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Valorization integrated solutions for Construction Demolitions Wastes flows: transborder approach for circular economy (2016-2020)

CTP, IMT Lille Douai, ULiège, INISMa, Neo ECO, GreenWin, Team2, CD2E

Luc COURARD, Romania, Iasi, September 6, 2017

Design and properties of self-compacting concrete based on fine recycled particles

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Supervisors: Prof. Luc COURARD, Prof. Sébastien REMOND

1. Introduction: context

-Environment: think globally, act locally
-Concrete: the most used construction material in the world
-Construction sector → 40-50% of natural resources

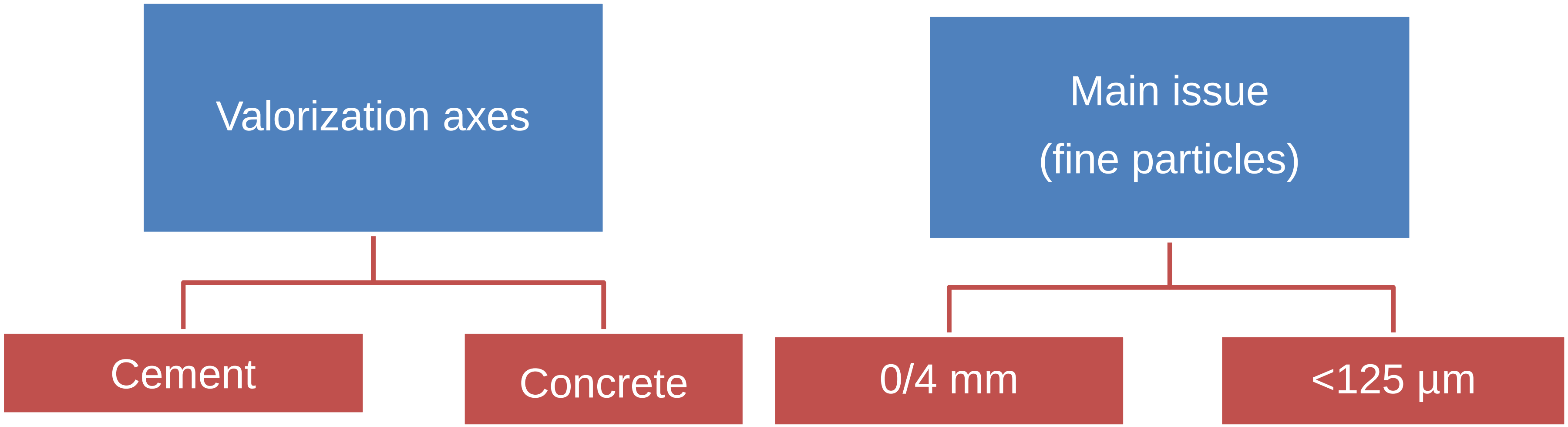
1 ton of concrete → ½ ton of demolition waste

-Construction sector: ± 7 millions of construction and demolition waste in Belgium per year

Goal: valorization of 70% construction and demolition waste (CDW) by 2020

1. Introduction: valorization/objective

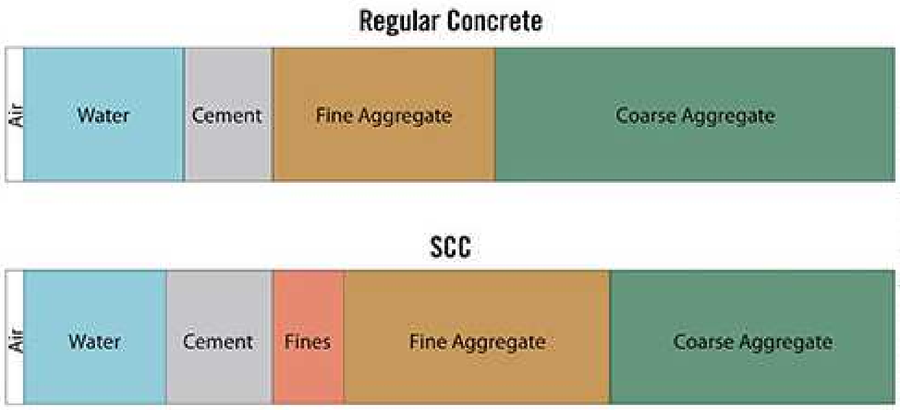
Construction and demolition wastes are inert wastes and vary according to their origin



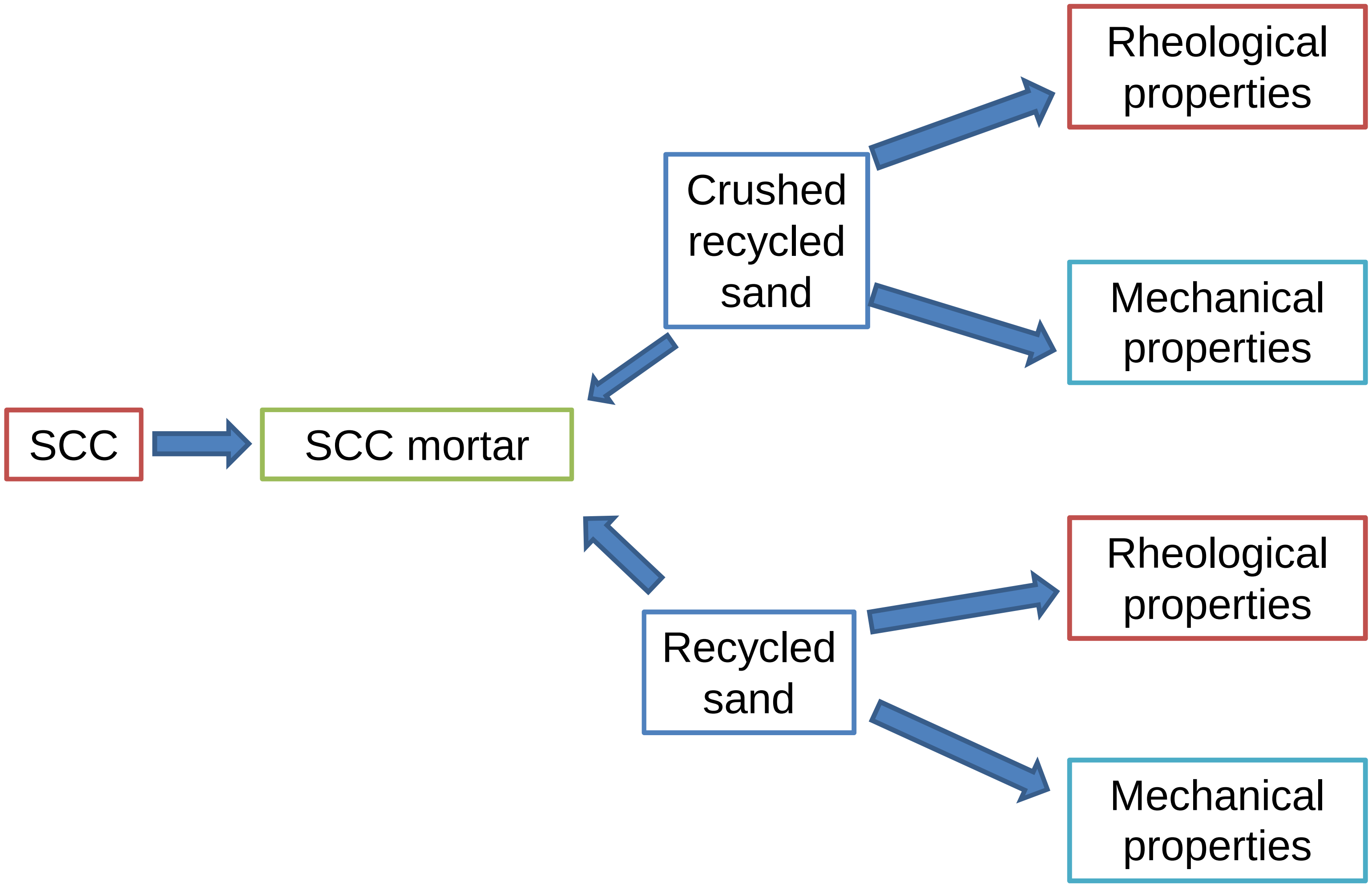
Objective: Use the fine recycled particles from CDW in the design of self-compacting concrete (SCC)

