Mitigation of alkali-silica reaction through carbonation of recycled concrete aggregates

S. Grigoletto[1], J. Hubert[1], J. Duchesne[2], B. Bissonnette[3], F. Michel[1] and L. Courard[1]

[1] Urban and Environmental Engineering, University of Liège, Belgium
[2] Department of Geology and Geological Engineering, Université Laval, Québec, Canada
[3] Department of Civil Engineering and Water Engineering, Université Laval, Québec, Canada

Concrete recycling

- Constant increase of concrete production volume
  → Increase in natural aggregates consumption

- Concrete = largest part of C&D waste
  → Waste management more and more challenging

Preservation of natural resources and promotion of circular economy

→ Use of **recycled concrete aggregates** (RCA)

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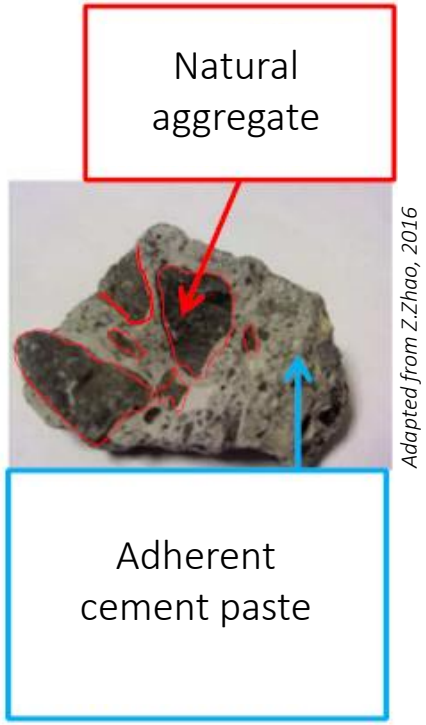
Recycled Concrete Aggregates and ASR

- Cement paste porosity higher
  - Water absorption ↑
  - Mechanical performances ↓

  → influence properties of concrete made of RCA
- Limitation of RAC utilization: lower mechanical and durability performances
- In particular, secondary induced expansion due to ASR may happen
- Many factors influencing ASR in the new concrete
  - Original aggregate reactivity
  - Expansion degree of the primary ASR
  - RCA production procedure
  - Exhibition of new faces



