Compressive strength of compressed earth blocks stabilized with calcium carbide residue and rice husk ash

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EARTH: A SUITABLE BUILDING MATERIAL

In developing countries, 1/2 of population lives in earthen housing, because earth is

- ✓ Widely available and affordable
- ✓ Provide healthy indoor environment

The quality of earth as a construction material can be improved to meet the required performance

- ➢ Clay binder in earth may be unstable
- ➢ Earth stabilization yields better & lasting performance

Harrison and Sinha, 1995; Houben and Guillaud, 2006, Yaser, 2009

CHEMICAL STABILIZATION OF EARTH

Hydration reaction occurs when cement is added to sandy earth and cures in ~ 28 days

$$\text{Cement} + \text{H}_2\text{O} \rightarrow \text{Calcium} - \text{Silicate} - \text{Hydrate} + \text{Ca}(\text{OH})_2 \quad (1)$$

Pozzolanic reaction: when lime_ Ca(OH)_2 or lime + pozzolan is added to clayey earth but cures slowly

$$\text{Clay} + \text{Ca}(\text{OH})_2 + \text{H}_2\text{O} \rightarrow \text{Cemetitious\_products} \quad (2)$$

Houben and Guillaud, 2006; Al-Mukhtar et al. 2010a, 2010b, 2014

CHEMICAL STABILIZATION OF EARTH

Calcium Carbide Residue: by-product from acetylene production

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \quad (3)$$

It contains lime_$Ca(OH)_2$ used to stabilize geotechnical soil.

Rice husk Ash : formed by controlled incineration of agricultural by-product. It has pozzolanic effect in cement applications

Cardoso et al., 2009; Horpibulsuk et al., 2013; Reddy et al. 2013

STABILIZED COMPRESSED EARTH BLOCKS

Compressed Earth Blocks, among other techniques, are formed by compressing earth-binder mixture in mold

(a)

(b)

(c)

Houben and Guillaud, 2006; Photos: Miraucourt 2017; Nshimiyimana 2016 (Ouagadougou)

AIM OF THIS STUDY

Calcium carbide residue (**CCR)** and rice husk ash (**RHA)** available in Burkina Faso for improving the mechanical performance of compressed earth blocks **(CEBs).**

1. Characterization of earth, CCR and RHA;
2. Mix design, and preparation of mixtures;
3. Mechanical testing of CEBs;
4. Chemical interaction in earth-CCR-RHA mixtures.

EXPERIMENTAL METHODS

METHODOLOGY : Materials

Earth	Added binder	
	CCR	RHA
Pulverized to < 5 mm	Pulverized to <125µm	Incinerated at 400°C (4 h) Pulverized to <80 µm
 (a)	 (b)	 (c)

METHODOLOGY : Mix design

Weight percentage of binder added to the earth

Mix design (CCR:RHA ratio)		Wt. %	
		CCR	RHA
CCR	0%	0	0
	5%	5	0
	8%	8	0
	10%	10	0
	15%	15	0
CCR: RHA	10 % (9:1)	9	1
	10 % (8:2)	8	2
	10 % (7:3)	7	3
	10 % (6:4)	6	4
	15 % (9:1)	13.5	1.5
	15 % (8:2)	12	3
	15 % (7:3)	10.5	4.5
	15 % (6:4)	9	6

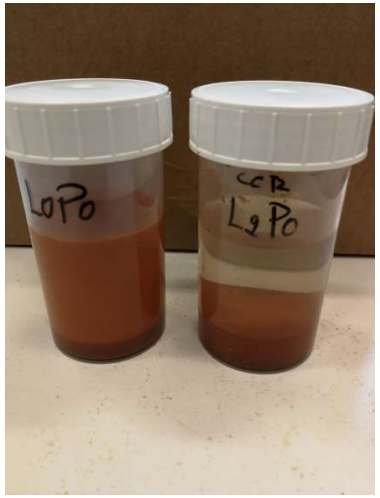
METHODOLOGY : Mix preparation and curing

Mixing earth-CCR-RHA with appropriate amount of water

– Molding of CEBs

(a)

– Preparing mix solutions and keeping in closed bottles



(b)

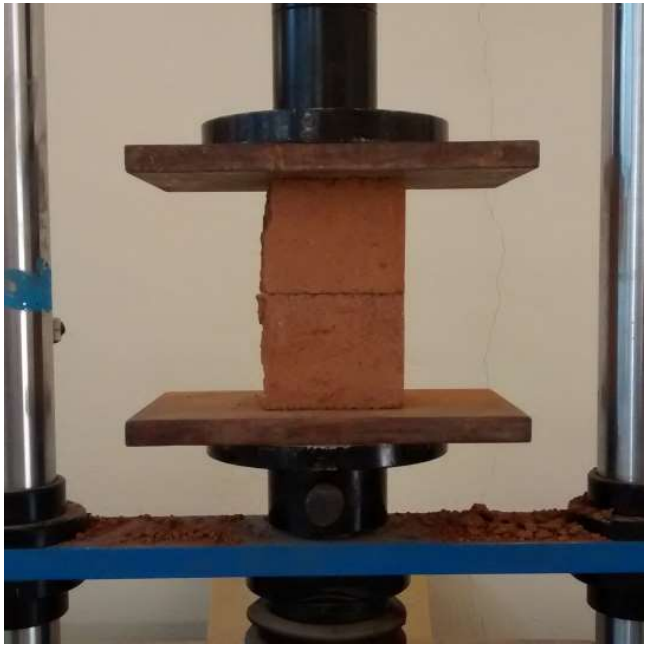
– Curing CEBs (45 days) and solutions (1-90 days) at 40 (±2) °C

