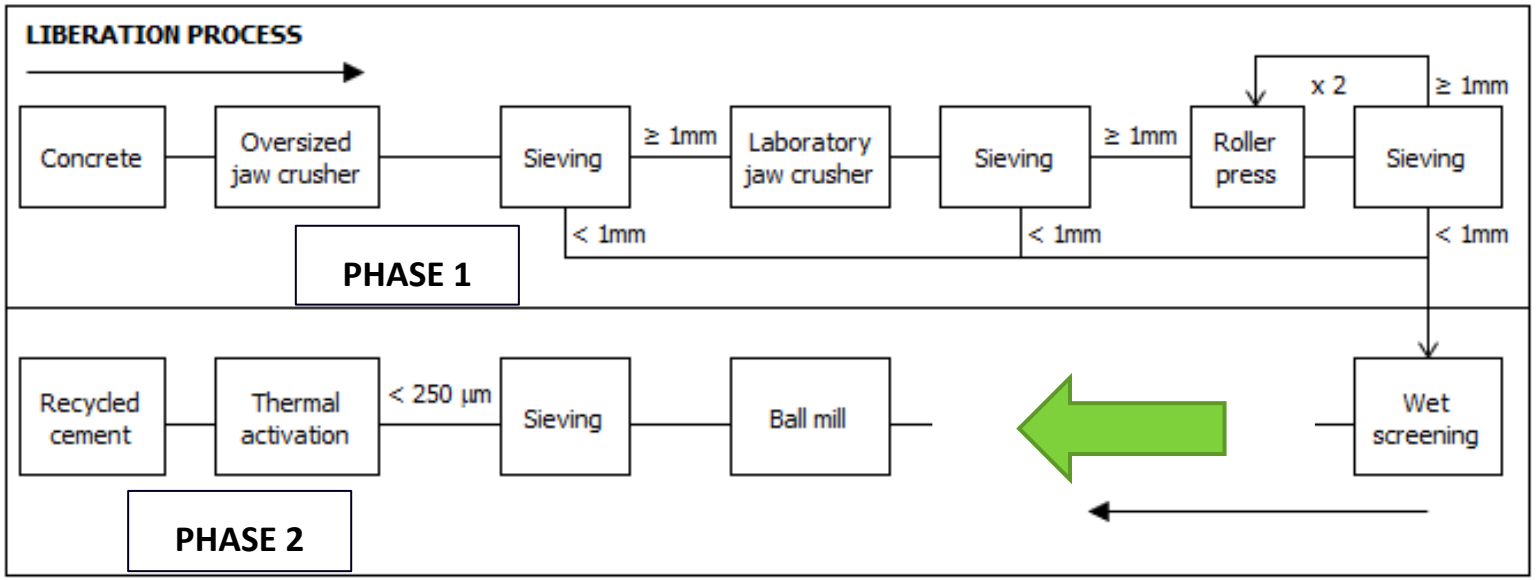


Soil properties (D<8mm)	
gravel (%)	20.1
sand (%)	48.4
silte+clay (%)	31.5
organic matter (%)	<1
OMC (%)	16
LL (%)	30
PL (%)	22
IP (%)	8
density (kg/m^3)	2700

RC production:

- From paste waste with > 90 days





- Phase 1 - grinding/sieving/ milling as in usual waste treatment
- Phase 2 – **Thermal activation treatment at low temperature – 650 ºC**

Composition and production

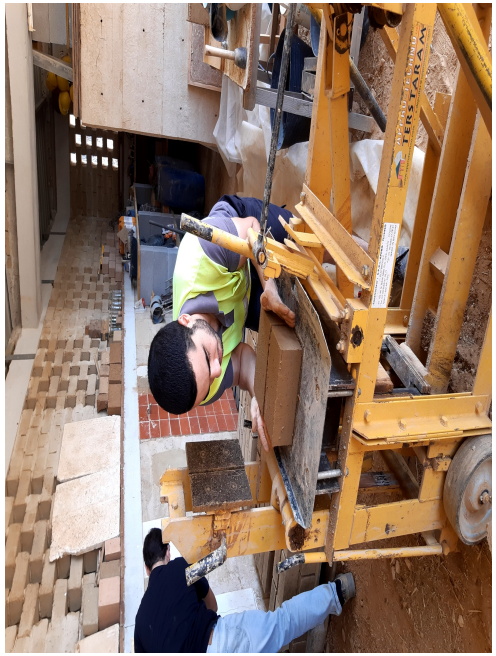
- 7 CEB compositions (220x105x60 mm):

