EVALUATION OF CALCINED DREDGING SEDIMENTS AS SUPPLEMENTARY CEMENTITIOUS MATERIALS

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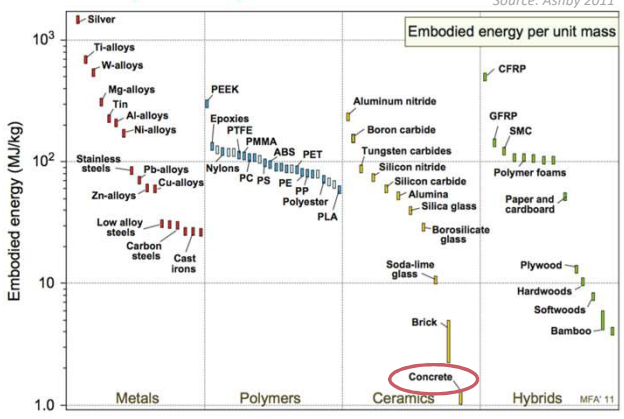
INTRODUCTION

- Concrete is an environmentally friendly material.

Source: Ashby 2011

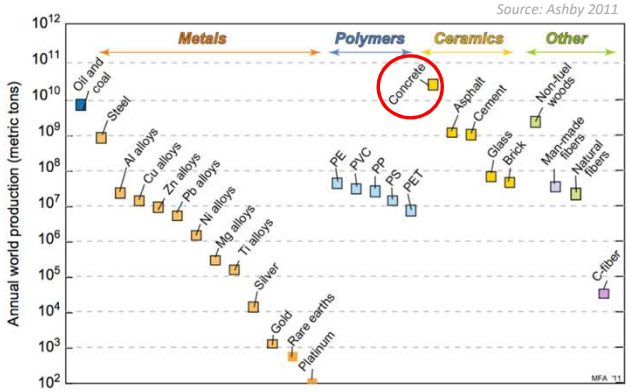


But …

INTRODUCTION

- Concrete is the most used material after water.

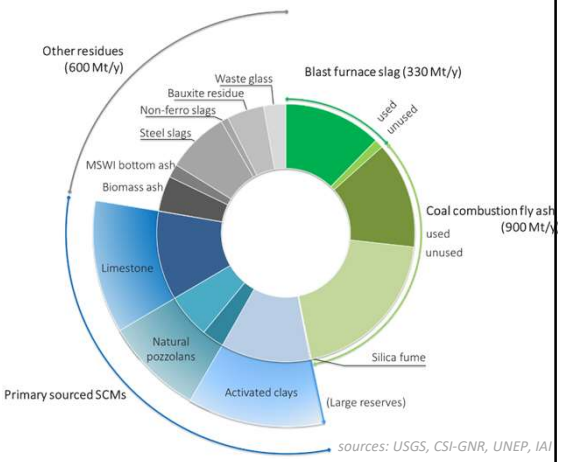
Source: Ashby 2011



- That is why is responsible for 8% of the anthropogenic CO_2 due to the cement production

MOTIVATION

- The most pragmatic approach to tackle environmental impact of concrete is to reduce the clinker factor by using Supplementary cementitious materials (SCM).
- Current convectional SCM's are mostly used in the production of blended cements.
- Potential SCM's locally available in abundance must be explored.



RESEARCH SIGNIFICANCE

- Previous research on valorisation of dredging sediments from Port of Antwerp:
  - Sandy fraction (>63 µm) used in civil works
  - Fine fraction dewatered by membrane filter press
  - Fine fraction low in organics and heavy metals
  - Flash calcination (750-900 °C) of fine fraction produced reactive SCM
  - First pilot testing succesfully completed, further upscaling ongoing

[Snellings et al. 2016, 2017; Van Bunderen et al. 2017, 2019]

Port of Antwerp

RESEARCH SIGNIFICANCE

- Extension of research to canal/waterway sediments (Interreg FWVL V VALSE project):
  - Cross-border Scheldt basin – supporting integration of dredging sediment management and valorisation
  - 3 canal locations:
    - Lens (F)
    - Brussels – Charleroi (B-Wallonia)
    - Ghent-Terneuzen (B-Flanders)