METHODOLOGY : Chemical and mineral analyses

- Chemical characterization: X-Ray Fluorescence;
- Mineral characterization: X-Ray Diffraction;
- Amorphous RHA: Dissolves in boiling NaOH for 3 min (Mehta 1978).

METHODOLOGY : Characterization of mixtures

1. Testing the dry **compressive strength** of cured CEBs;



(a)

2. Measuring the **electrical conductivity** and **unconsumed calcium** ion of cured mix solutions;

(b)

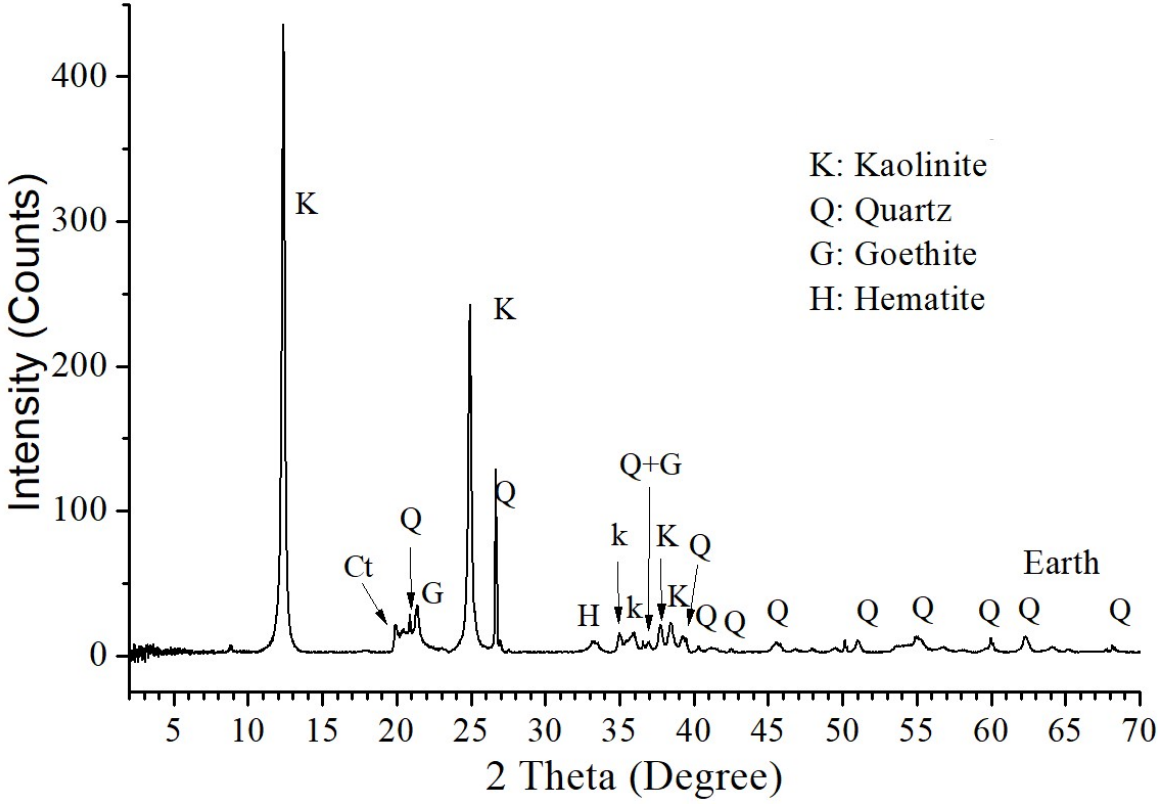
3. Characterizing **phase changes** in mixtures (XRD).