Adapted from Z.Zhao, 2016

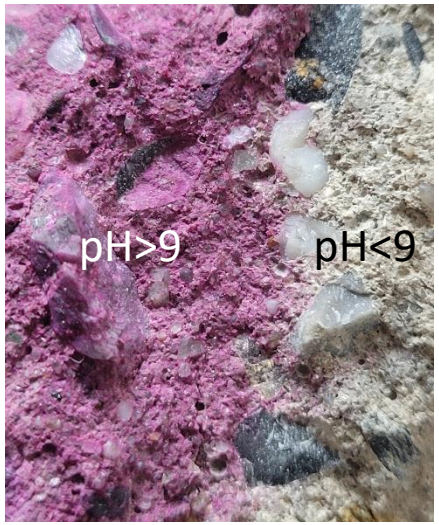
RCA Carbonation

- Various methods to enhance RCA performances, among which carbonation treatment

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

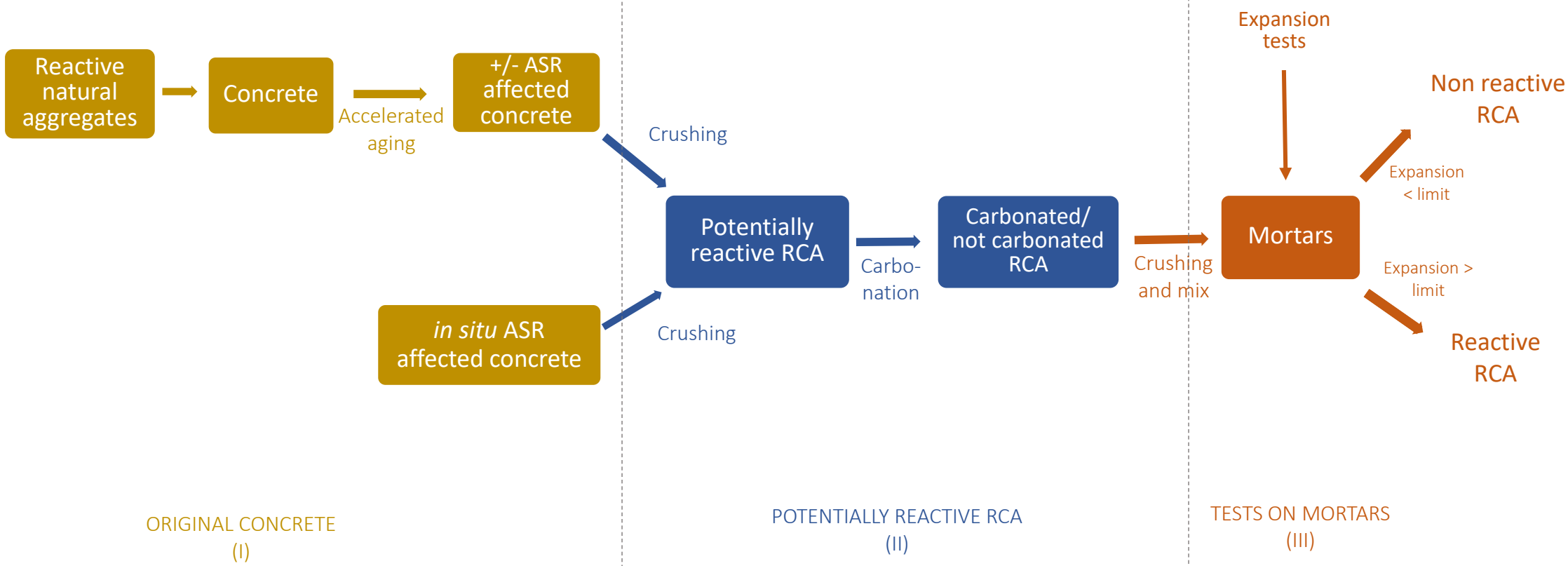
- $CaCO_3$ precipitates gradually and fills the pore of the mortar paste of the RCA
  - RCA water absorption ↓ and concrete transport properties ↓
  - pH ↓ and alkali hydroxides quantity ↓

→ could be beneficial regarding ASR as well



Carbonation progress

Procedure


Reactive natural aggregates
Concrete
Accelerated aging
+/- ASR affected concrete
Crushing
Potentially reactive RCA
Carbo-nation
Carbonated/ not carbonated RCA
Crushing and mix
Mortars
Expansion tests
Non reactive RCA
Expansion < limit
Expansion > limit
Reactive RCA
in situ ASR affected concrete
Crushing
ORIGINAL CONCRETE (I)
POTENTIALLY REACTIVE RCA (II)
TESTS ON MORTARS (III)

Materials

- Portland cement (CEM I 52.5 N – 0.68% Na_2O_{eq})
  - RCA manufacturing
  - Reactivity tests (mortar samples)

- 3 types of aggregates (4/20)

Natural reactive aggregates

Tournaisis siliceous limestone

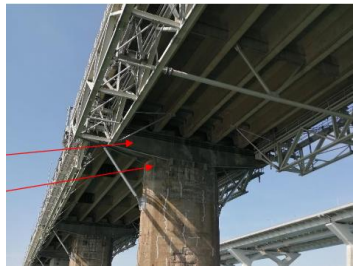
	Density (kg/m³)	WAI_{24} (%)
Sand (0/4)	2677	0.3
Gravels (2/7 - 7/14 - 14/20)	2660	0.5

RCA from an ASR affected structure

Obtained by crushing concrete elements retrieved from the Champlain Bridge

Transverse beam (C-B)

Pile (C-P)



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Manufactured potentially reactive RCA

Produced from laboratory concretes manufactured with fine and coarse Tournaisis aggregates