5-10% stabiliser

0, 20, 50, 100% RC

- Pulverization → sieving < 8mm
- Manual Press

CEB	Soil (%)	OPC (%)	RC (%)	Water (%)	w/b
OPC10	90	10	-	15	1.45
RC10	90	-	10	16.5	1.6
OPC5	95	5	-	15.2	2.93
RC5	95	-	5	16.2	3.13
RC2OPC8	90	8	2	15	1.45
RC5OPC5	90	5	5	15.5	1.5
UCEB	100	-	-	14.4	-



Test Methods:

- Water absorption (immersion, capillary, low pressure);

Water immersion

Capillary water absorption

Low presssure water absorption

- **Curing:** 7 days sprayed; Then, lab conditions (19-26ºC and 55-75% RH)
- **Capillary and low pressure:** Oven-dried at 100ºC before testing

Test Methods:

- Water permeability; Water erosion (representative of heavy rain impact)

Water permeability

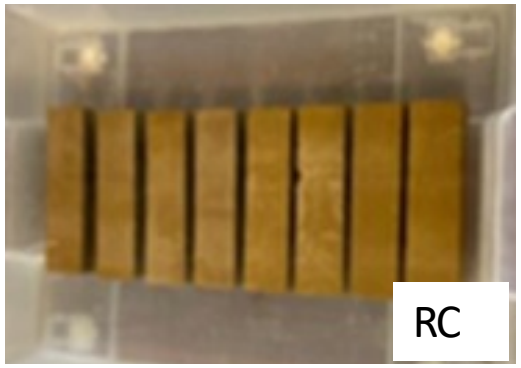
Water erosion – Spry test

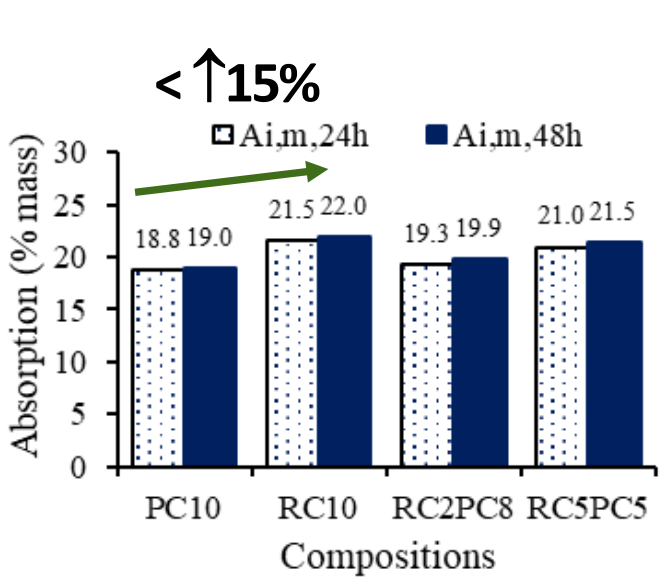
- **Water permeability:** Saturated and subjected to 100 KPa pressure head
- **Spry test:** Subjected to **50**-250 kPa for 1 hour (5x higher the standard)