RESULTS

RESULTS : Chemical and mineral properties of material

Earth contains:

- Silica_SiO_2 (50 %), Alumina_Al_2O_3 (24 %), Iron (III) oxides_Fe_2O_3 (12 %)
- Kaolinite clay (76 %), quartz (11 %) and goethite (9 %)



RESULTS : Chemical and mineral properties of materials

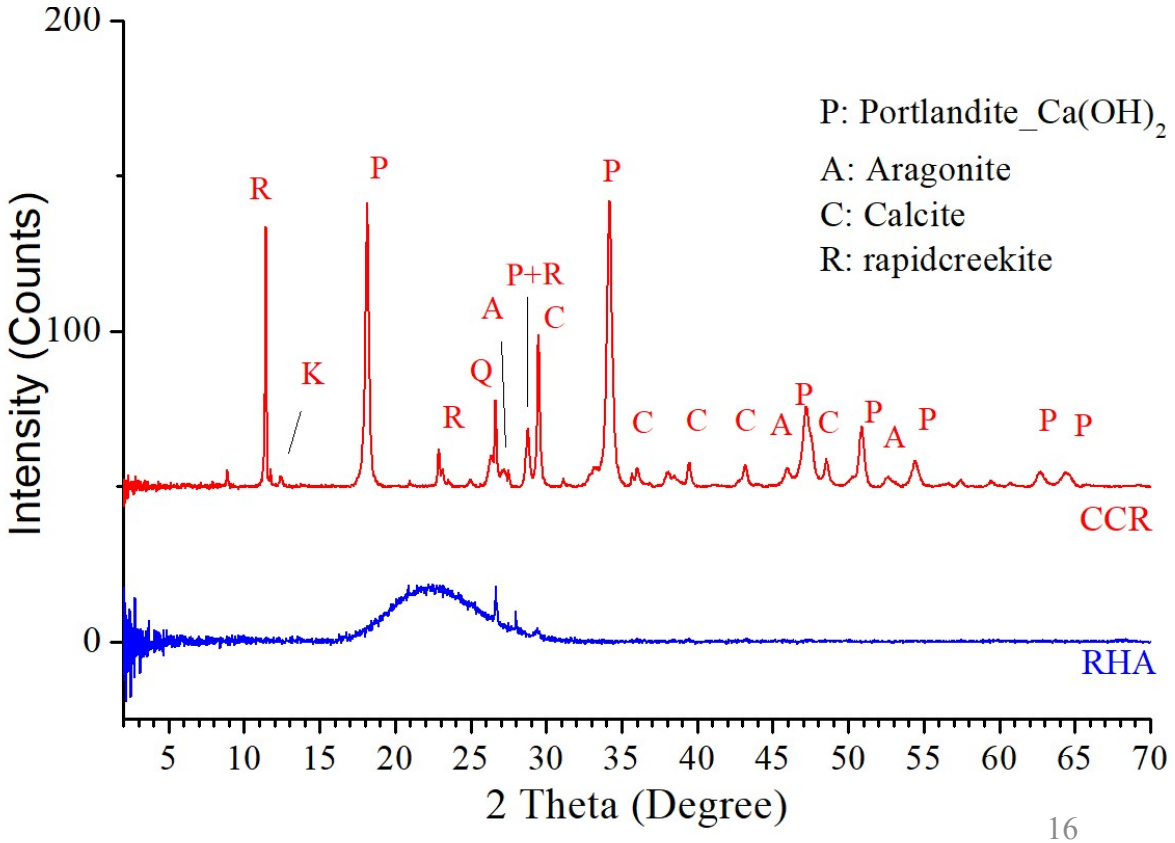
Calcium Carbide Residue:

- Calcium oxide_CaO (67 %), loss on ignition (26 %)
- Portlandite (lime)_$Ca(OH)_2$ (43 %) and carbonates

Rice Husk Ash:

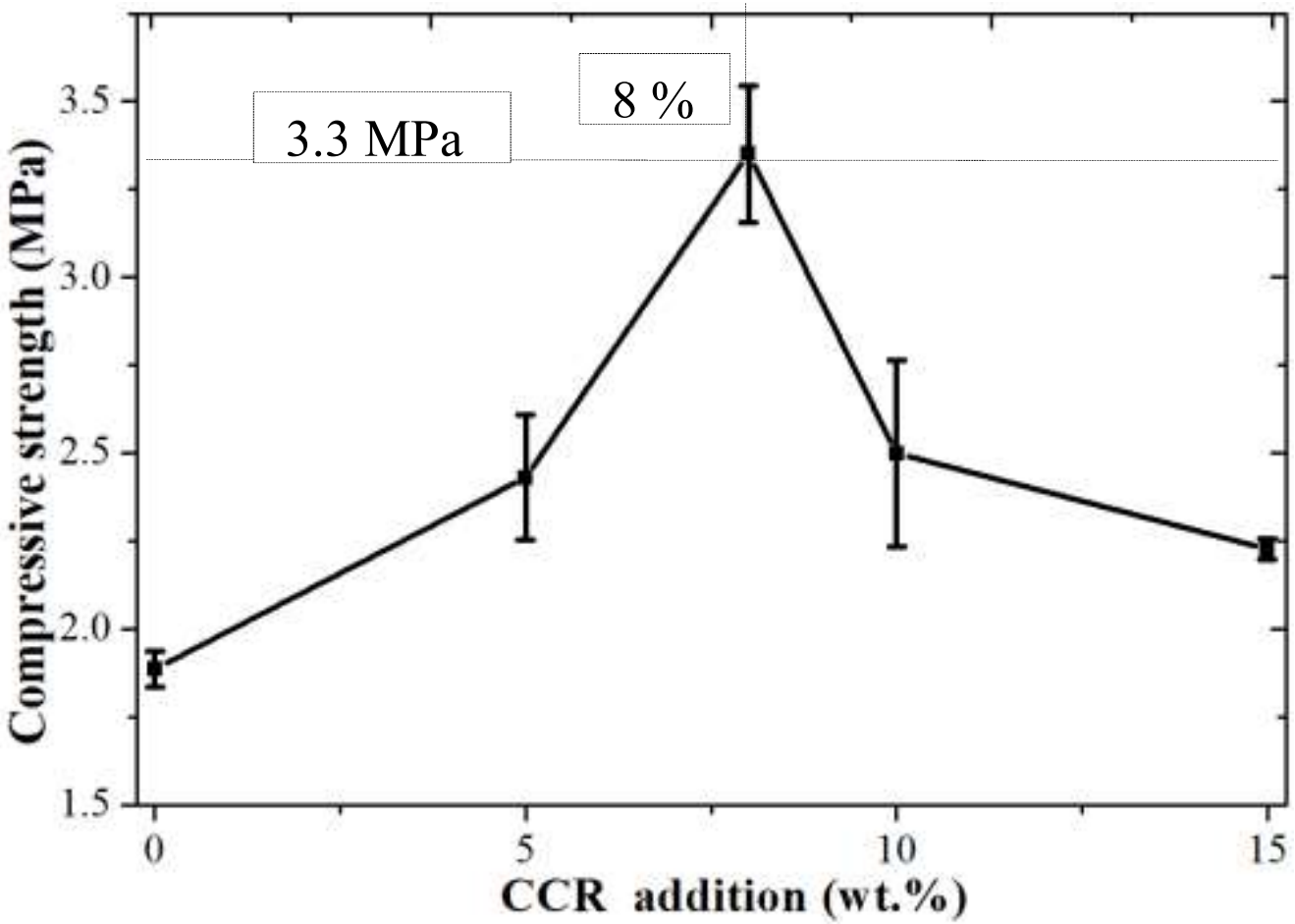
- Silica (90 %)
- Amorphous

(68 % dissolving silica)