Manufactured potentially reactive RCA

Production of original concrete

- 70 x 70 x 280 mm³

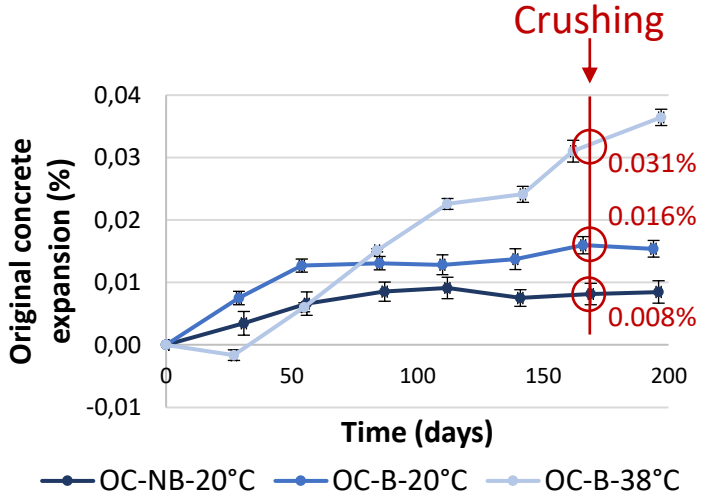
		Boosted	Not boosted
Cement		395	395
NaOH		3	-
Water		204	207
Sand		657	657
Coarse aggregates	2/6.3	173	173
	6.3/14	423	423
	14/20	518	518
Plasticizer		1	1

Mix proportions (kg/m³)

Storage

- Climatic chambers in water saturated atmosphere
- 20°C and 38°C

Expansions monitoring



Crushing of original concrete

- Sieved to recover coarse RCA (4/20 mm)

Carbonation of RCA

- Equipment: 2 air-tight incubators
- Test conditions:
  - Atmospheric pressure
  - T° = 39°C
  - [CO_2] = 20%
  - 60% RH (saline solution)
  - 11 days
- Applied to the 4/20 mm fraction

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Reactivity tests on mortars (NF P18-594)

- Fast screening test (4 days)
- Measurement of length variations before and after curing in autoclave

$$\varepsilon_i\ (\%) = \frac{L_{1i} - L_{0i}}{L_0} \qquad \text{with } L_0 = 140 \text{ mm}$$

- 2 Cement/Aggregates (C/A) ratios : 0.5 and 1.25
- Expansion limit = 0.15 %
  - potentially reactive (PR) if average expansion > for at least one C/A ratio
  - pessimum effect when expansion does not decrease when C/A ratio increases

Reactivity tests on mortars (NF P18-594)

Crushing of the 4/20 mm RCA

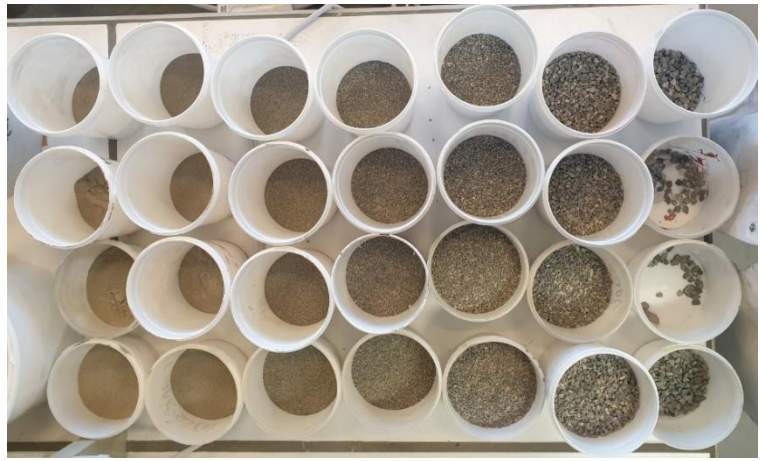
- Use of a jaw crusher
- Sieving to obtain a 0.16/5 mm recomposed sand having the required grain size

Samples preparation

- 40 x 40 x 160 mm^3
- 24h at 90% RH - 20°C + 24h in water at 20°C

Curing in autoclave

- 5h at 127°C and 1.5 bars



C/A ratio	0.5	1.25
Sand (g)	1200	720
Cement CEM I 52.5 (g)	600	900
Mixing water with NaOH (ml)	300	450

Mix proportions

4% Na_2O_{eq} of cement mass

Reactivity tests on mortars (NF P18-594)