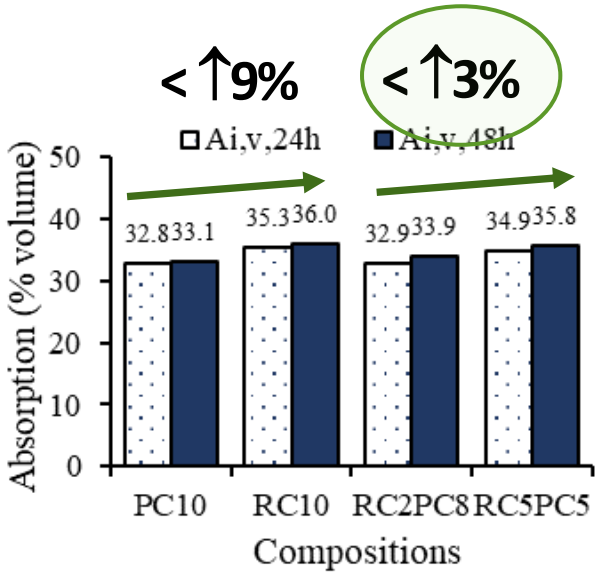
Results and discussion

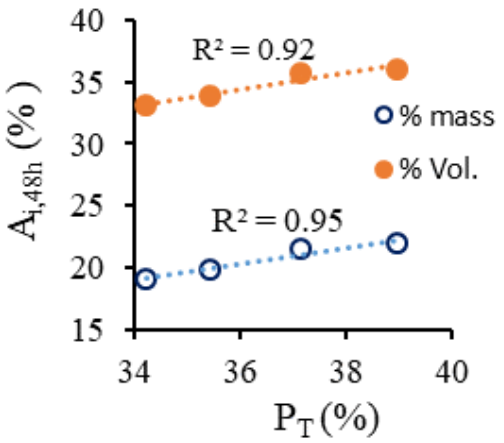
Immersion water absorption

- **UCEB disintegrated in water**
- **↑absorption with ↑%RC**
  (↑ P_T; ↑water and paste volume)
- Not significant up to **50% RC**



