Reactivity tests for Supplementary Cementitious Materials (SCMs)

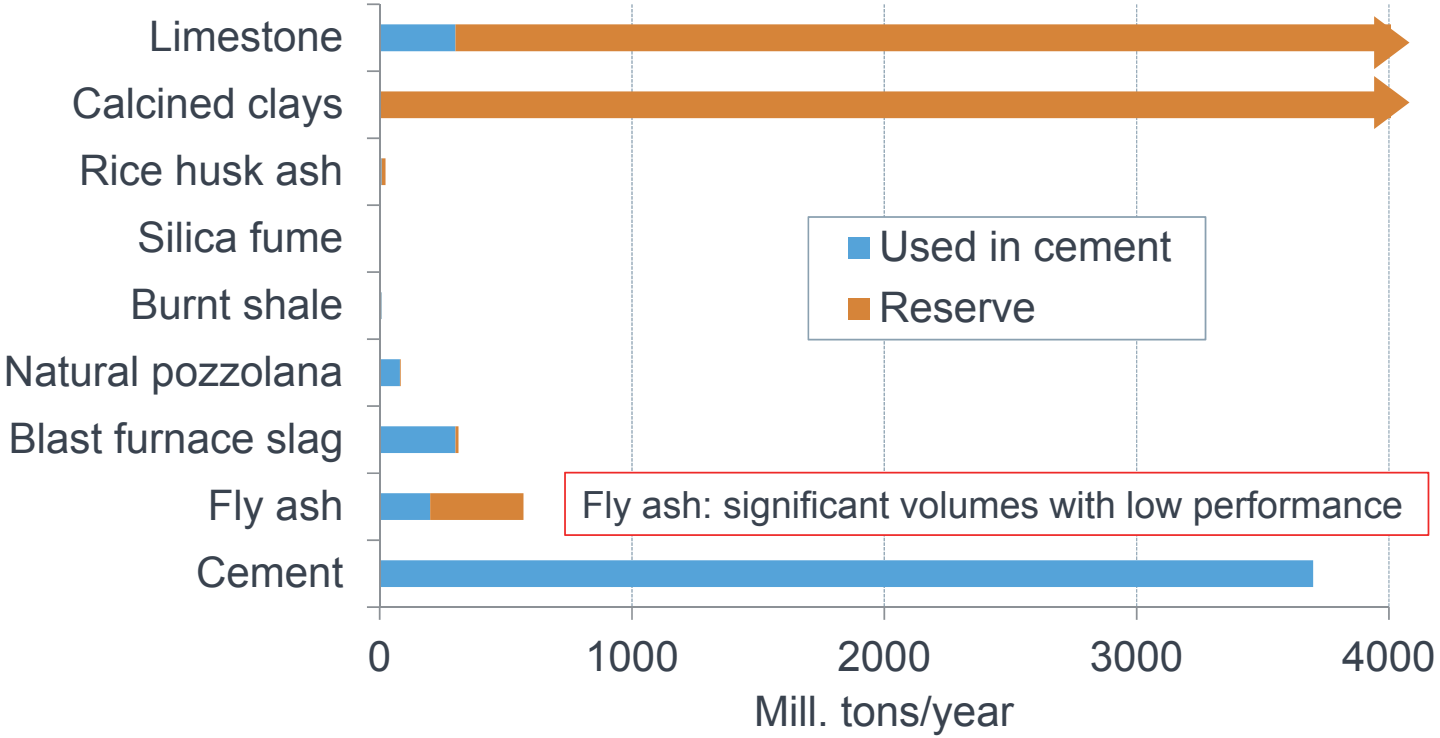
François Avet, Xuerun Li, Karen Scrivener

RILEM TC-267 TRM committee

12.12.2018

Decrease of the availability of traditional SCMs

- New sources or combination of SCMs are considered
- Wide availability of calcined clay with various grades and also limestone



Scrivener K., Gartner E., John V. UNEP report (2016)

Assessment of SCM reactivity

- Usual way: measurement of compressive strength of blended cement
- However, this test is time and material consuming (28 days as reference value)

- Reactivity tests developed to get a quicker indication of the reactivity of SCMs
- Ideally, tests as quick, simple, robust, reproducible and cheap as possible

RILEM TC 267-TRM aims to compare existing and innovative reactivity tests to give a recommendation that can be adopted as standard testing method.