1. Introduction: self-compacting concrete (SCC)

- **Properties of SCC**
  - Be able to consolidate under its own weight
  - Contains between 500 and 600 kg/m^3 of fine particles (cement + limestone fillers)
- **Specifications**
  - Good workability
  - Good resistance to segregation
  - Need to use superplasticizers
- **Advantages**
  - No need to use any vibrator
  - Easily cast in complicated formwork and in presence of dense reinforcement
  - Mechanical properties similar to conventional concrete
- **Disadvantages**
  - Higher cost than conventional concrete



2. Methodology



3. Self-compacting concrete/mortar composition

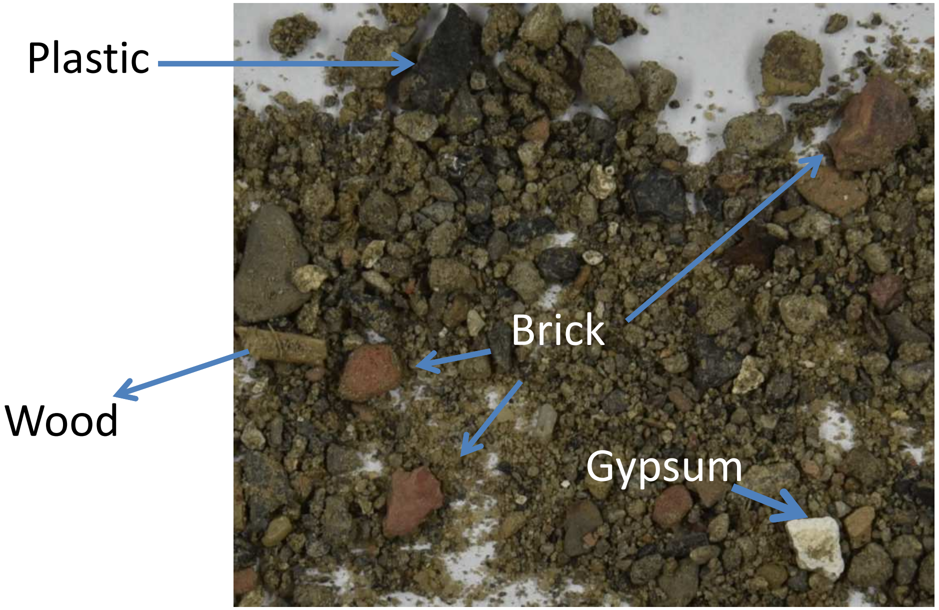
Materiel	SCC mix design (kg/m³)	Mortar mx design (kg/m³)
CEM I 52.5N	311	448
Limestone filler	207	298
Sand 0/2	918	1323
Aggregate 2/7	295	/
Aggregate 7/14	554	/
Water	165	238
SP (% cement)	2.1	2.1
W/C	0.53	0.53

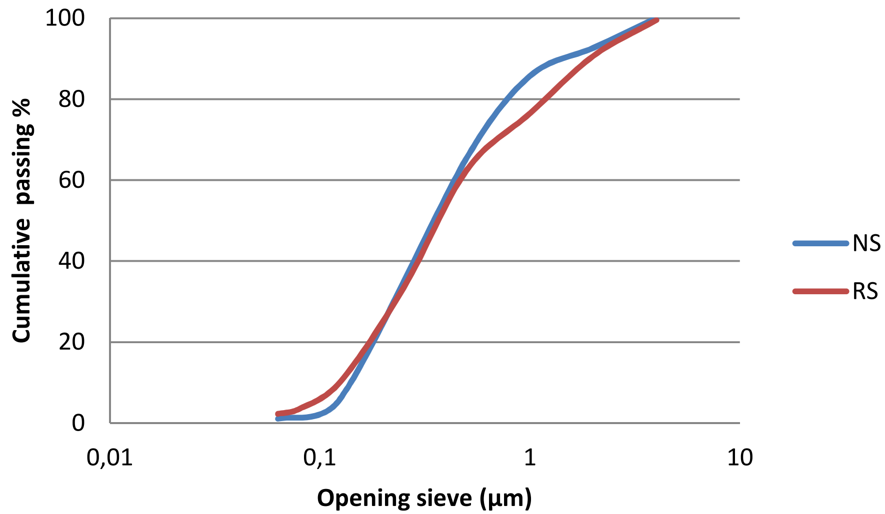
SCC rheological properties	
Slump (mm)	700
Time of slump (s)	4.5
Slump after 60 minutes (mm)	565
U-box (mm)	334
Time of U-box (s)	9.9
V-funnel (s)	14.3
% air	2.5

Substitution of natural sand by recycled sand (RS) : **20%, 40%, 60%, 80%** and **100%**

Substitution of limestone filler by crushed recycled sand (CRS) : **20%, 40%, 60%, 80%** and **100%**

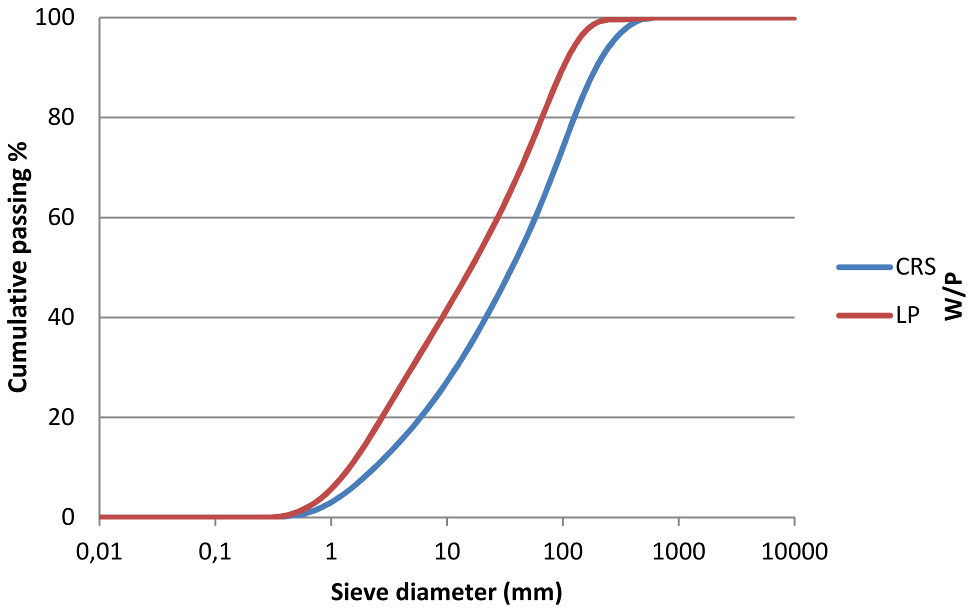
3. Characterization: recycled sand/natural sand