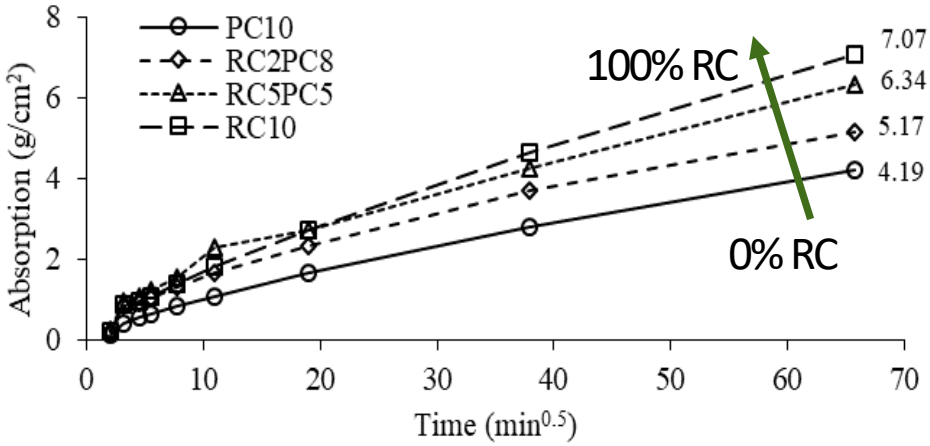


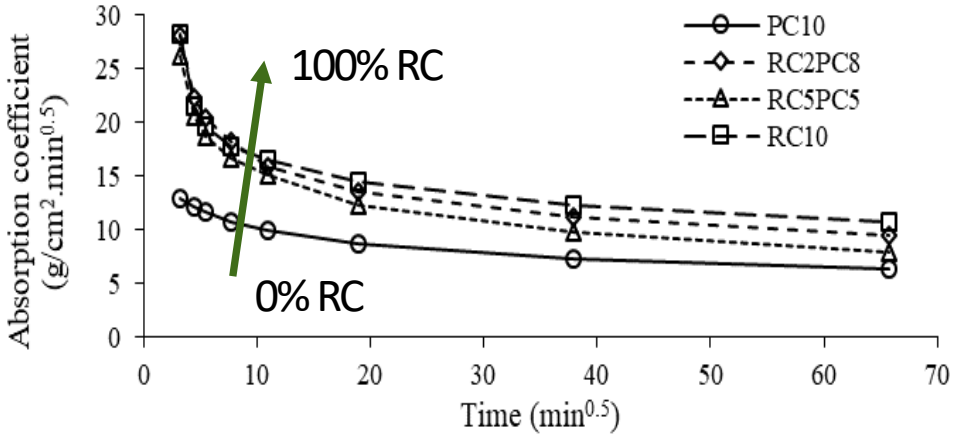




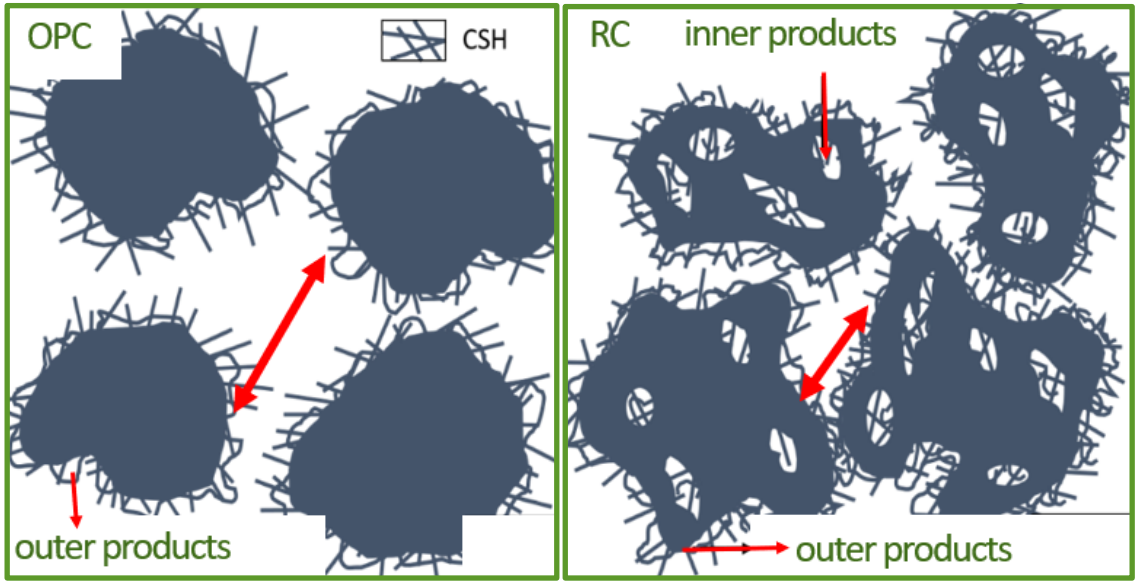
Capillary water absorption

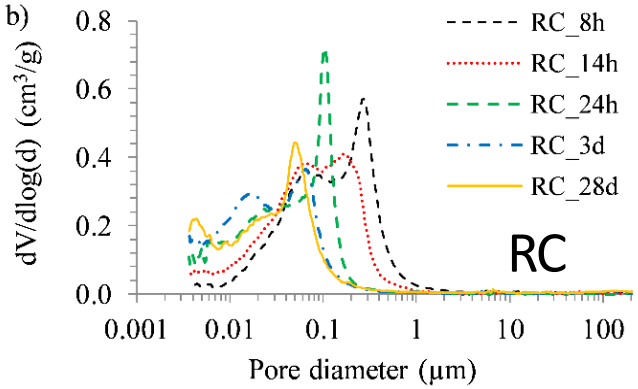
- ↑$A_{bs,72h}$ and ↑ **CA with ↑%RC** (up to 69%)
- **More refined porosity in RC** (↑ cap. action)
- Pre-dried at 100ºC
  (Higher volume of finer pores in RC)