- 21 participants
  - 11 SCMs
- 10 different techniques

Objectives of the RILEM TC 267-TRM

- Phase I work:
  - Comparison of existing and novel methods
  - Test on a wide range of SCMs
  - Correlation with reference mortar strength
  - Selection of the most accurate tests

- Phase II: Test robustness of protocols
  - Identification of key parameters
  - Improve the protocols

Materials and Methods

SCMs
2 calcined clays
2 slags
2 calcareous fly ashes
2 siliceous fly ashes
Natural pozzolana
Quartz as inert

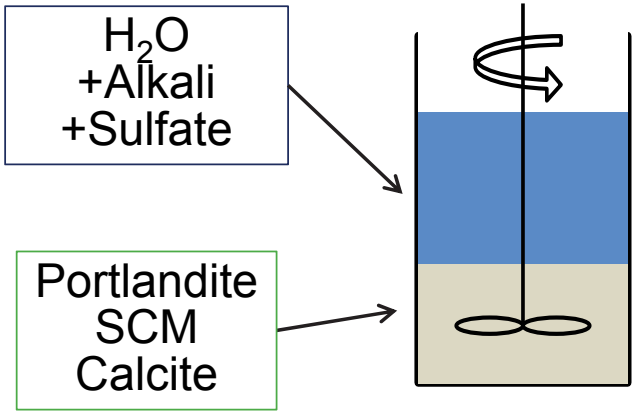
Test	Standard
Chapelle test or modified version	NF P18-513
Frattini test	EN 196-5
Reactive silica	EN 197-1 / EN 196-2
Lime reactivity test	IS 1727
R^3 test	-

Measures the reactivity of SCM based on CH characterization

Compressive strength measurement of SCM:CH binary blends

Monitoring reactivity of SCMs: R^3 test

- Rapid, Relevant and Reliable (R^3)
- Focus on SCM reaction only
  - Adjustment of sulfate and alkali content to reproduce the reaction environment of hydrating blended cements

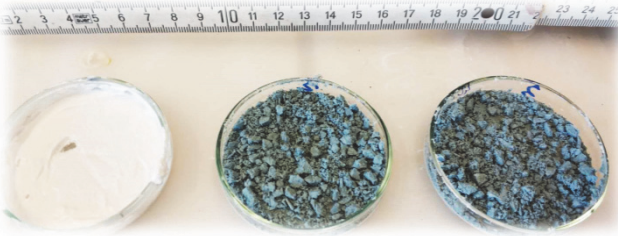


Components	Mass (g)
SCM	11.11
Portlandite	33.33
Deionized Water	60
KOH	0.24
K_2SO_4	1.20
Calcite	5.56

Two ways of measuring the reactivity

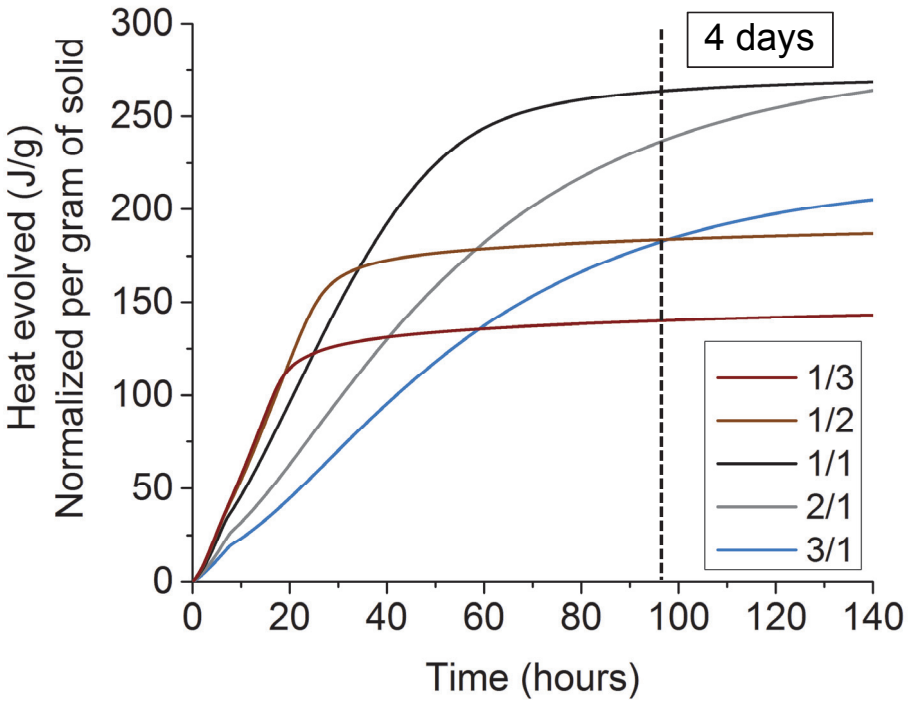
Isothermal calorimetry
at 40°C
Heat release 7d