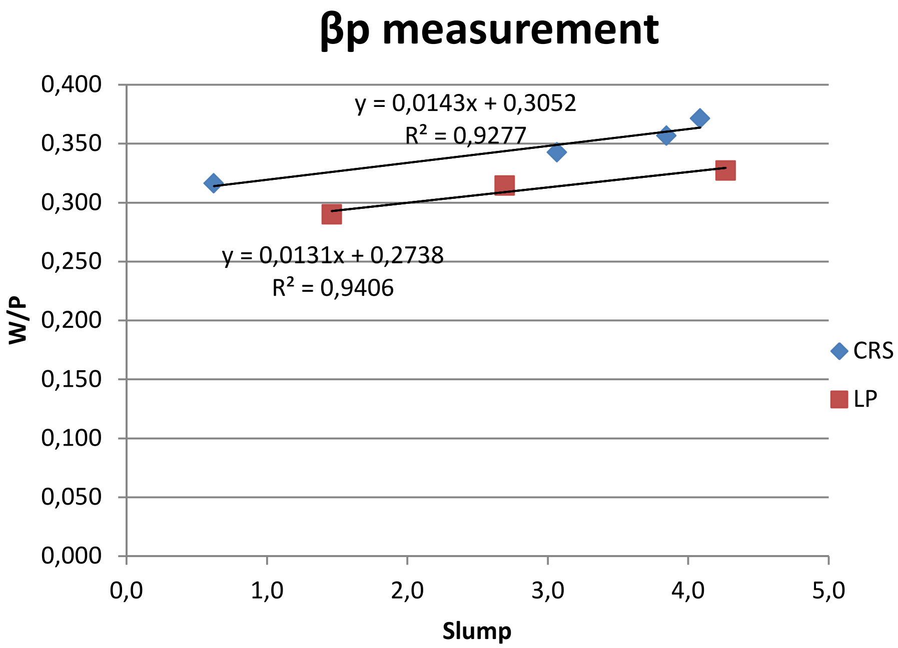




	Recycled sand		Natural sand	
	Value	Standard deviation	Value	Standard deviation
Apparent particle density (g/cm³)	2.456	0.033	2.606	0.019
Particle density on an oven-dried basis (g/cm³)	2.238	0.028	2.514	0.018
Particle density on a saturated and surface-dried basis (g/cm³)	2.327	0.029	2.549	0.018
Helium apparente density (g/cm³)	2.64	0.004	2.66	0.003
Accessible porosity (%)	9.7	0.13	4	0.03
Water absorption (%)	3.95	0.19	1.41	0.33

3. Characterization: Crushed Recycled Sand/limestone filler (powder)



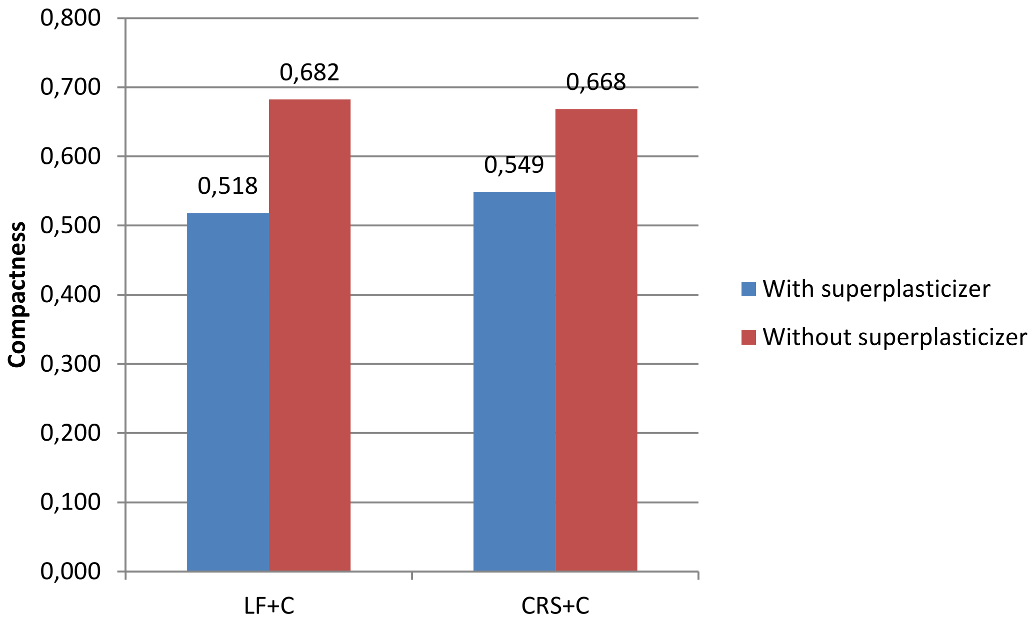


	CRS	LP
Density (g/cm³)	2.69	2.71
Blaine Specific Surface area (cm²/g)	3360	3180
BET Specific Surface area (m²/g)	2.771	0.772
βp	0.3052	0.2738