RESULTS : Mechanical properties of the CEBs

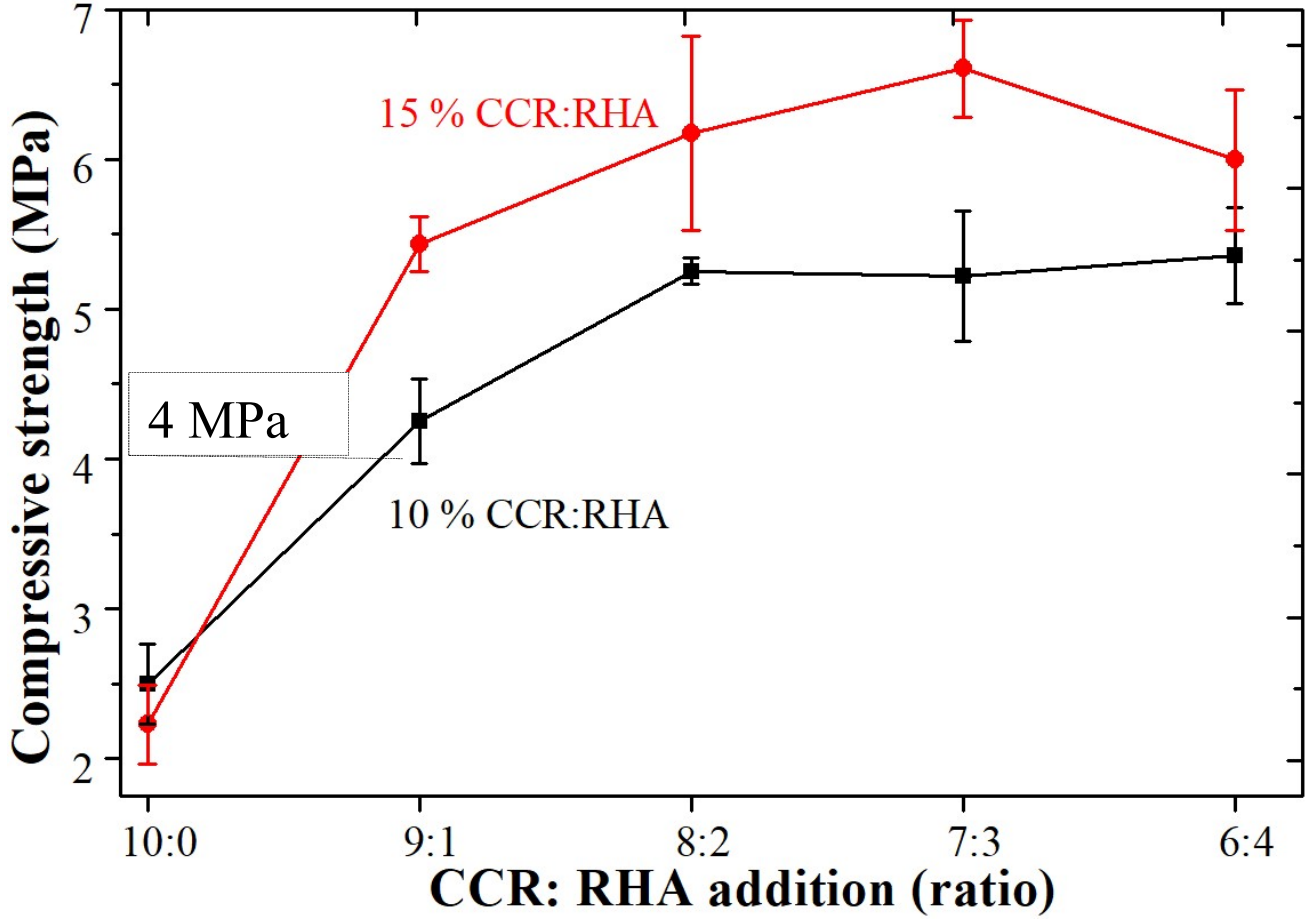
CCR addition to earth



Pozzolanic reaction took place between earth and CCR

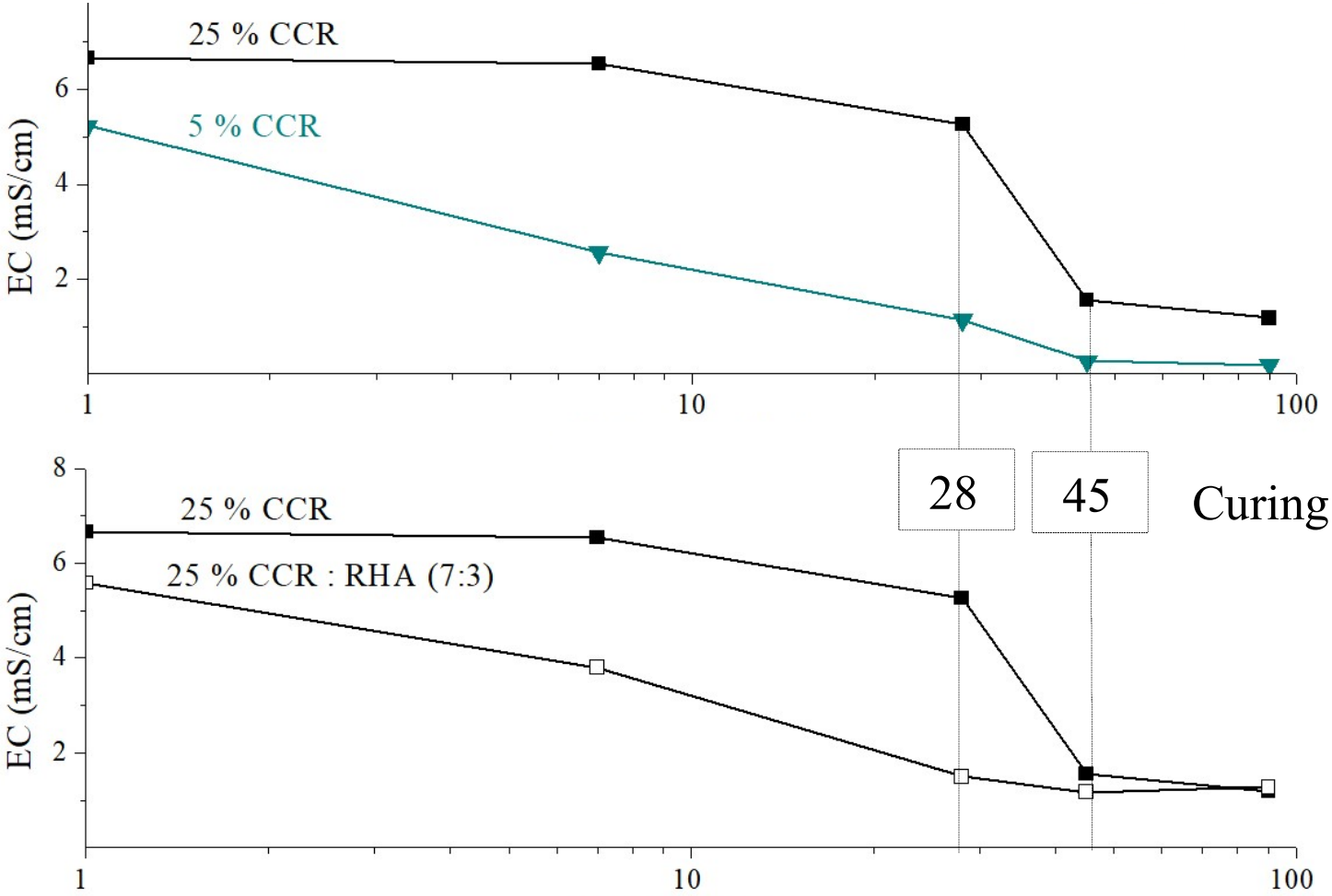
RESULTS : Mechanical properties of the CEBs