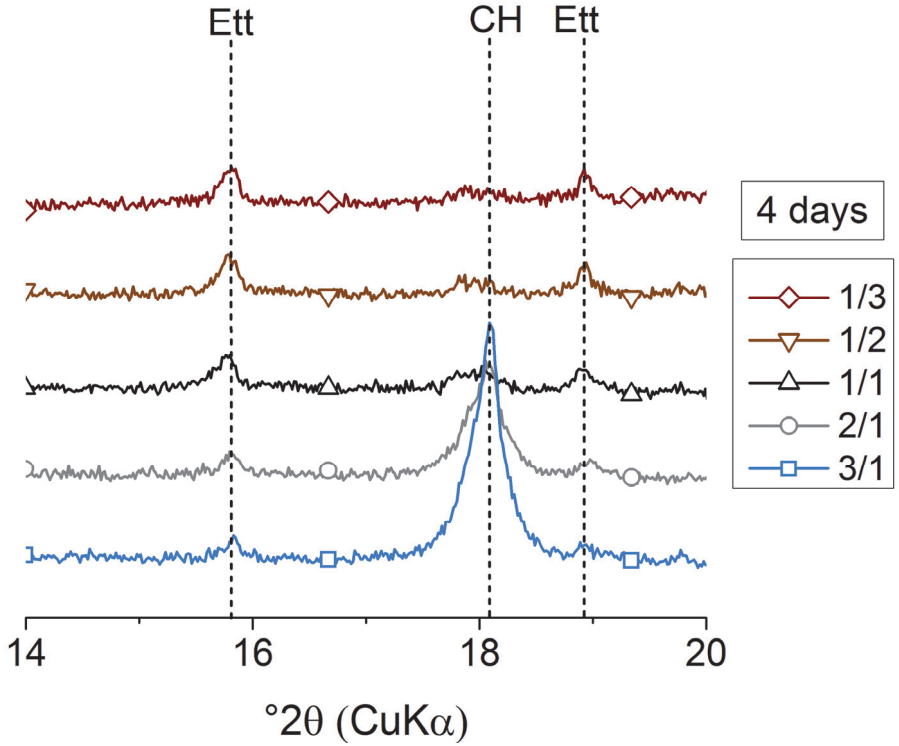
Oven thermal
treatment at 350°C
Bound water 7d



Adjustment of portlandite to SCM ratio

- Plateau reached for 1/3 1/2 and 1/1
- In order not to run out of portlandite, 3/1 was chosen