5. Compactness

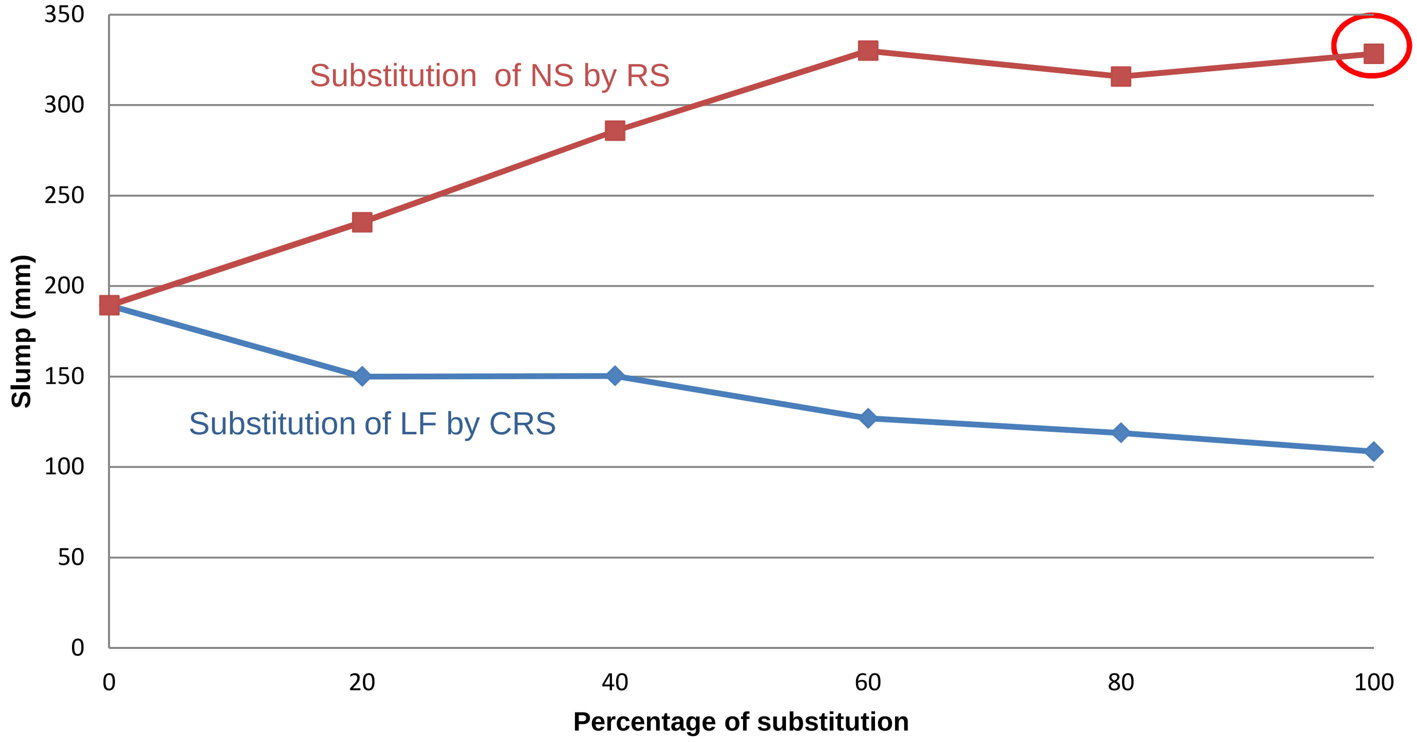
	Cement	LF	CRS	SP	W with SP	W without SP
Mix 1	284	188	0	0 or 5.96	75	150
Mix 2	287	0	185	0 or 6.03	80	132

$$C_{exp}=\frac{1000}{1000+Mv*\frac{Me}{Mp}}$$



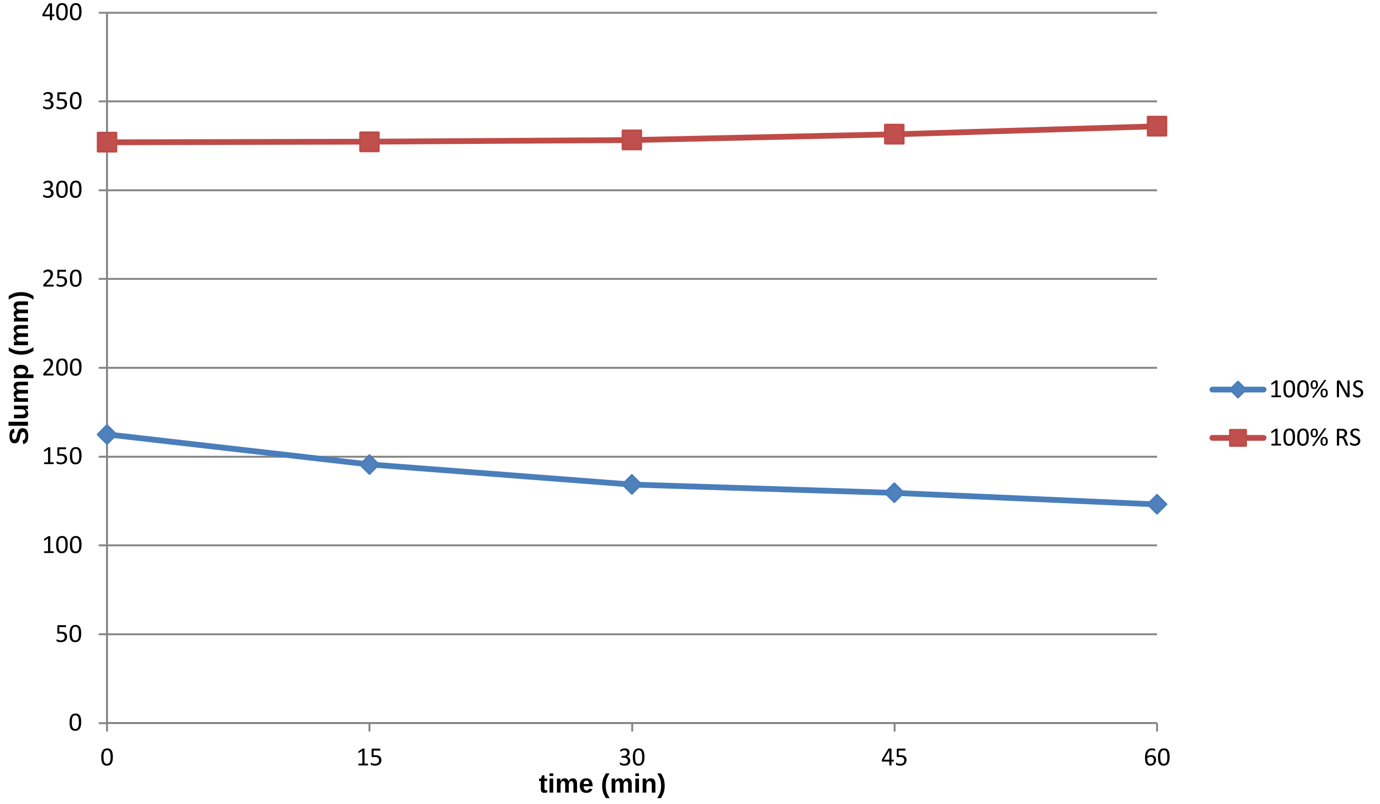
With superplasticizer: CRS+C higher packing density than LF+C
Without superplasticizer: LF+C higher packing density than CRS+C

6. Rheological test: slump



Workability of mortar increases with the increase of substitution of NS by RS
Workability of mortar decreases as the substitution of LF by CRS increases