CCR: RHA addition to earth



4 MPa is required for wall construction of two storey housing

RESULTS : Electrical conductivity (EC) of mix solutions



(a)

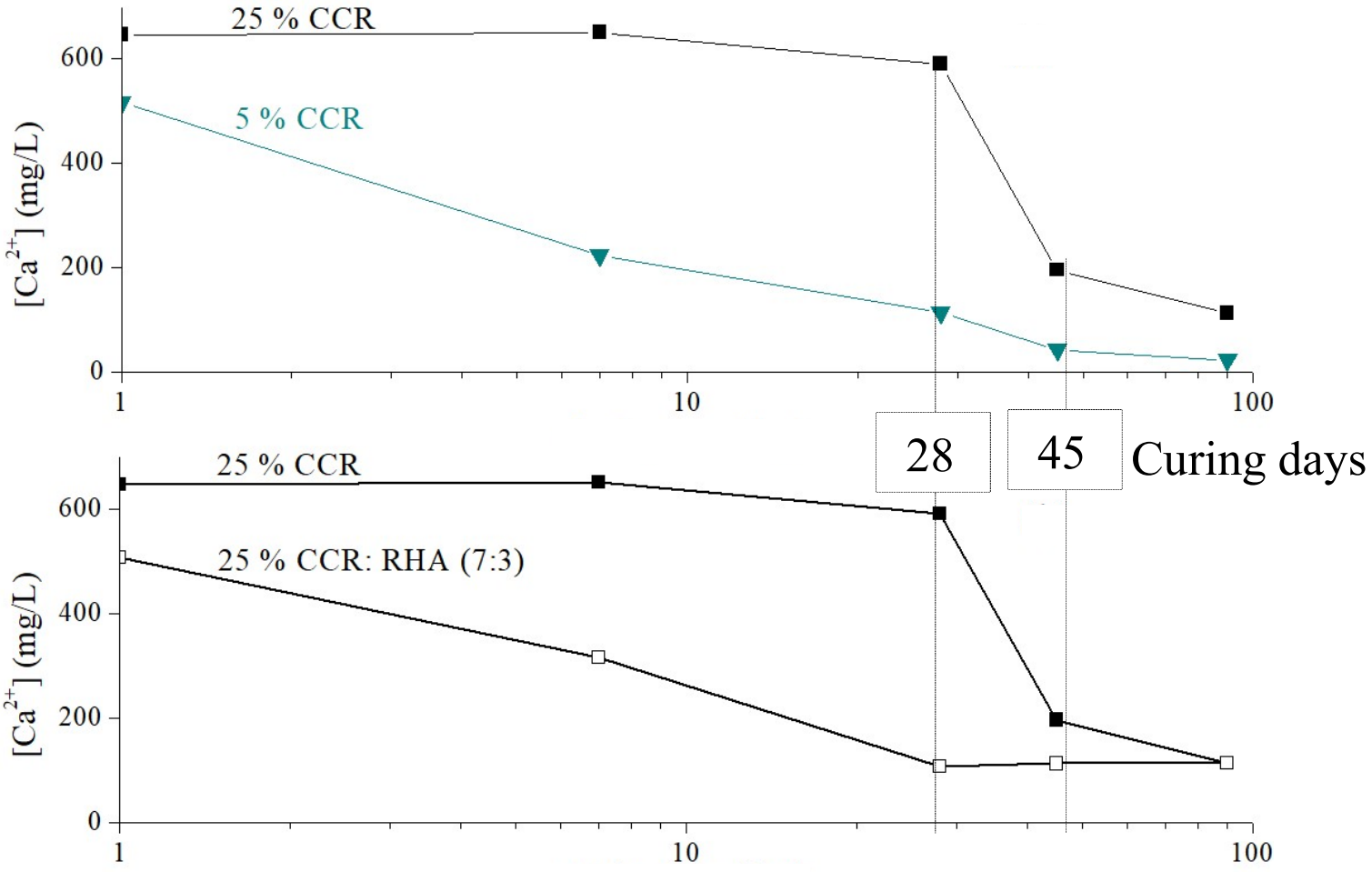
(b)

...related to the reaction in earth-CCR-RHA mixtures

RESULTS : Calcium concentration [Ca^{2+}]f mix solutions

(a)