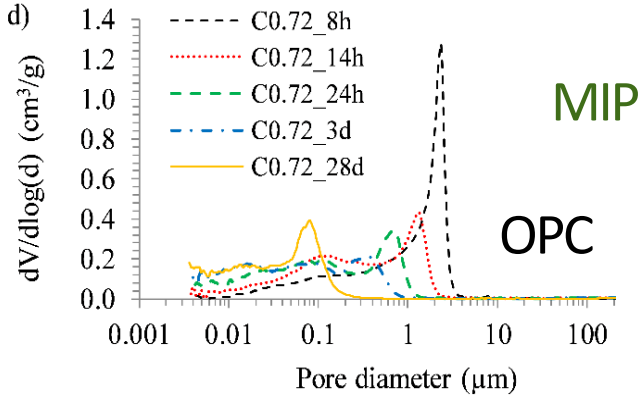




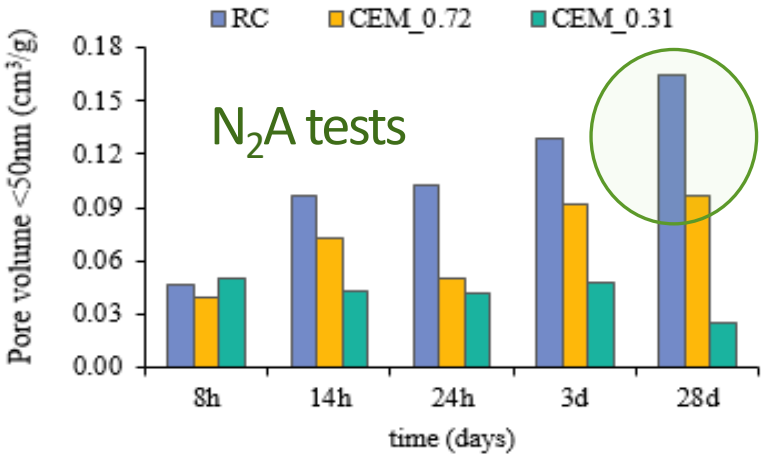
MIP and N_2A tests







MIP tests



RC paste – more refined microstructure

RC paste with higher volume of finer pores (< 50 nm)

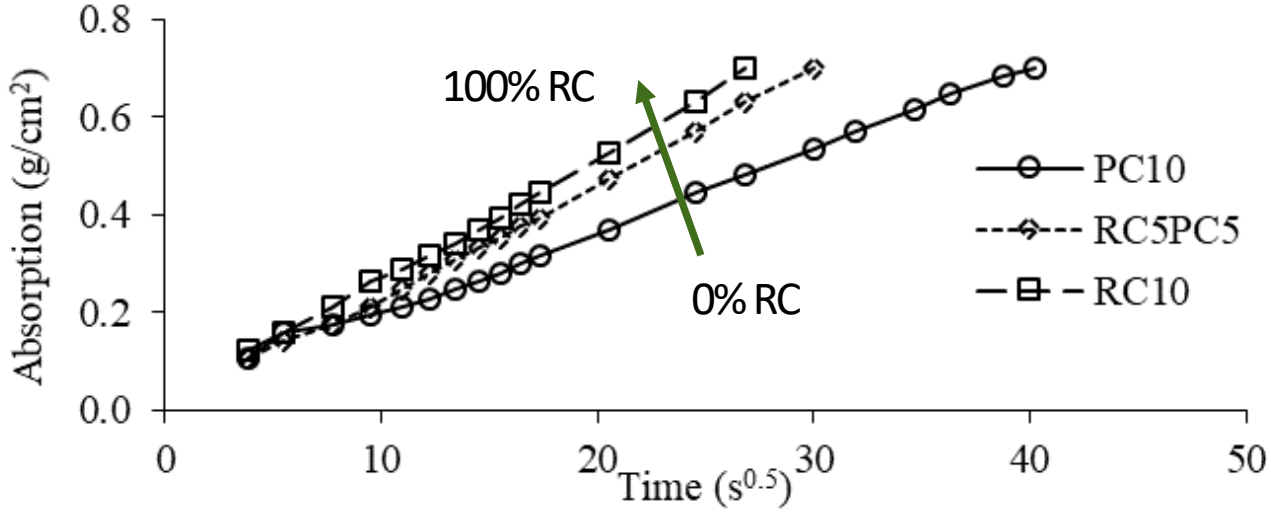
Capillary water absorption

- RC blocks within the low absorption class

CEB	$C_{b,10min}$	$C_{b,10min}$ Class	NTC 5324 (2004)
OPC CSEB	13 g/cm^2.min$^{0.5}$	< 20 g/cm^2.min$^{0.5}$	Class I - very low absorption
RC CSEB	28 g/cm^2.min$^{0.5}$	< 40 g/cm^2.min$^{0.5}$	Class II - low absorption