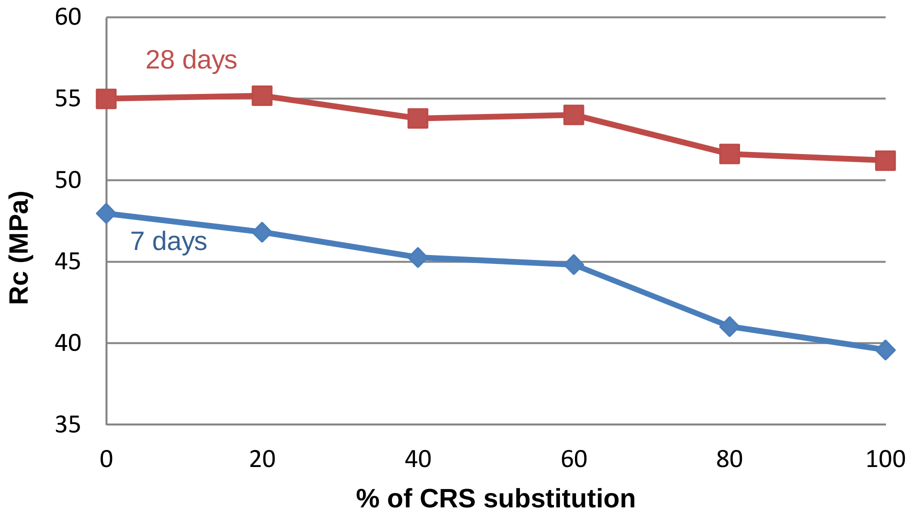
6. Rheological test: time of slump

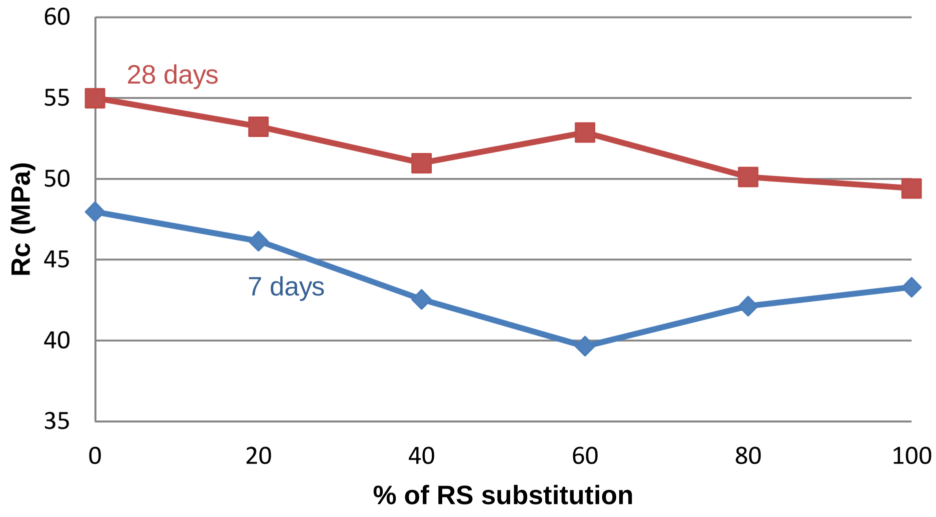


Slump of mortar made with recycled sand kept unchanged after 1 hour

7. Mechanical properties

Effect of CRS and RS on the mechanical properties





Significant difference in compressive strength at 7 and 28 days compared to the reference mortar

8. Conclusions

Crushed recycled sand

-Worse workability

-Significant difference in mechanical strength

Recycled sand

-Better workability

-Significant difference in mechanical strength

9. Perspectives

- Simulation of packing density by Compressible Stacking Method (CSM)
- Understand the rheology of mortar/concrete based on recycled material
- Formulation of SCC based on recycled material with CSM
- Validation of the scientific approach with different recycled materials from different companies
- Study the influence of sulfate contents on the rheological properties of mortar

Gypsum residues in recycled materials

Effects on microstructural and mechanical properties of cementitious mixes

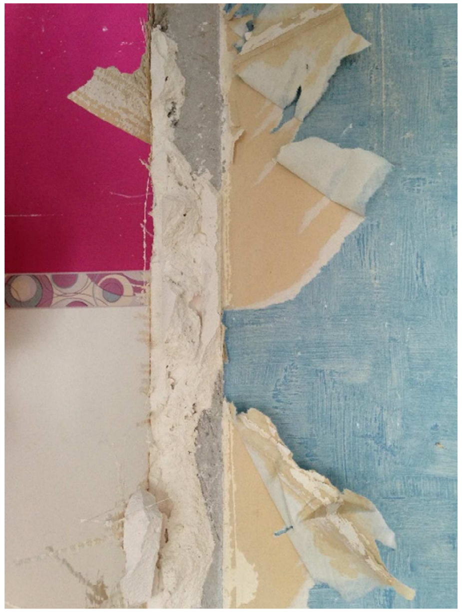
Charlotte Colman

Supervisors: Prof. Luc Courard, Prof. David Bulteel

Problem definition: fine particles

The incorporation of fine recycled particles into new concrete has a negative influence on its strength and durability properties.

Construction and Demolition Waste is contaminated with materials from the construction site

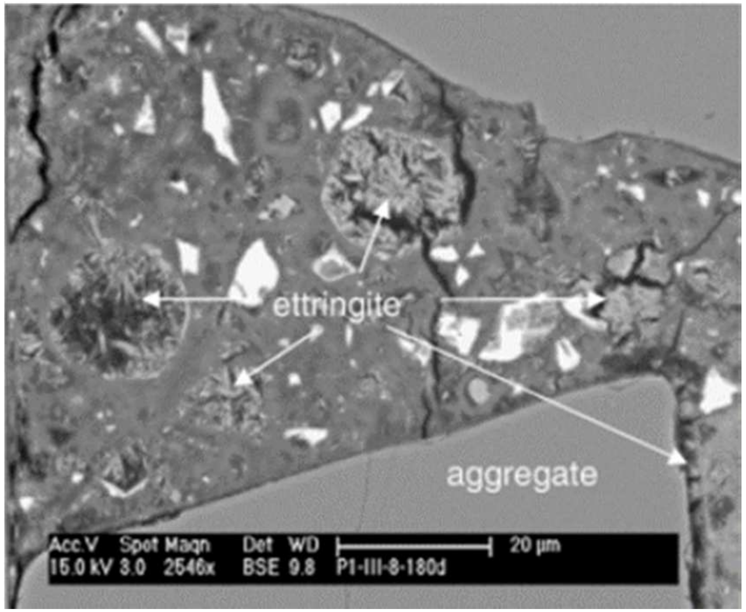


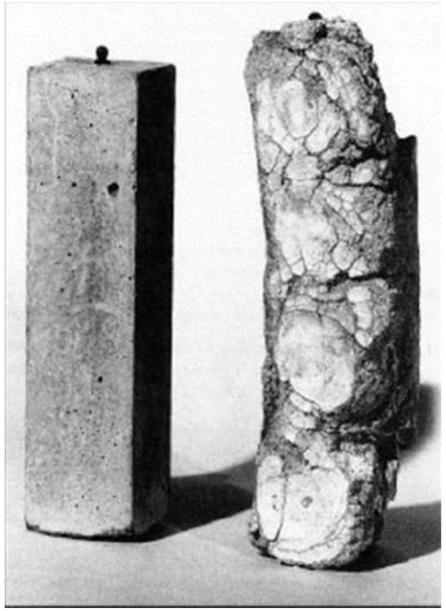
Even with a careful '*deconstruction*' instead of a demolition, a lot of contaminants still end up in the recycled waste

Problem definition: sulfate attack

Gypsum ($CaSO_4.2H_2O$) contamination in fine recycled particles may complicate, enhance, accelerate the effects of sulfate attack

Sulfate attack is a deteriorating process for concrete, causing the expansive formation of sulfate containing minerals such as ettringite.





The formation of this secondary ettringite leads to expansive behaviour:
$(CaO)_3(Al_2O_3).6H_2O+(CaSO_4)_3.2H_2O+26H_2O \rightarrow (CaO)_3(Al_2O_3)(CaSO_4)_3.32H_2O$

Problem definition: research objectives

Which proportion of residual gypsum contamination from demolition waste is acceptable for designing new concretes?