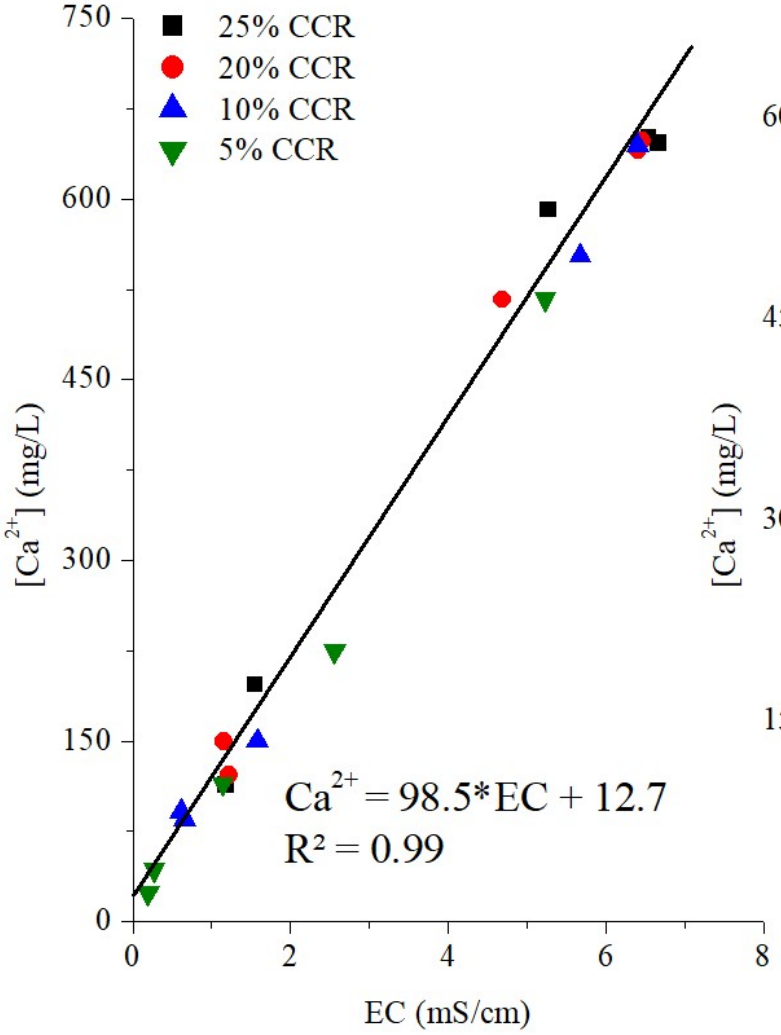
(b)



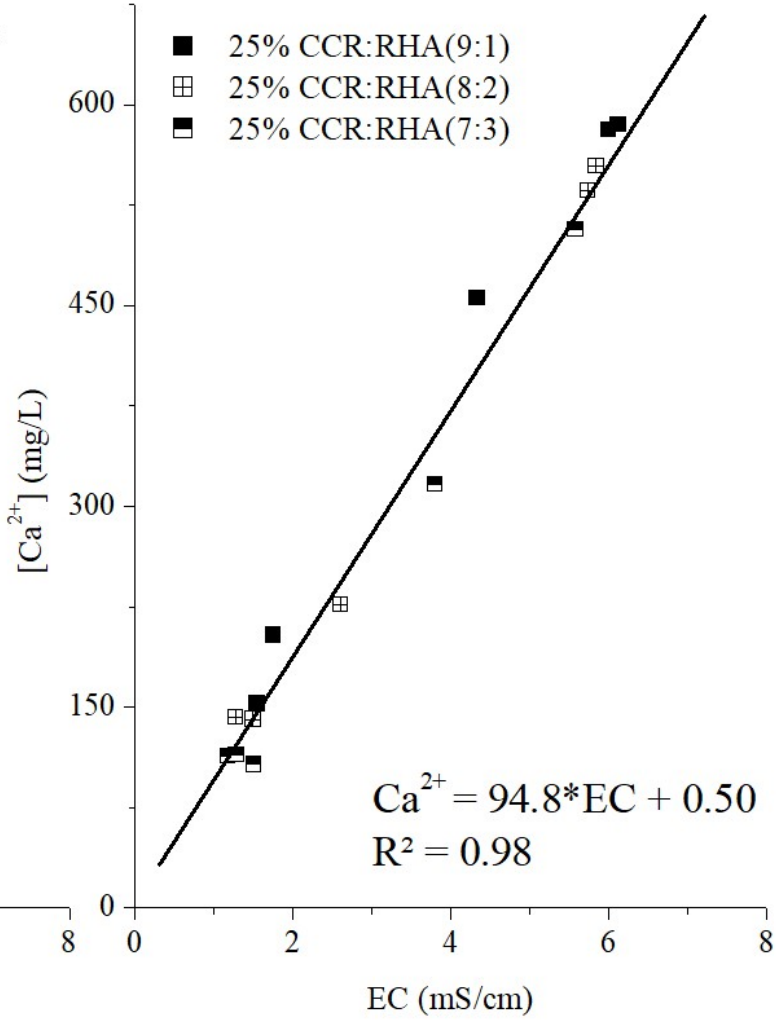
...related to the consumption of free Ca^{2+}