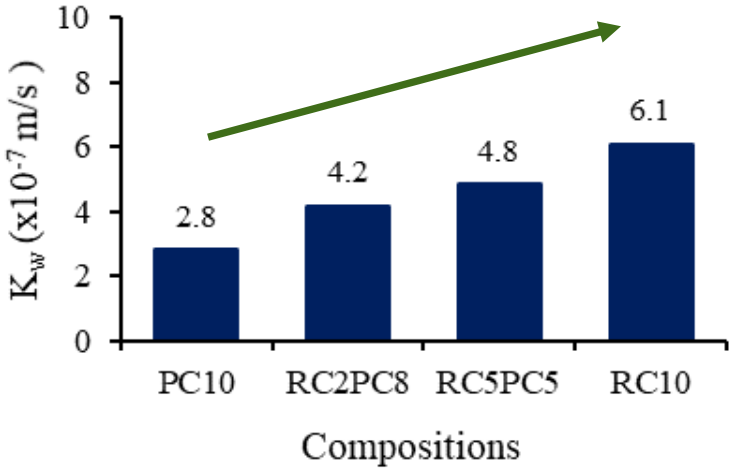
Low pressure absorption (Karsten)

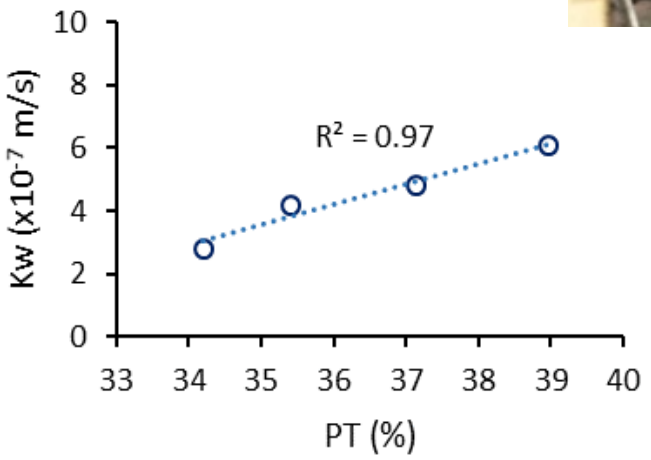
- **Same trend in surface absorption**
- 50% higher $C_{abs,LP,5min}$ in RC CEB than OPC CEB
- Also pre-dried at 100ºC
  (all pore space available for absorption)



Water permeability

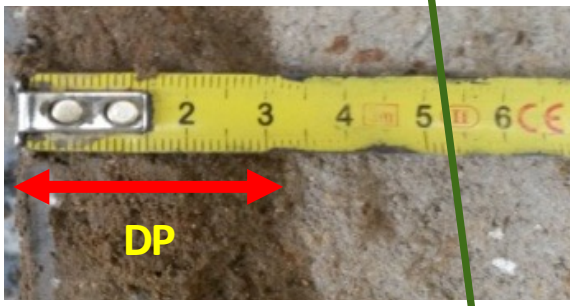
- $K_{w,RC\ CEB} \cong 2 \times K_{w,OPC\ CEB}$
- More **affected with pore connectivity** (Low P_T variation $\Rightarrow$ high $\uparrow$ of K_w)
- **Better hygrothermal inertia and water vapour permeability**