Source: Simina Margareta Stanc, et al. 2009

RESEARCH CHALLENGES AND OBJECTIVES

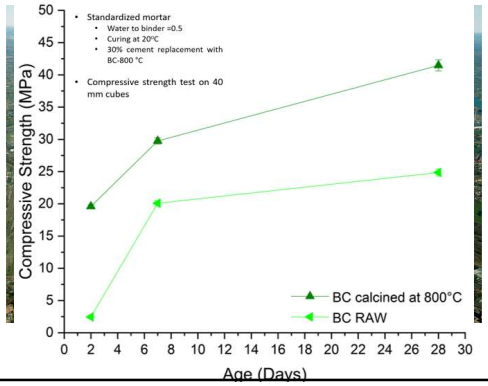
- Region of intense (historic) industrial activity (coal mining, steel production, chemistry)

Challenges:

1. Higher levels of organics and heavy metals, concentrated in fine fraction
2. Canal sediments are more variable in composition, reflecting local geology and activities

Objectives:

- Evaluate impact on calcined SCM reactivity and PC hydration of:
  - Organics and heavy metals
  - Variations in sediment composition
- Establish optimum calcination temperatures for each sediment



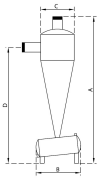
Results

Calcined dredging sediment characterisation

MATERIALS: PRE-TREATMENTS BEFORE CALCINATION

Sediment's
- Lens Channel
- Brussel – Charleroi Channel
- Gent-Terneuzen Channel

Removal of sand fraction (>63 µm)



dewatering using a pilot filter press

filter cake

Crush and oven dry in lab at 40°C for 24 h

Ball mill

2 min @ 400 rpm
90 g sample with 6 balls of 30 mm diameter.

Calcination in a box furnace

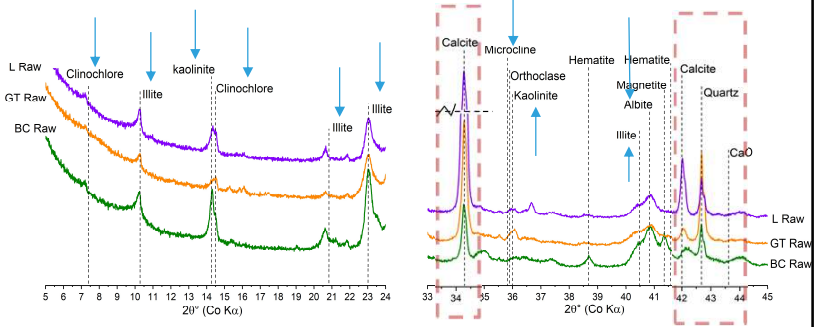
Static conditions, 1 h at 500 °C, 600 °C, 700 °C and 800 °C, in air.

Ready for chemical and physical analysis

MATERIALS: CHEMICAL COMPOSITION AND MINERALOGY

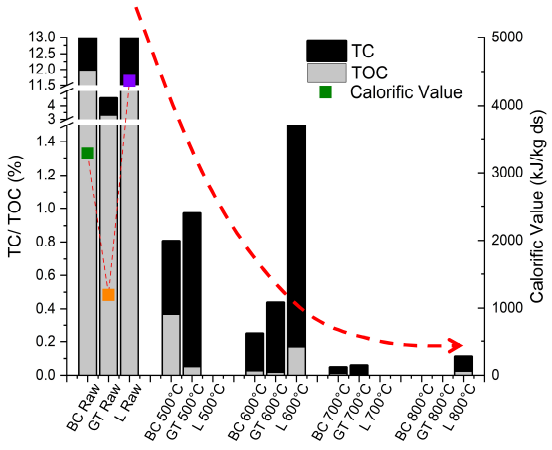
Raw Sediment	Chemical composition (wt.%)											
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	LOI	TC	TOC
BC	40.8	13.9	10.0	2.6	1.1	2.1	0.5	1.0	1.1		13.18	11.97
GT	61.8	9.9	4.1	5.5	1.3	1.4	<0.7			13.3	4.50	3.62
L	32.2	8.2	4.3	10.8	0.9	1.6	1.9	4.0	1.4		13.79	10.35

- Presence of quartz GT>L>BC
- Presence of calcite L>GT>BC
- Clay minerals (Clinochlore, kaolinite, and illite)
- Feldspar minerals (albite and microcline).