RESULTS : Correlation of EC and [Ca^{2+}] of mix solutions

(a)

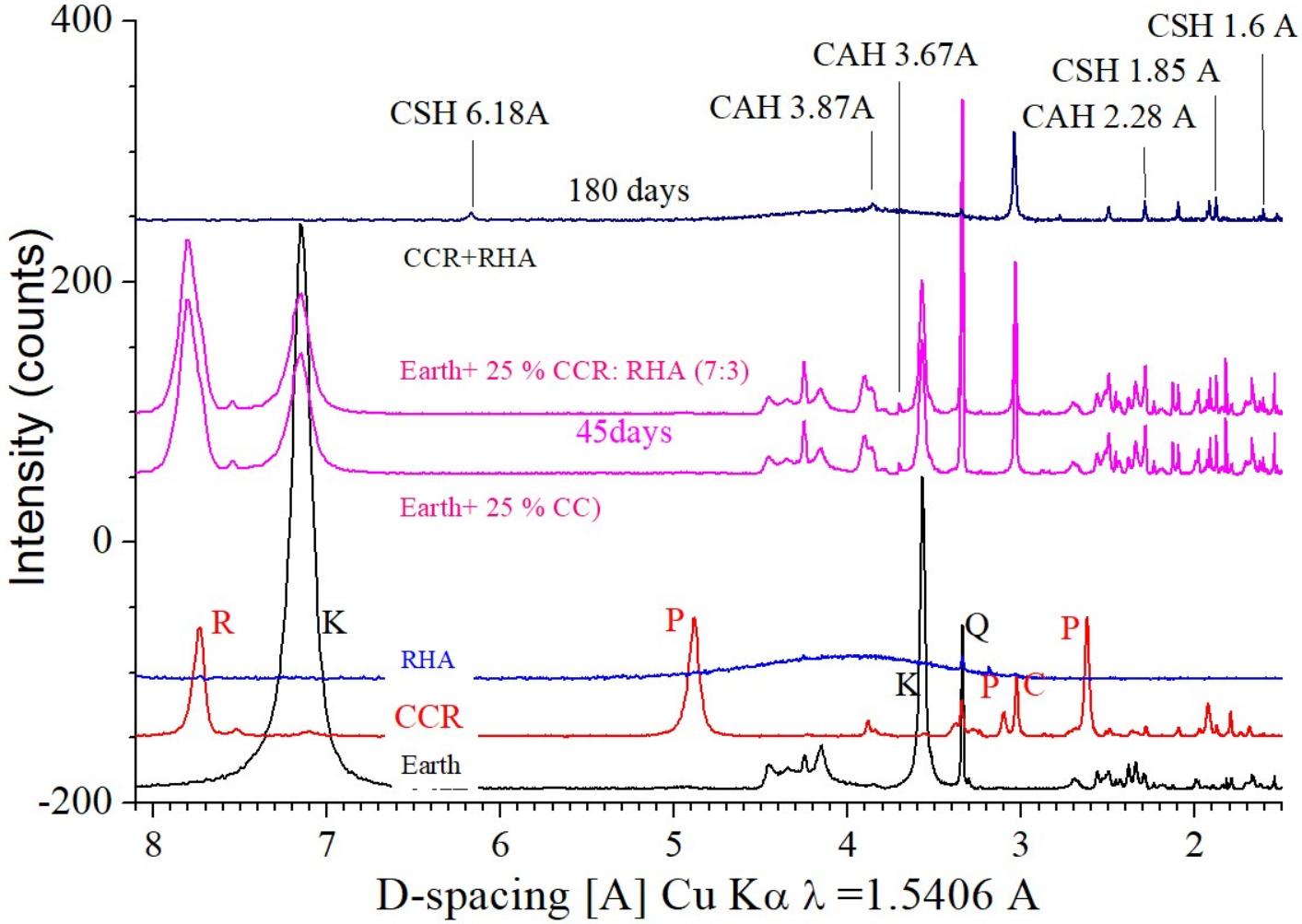


(b)



...possibility to monitor the curing process

RESULTS : Products of pozzolanic reaction in the mixtures



Calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH)

CONCLUSIONS

CCR and RHA are valuable for improving the mechanical performance of CEBs:

- ✓ The pozzolanic reaction took place in earth-CCR-RHA mixtures;
- ✓ The RHA accelerated the curing process and further improved the compressive strength of CEBs to meet the requirements.

WORK IN THE FUTURE

It can be recommended to:

- Investigate the mechanical performance of CEBs at early age;
- Assess the long term performances of CEBs: Study the hydro-thermal and durability performances.

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MERCI
FOR YOUR ATTENTION!

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