→ Understand the effects of sulfate attack on various properties of concrete based materials derived from demolition waste

→ Establish the relation between pore fluid chemistry and volumetric deformation

Methodology

1. Characterization of recycled sand

Fine recycled materials, obtained from construction, recycling or demolition companies are analyzed chemically, physically, mineralogically.

2. Swelling measurements

Mortar parameters are varied to assess their influence on the swelling process (cement type, gypsum content, humidity, temperature, ...). Swelling is measured in the classical way, but also with oedometers.

3. Following the development of sulfate attack

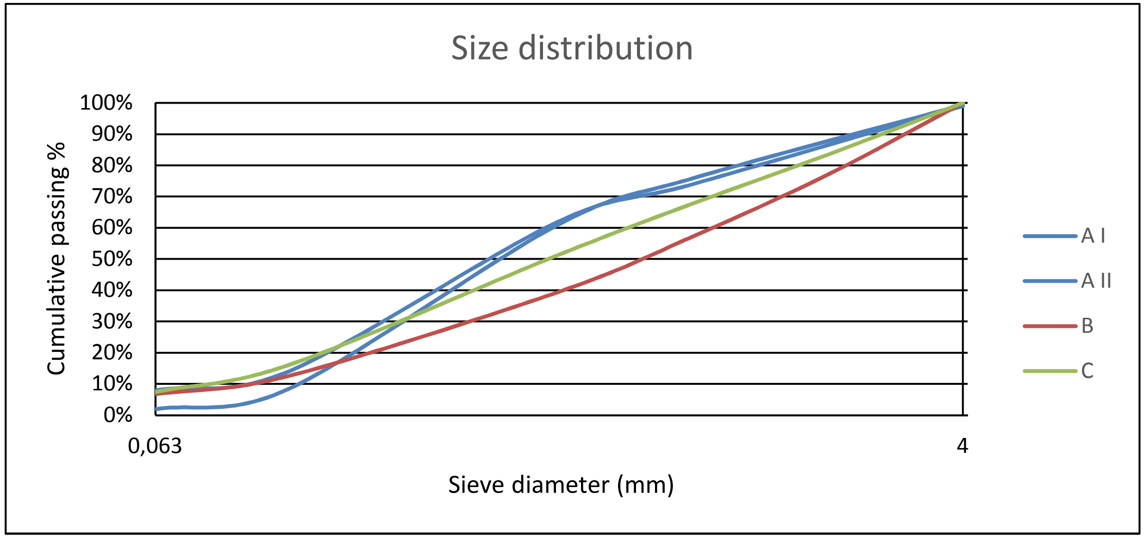
With different analytical techniques (SEM, nano indentation, petrography, ...), different stages of sulfate attack are researched in hardening pastes.

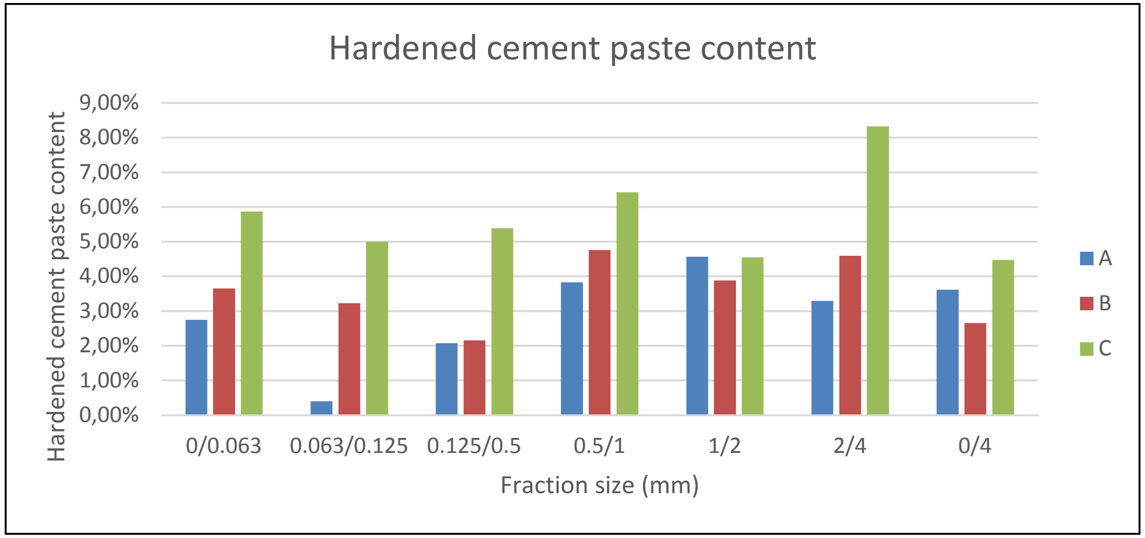
4. Development of a quantitative relation

The gypsum content of a material is directly related to its volumetric deformation