X-ray diffraction patterns of the three raw sediments

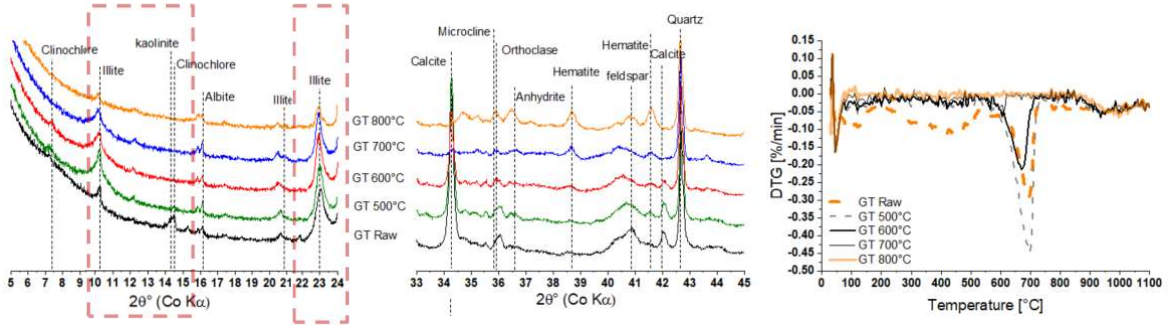
RESULTS: TOTAL CARBON (TC), TOTAL ORGANIC CARBON (TOC), AND CALORIFIC VALUE FROM BOMB CALORIMETRY



- Already at 500 °C, most organic matters have been decomposed.
- By 800 °C the TC and TOC values in case of BC and GT are negligible.
- L, organic matter persisted up to 600 °C, and even at 800 °C.
  - Rock-Eval pyrolysis can be carried out to better understand the source of its organic carbon

CHEMICAL CHARACTERIZATION OF SEDIMENTS AS FUNCTION OF CALCINATION TEMPERATURE

- Mineralogical modification of clay fractions:
  - Reflection of some clays such as kaolinite and Illite to disappeared or weaken making the sediment more amorphous. For example in case of GT:



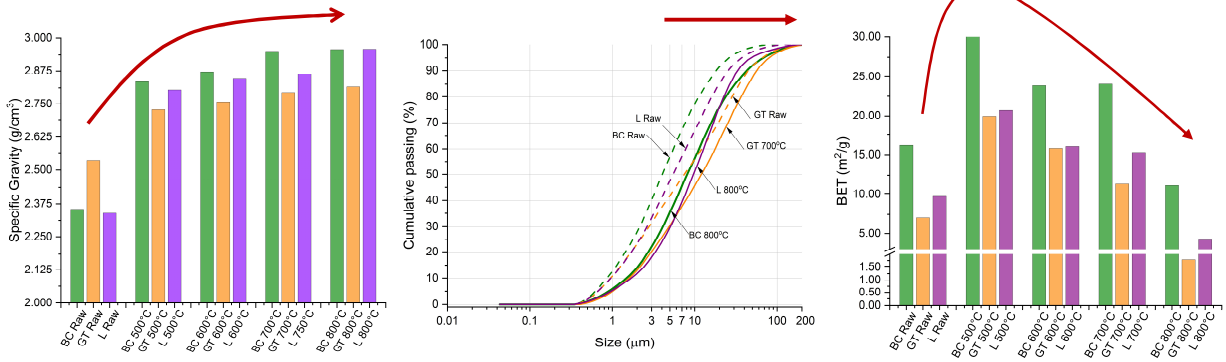
RESULTS: SPECIFIC GRAVITY, PARTICLE SIZE DISTRIBUTION (PSD), BET SPECIFIC SURFACE AREA

- Mineralogical modification & changes in chemical composition of the dredging sediments is reflected on their physical characteristics

Specific gravity of all sediments increases with increasing calcination temperature up to 700 to 800 °C

PSD shifts to coarser size with increasing calcination temperature

Increase of the specific surface at 500 °C, and thereafter they continuously decrease



Results

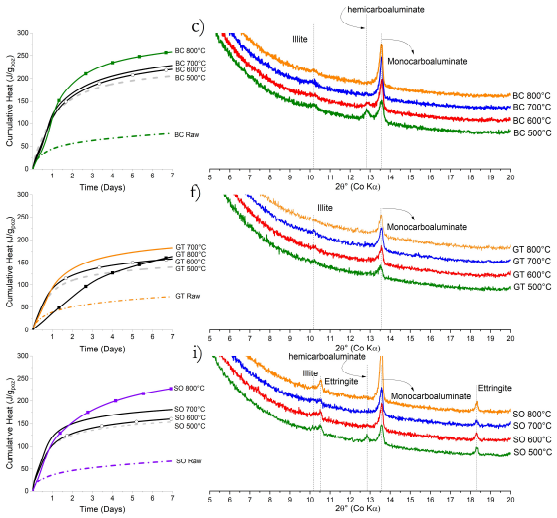
R^3 test

R^3 TEST - INTRODUCTION

- Incorporating materials with different origins in Portland cement is a subjective method in assessing their pozzolanic reactivity, due to the reaction of the OPC phases.
- In RILEM TC 267-TRM, a model system has been established where the material is mixed with Calcium hydroxide and alkali sulfates, limestone powder and water.
- The rate and magnitude of the chemical reaction of the material within the mix, represent the reactivity potential of the material.
- For quantification of this reactivity, Isothermal calorimetry cumulative heat is used and supplemented with XRD and TGA.