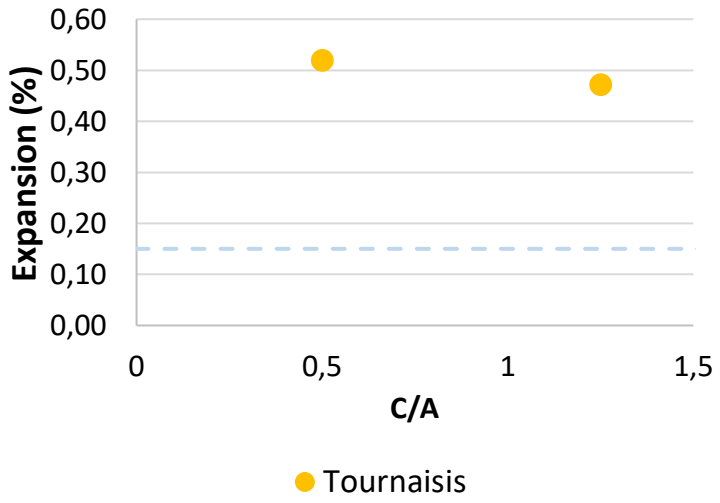
Adjustments

- Higher water absorption → pre-saturation *(Delobel et al., 2016)*
- Risk of RCA alkali lixiviation → slight washing *(Adams et al., 2012)*
- Crushing of coarse RCA → modified chemical and physical properties
- RCA coming from alkali-boosted concrete manufactured in the laboratory → artificial alkalinization deducted to the quantity of NaOH needed to reach 4% Na_2O_{eq}

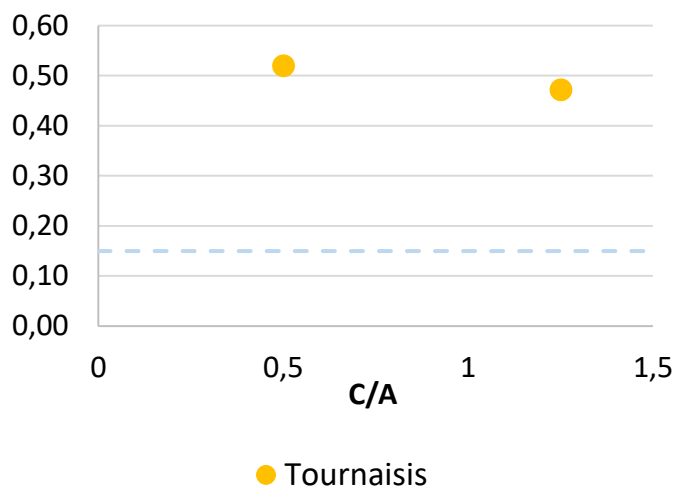
Reactivity tests on mortars (NF P18-594)

Manufactured potentially reactive RCA

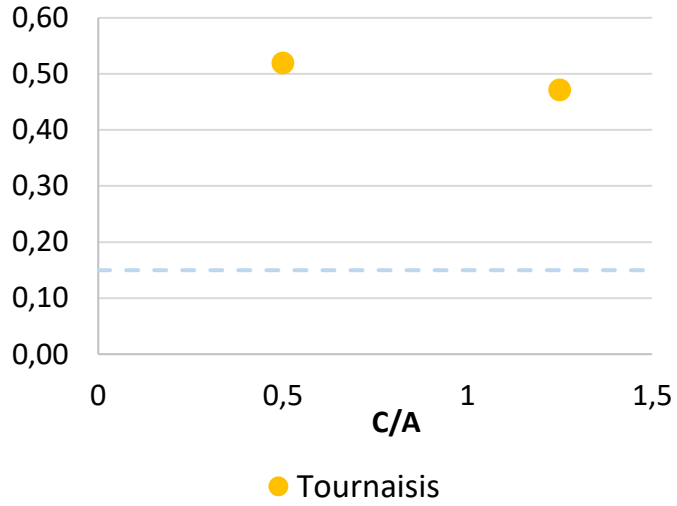
Original concrete expansion: 0.008 %



0.016 %



0.031 %



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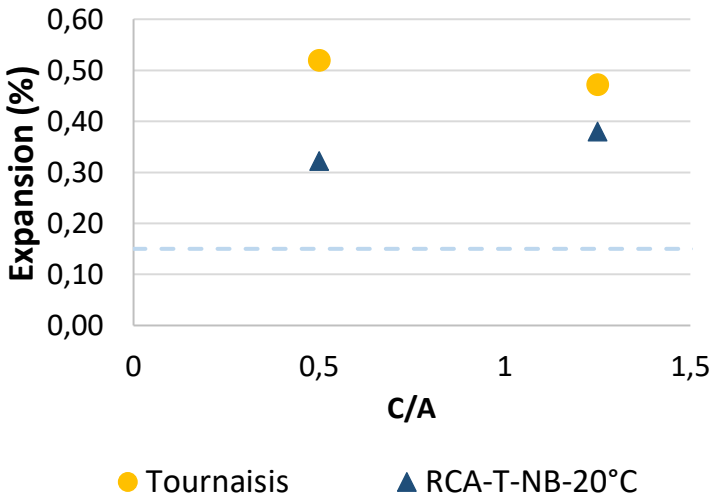