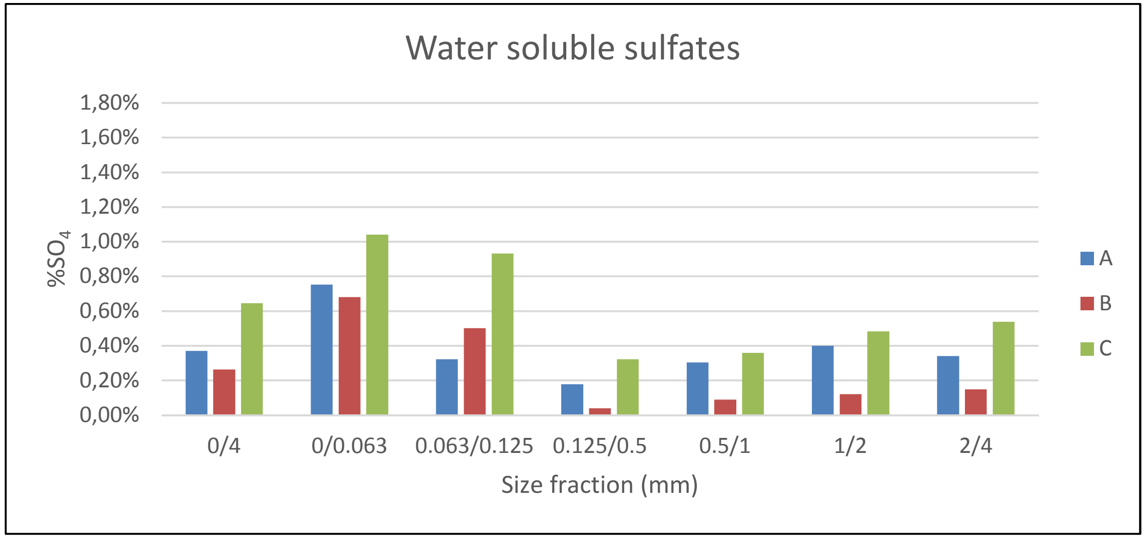
Characterization results

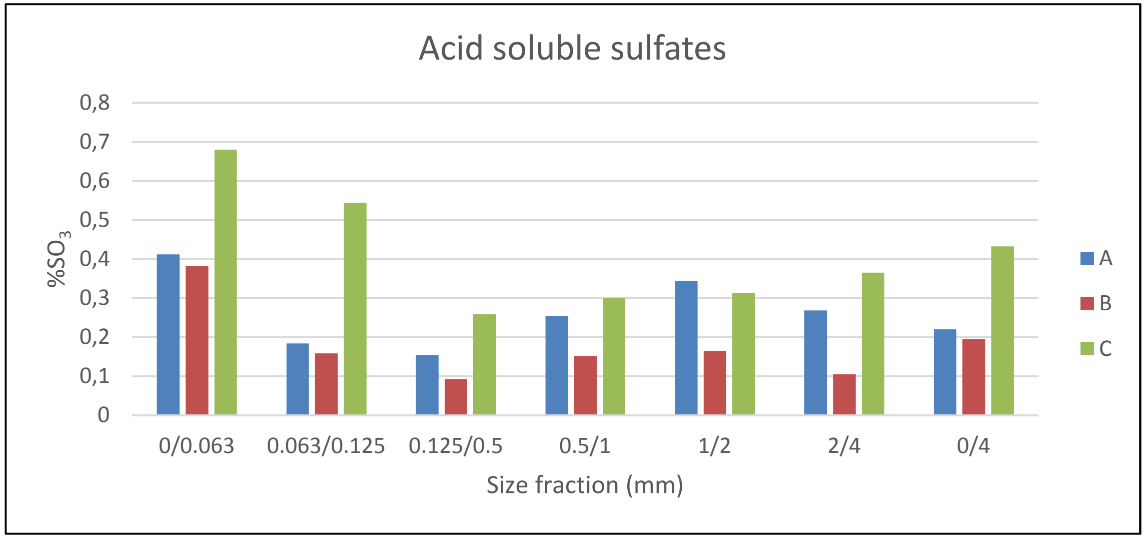
Characterization results show a large variation between different sources, even between different batches of the same source