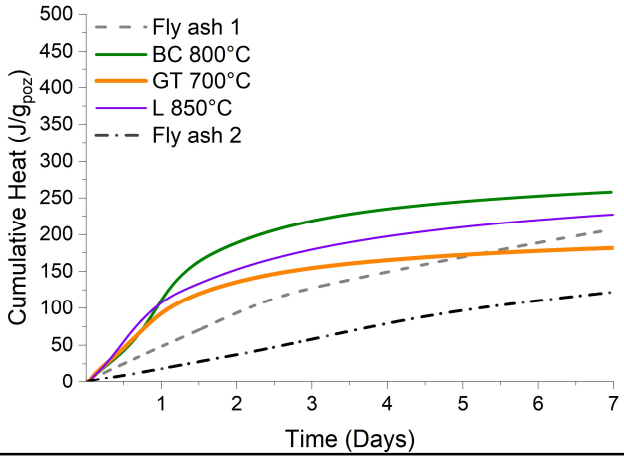
RESULTS: R^3 TEST

- R^3 tests suggest that the optimum calcination temperature for BC and L is around 800 °C while in case of GT is around 700 °C.
- GT calcined at 800 °C decreases the reactivity
  - Recrystallization and formation of high temperate phases.
  - Decrease in the amorphous content coming from the clays mineral content.



RESULTS: R^3 TEST: COMPARISON WITH CONVECTIONAL SCMS

- The calcined dredging sediments, show similar or higher reactivity than of silica rich fly ashes.



CONCLUSIONS

- Calcination of the 3 dredging sediments led to
  - Breakdown of the organic matters.
  - Activation of clay minerals (Kaolinite and chlorite) and to some extent Illite.
  - Mineralogical and chemical changes due to calcination, resulted in changes in physical characteristics of the dredging sediments:
    - Higher specific gravity
    - Coarser particle size distribution
    - Lower specific surface area.

- R^3 test proposes the optimum calcination temperatures for use of dredging sediments as SCMs:
  - L and BC at 800 °C
  - GT at 700 °C

WHAT'S NEXT

- The optimum calcination temperature obtained for each dredging sediment will be used to carry out:

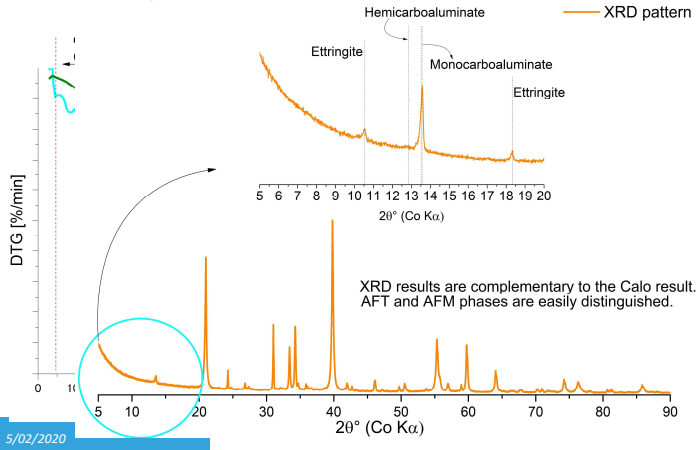
1. Hydration study, at the **paste scale** at 20°C isothermal conditions
   - Reaction kinetics and mechanism
2. Mechanical properties development, at the mortar scale at 20oC isothermal conditions.
3. Environmental quality by carrying out leaching tests

Thank you

5/02/2020

R³ TEST - INTRODUCTION

- For objectivity, and quick assessment, the tests are carried out at 40°C and the results are reported at 7 day.



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PRELIMINARY RESULTS

- Standardized mortar
  - Water to binder =0.5
  - Curing at 20°C
  - 30% cement replacement with BC-800 °C
- Compressive strength test on 40 mm cubes