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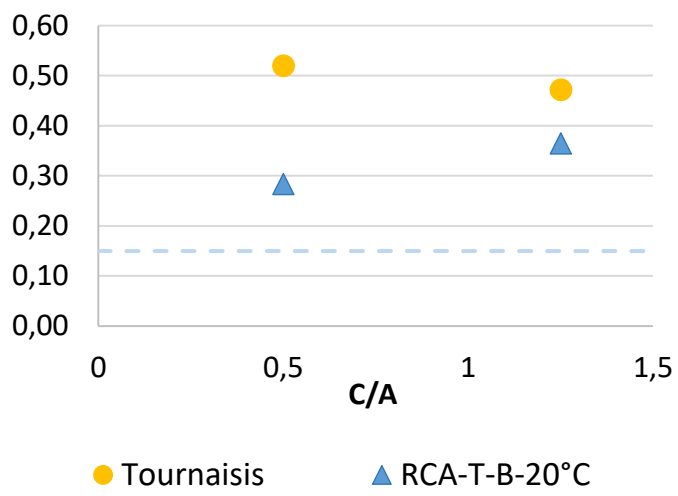

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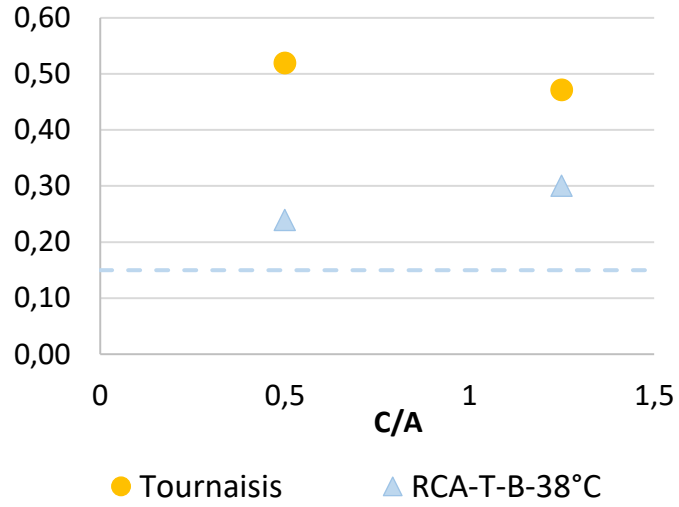

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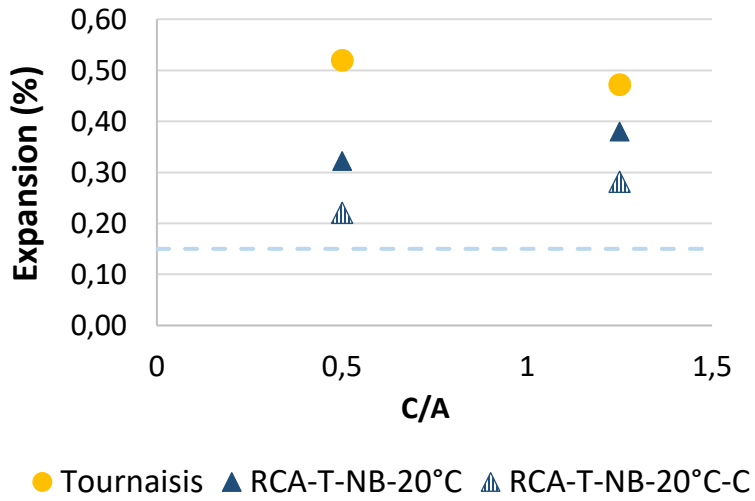