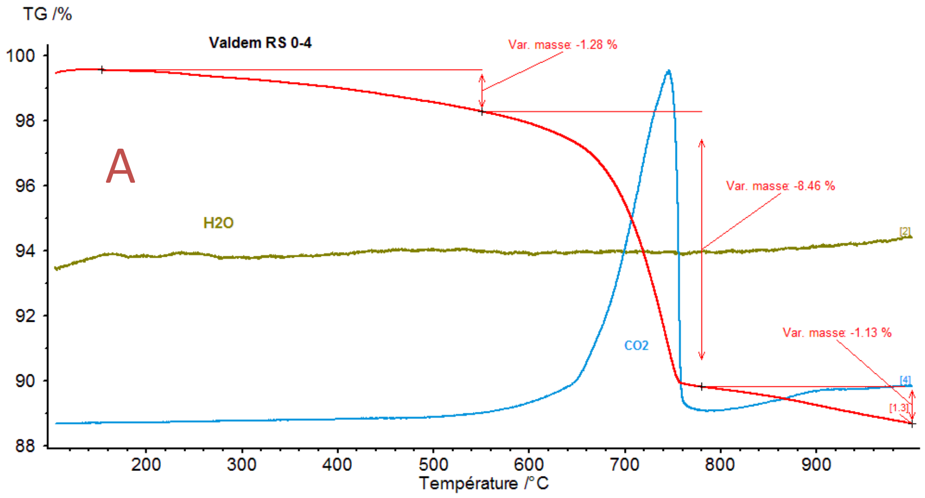


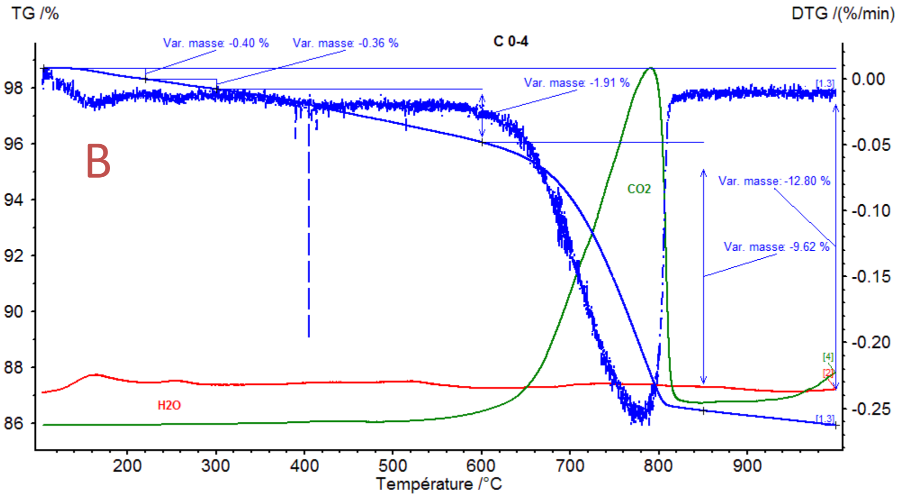
Characterization results



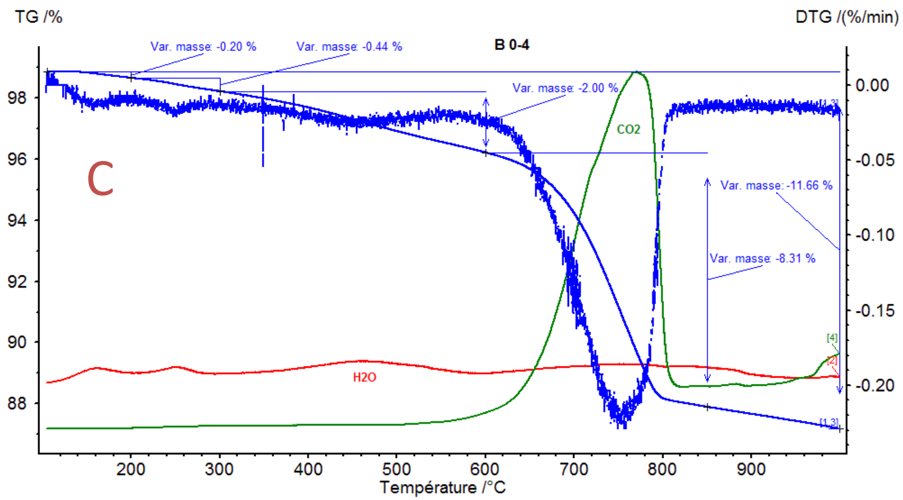


Characterization results

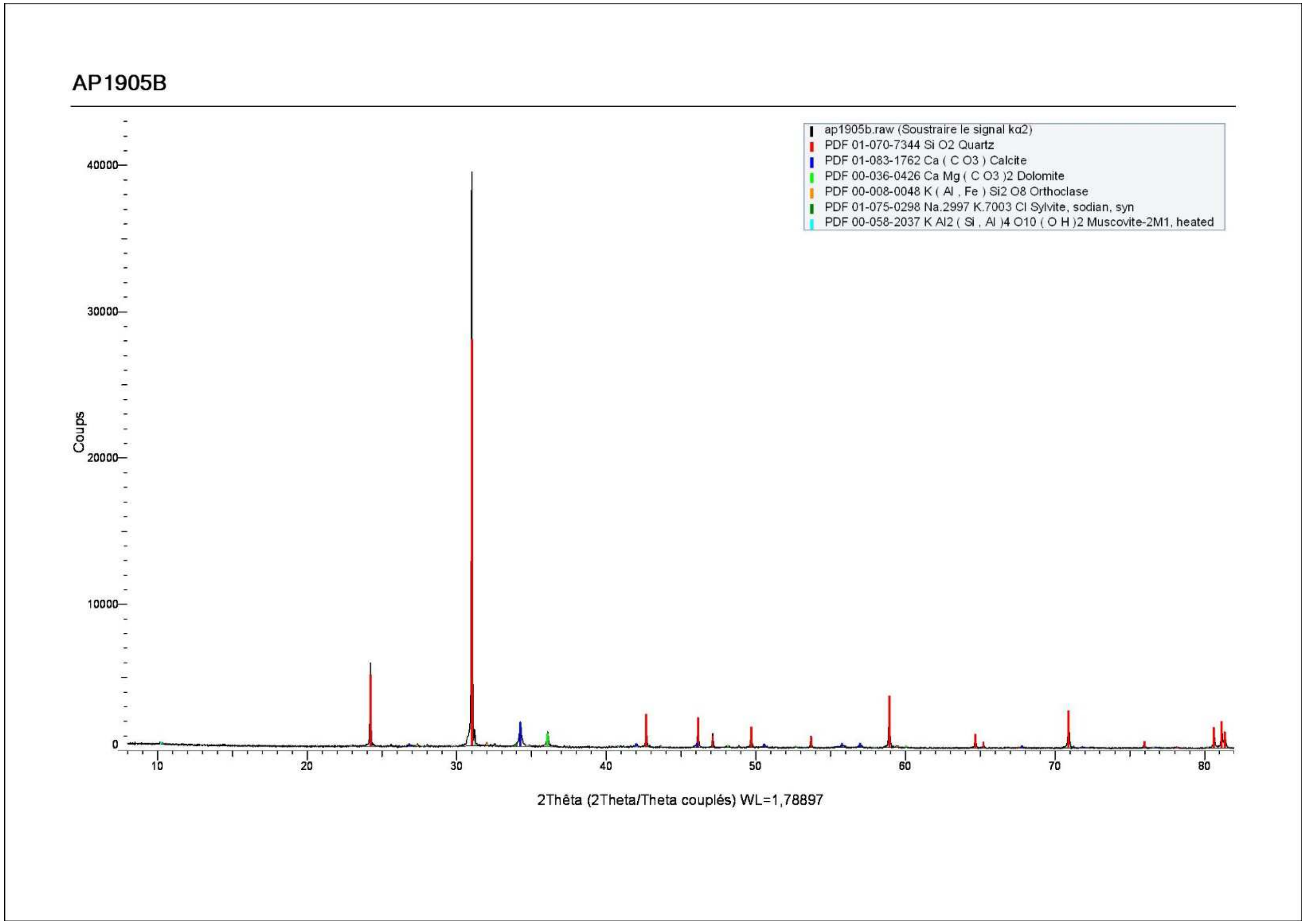




Thermogravimetric analysis for source B and C is similar. Sand from source A is fully carbonated!

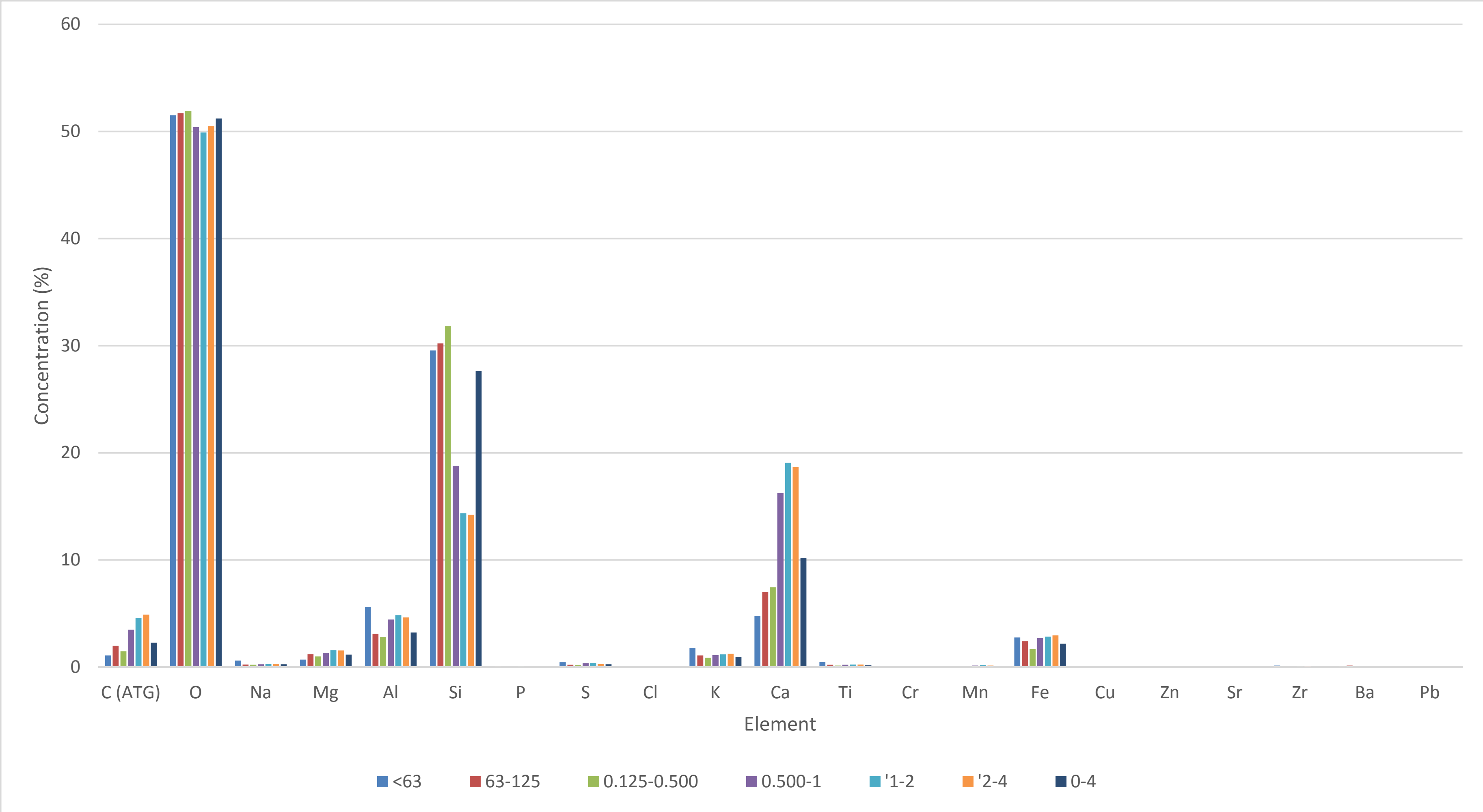


Characterization results



XRD: a very large quartz peak may be hiding information about ettringite

Characterization results



XRF: larger fractions are more rich in C and Ca, and less in Si

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Thank you for your attention
Questions?