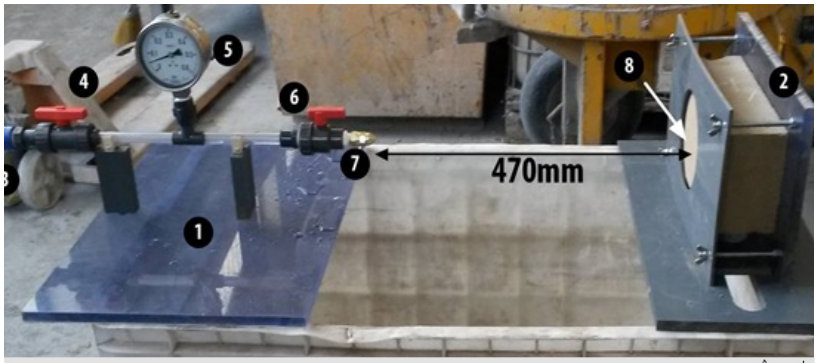


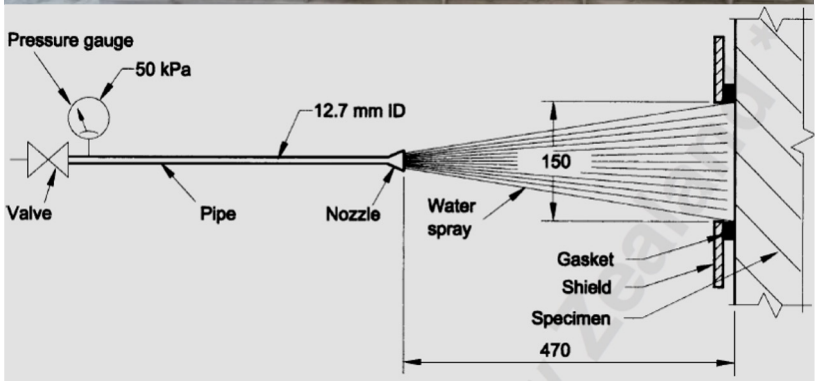


Water erosion –Spry Test

- **CSEB - Erosion rate <1 mm/h (0.5 - 2.5 bar)**
- **Similar water depth penetration (DP)**







Mixture	Pressure (bar)	Test time (min)	DE (mm)	Erosion rate (mm/h)	DP (mm)	Class (mm)
PC10	2.5	60	-	< 1	38	**EI1**
RC5PC5	2.5	60	-	< 1	36	**EI1**
RC10	2.5	60	-	< 1	39	**EI1**
UCEB	0.5	7	60	514	N/A	**EI5**

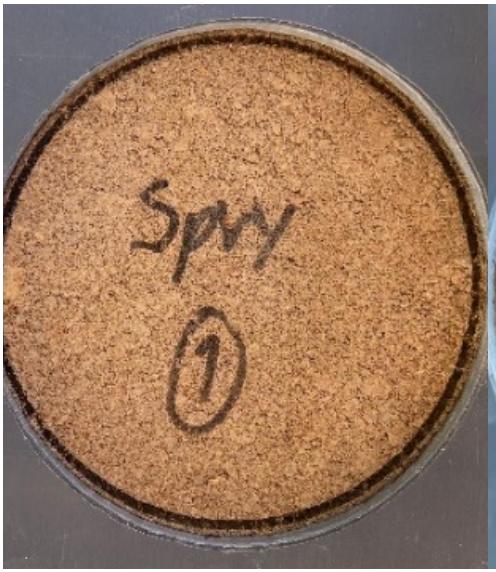
NZS 4298 (1998) - 1 h at 50 kPa

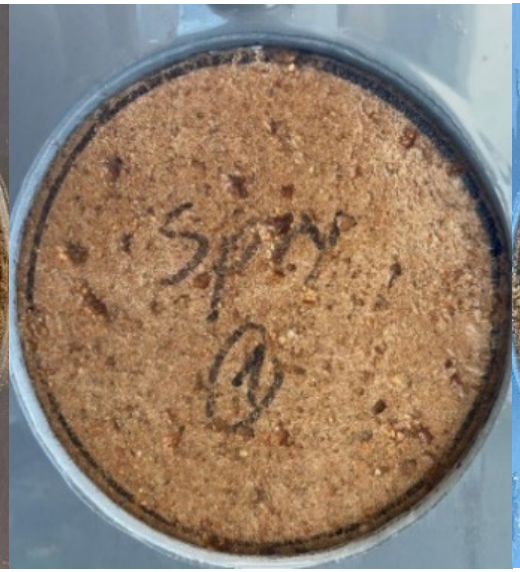
Classes	DE (mm/h)
EI1	<10
EI2	10 < DE < 25
EI3	25 < DE < 45
EI4	45 < DE < 60
EI5	60 ≤ DE

EI - Erosion index

Water erosion –Spry Test

- **CSEB** – Low erosion rate <1 mm/h (2.5 bar)
- **Stabilization is fundamental**





Before Test

OPC CSEB

RC CSEB

UCEB

Lost of only some few particles (<2 mm)

Fully eroded after 7 minutes

Conclusions:

Water absorption and permeability increased with RC content

Mix design optimization to improve compactness is needed

No significant reduction of water resistance, even after 48 h water immersion and severe water erosion (compared to OPC)

$\cong$ **180 kg/m^3 stabiliser** (10%) $\Rightarrow$ **100% RC** $\Leftrightarrow$ **55 kg/m^3 clinker**

CO_2 savings - 20% RC (16%); 50% RC (38%); 100% RC (72%);

RC proves to be viable as a stabilizer for CEB

Thank you for your attention