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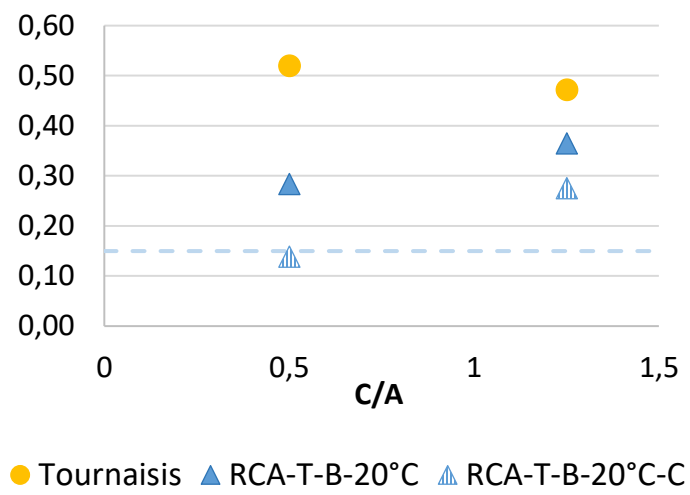

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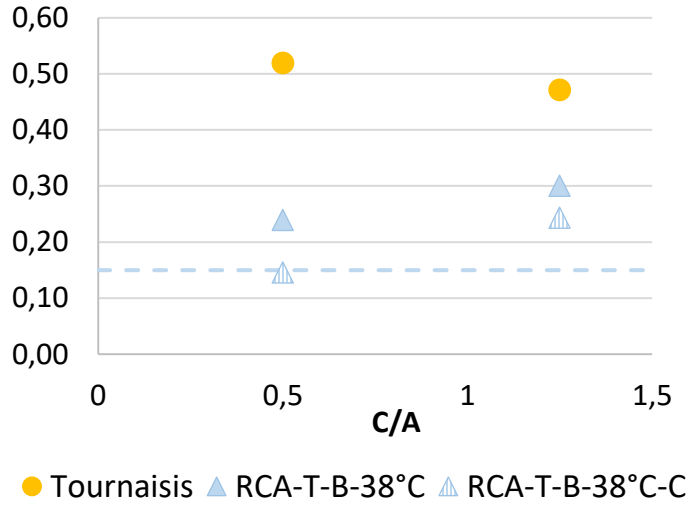
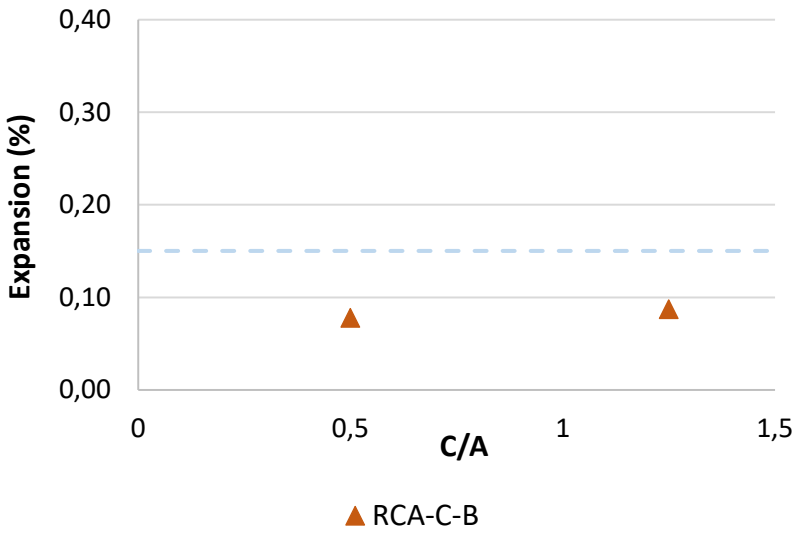
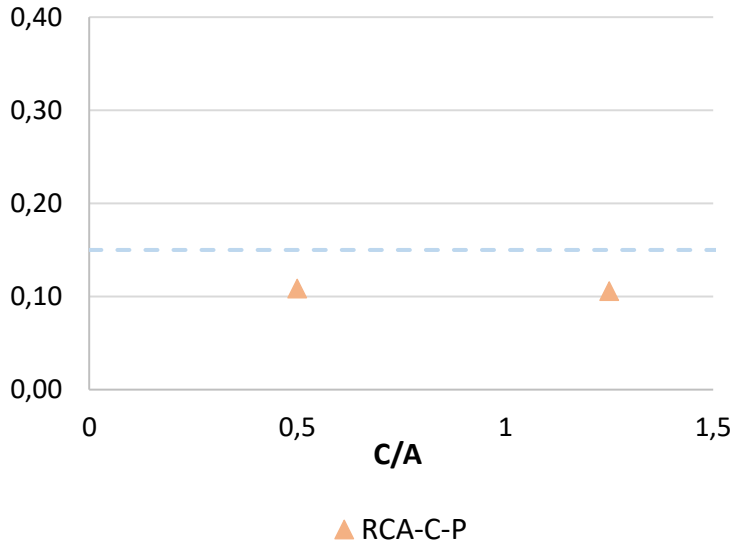


Reactivity tests on mortars (NF P18-594)

RCA from an ASR affected structure





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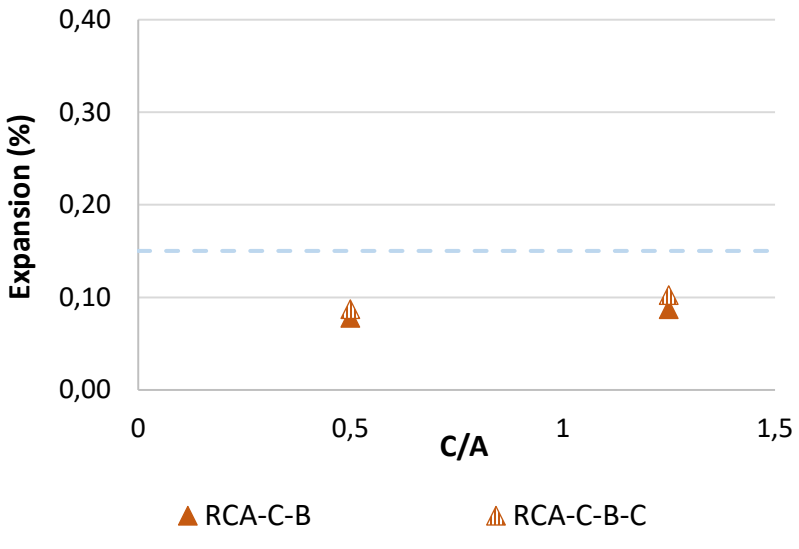

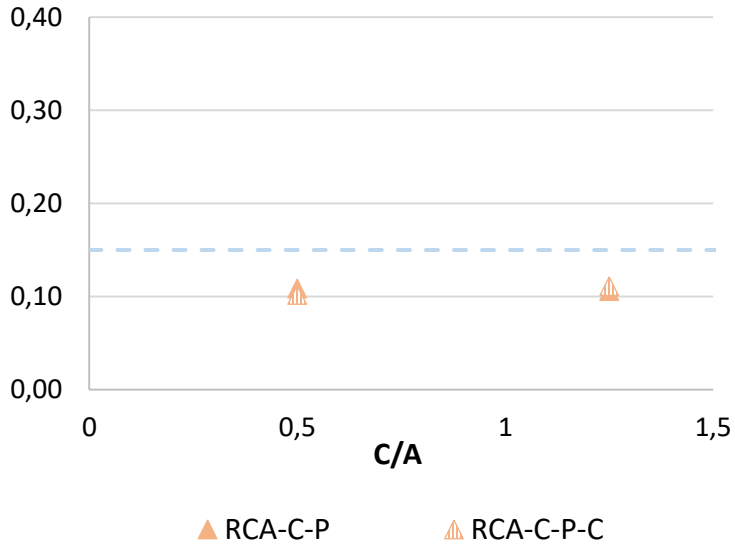

CONCLUSIONS

- Manufactured potentially reactive RCA
  - Mortar expansions < original aggregate, but still > 0,15% (with pessimum effect)
  - The higher the original concrete expansion, the lower the RCA mortar expansion
  - Expansion significantly decreased by carbonation

    But does not seem to be sufficient → combined with SMCs ?

- RCA coming from Champlain Bridge
  - Classified as non-reactive aggregates
  - No influence of carbonation

- Need to perform long term tests on concrete to confirm these results, as they should be more suitable.

Thank you! Questions?

sophie.grigoletto@uliege.be

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