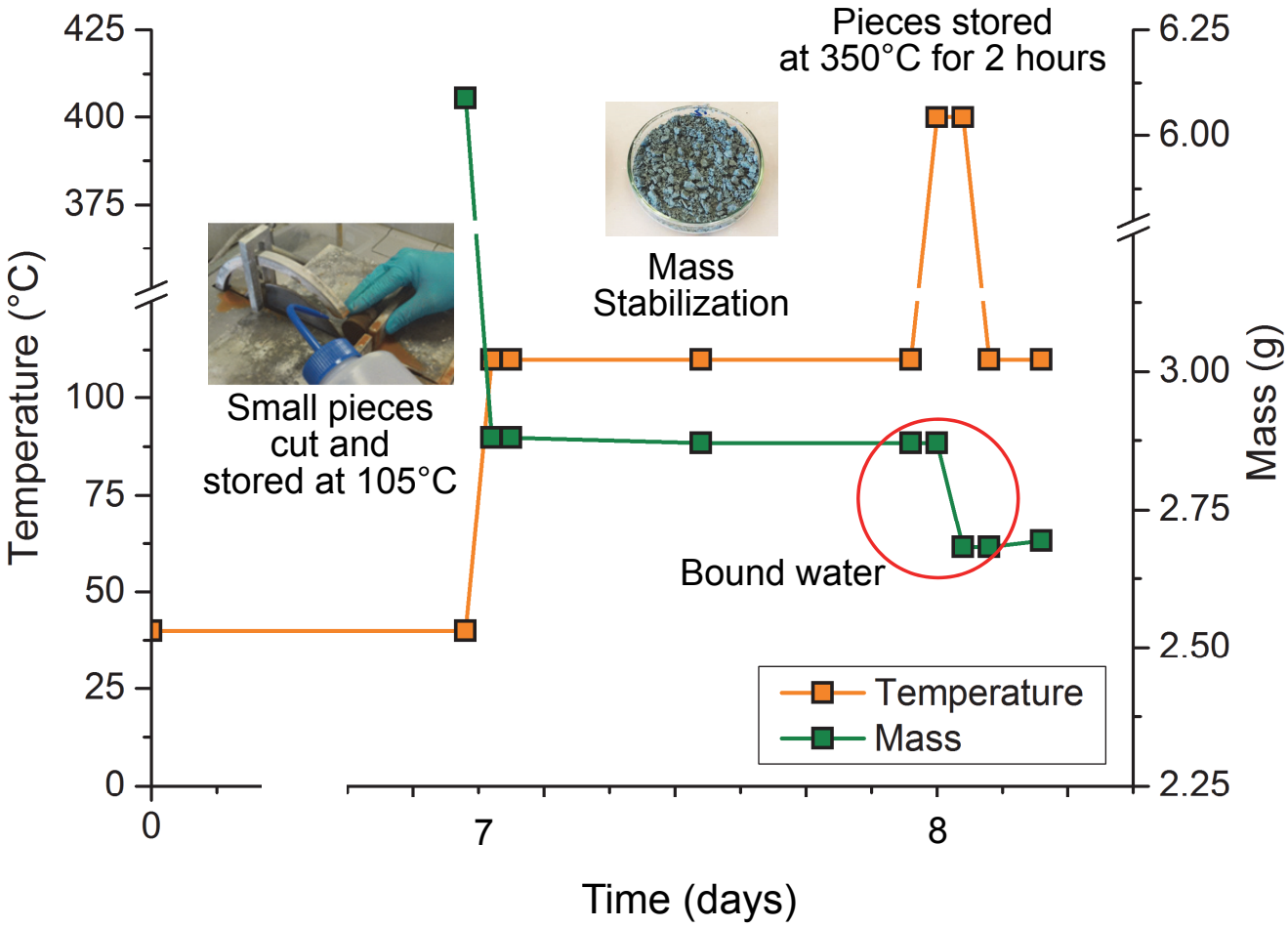




Avet et al (2016)

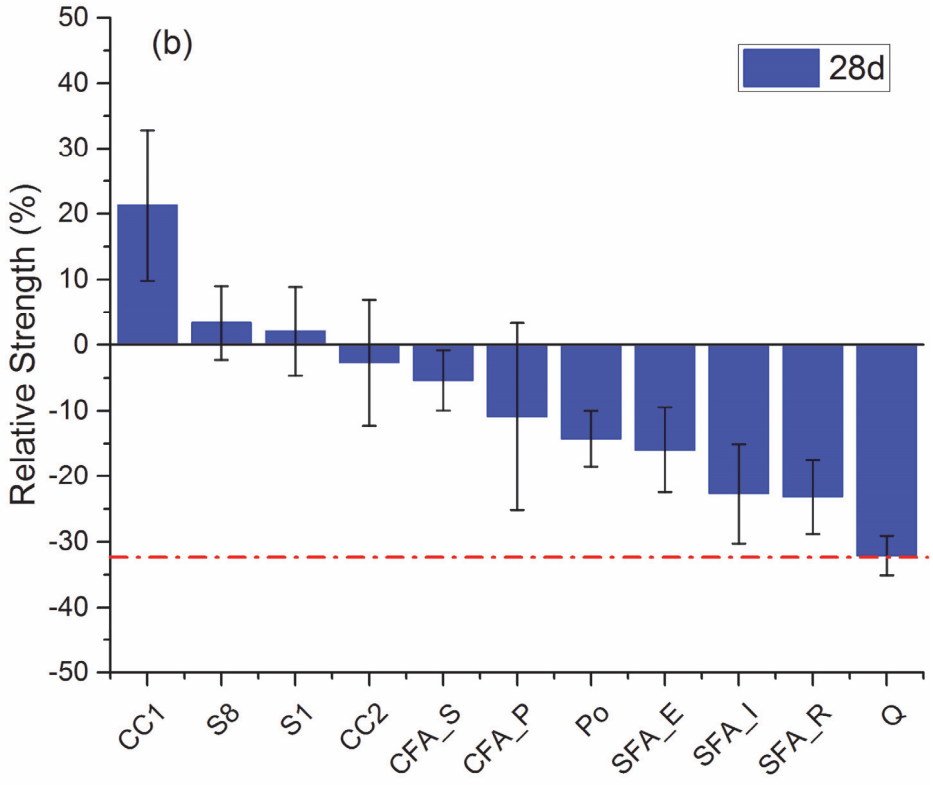
Determination of bound water

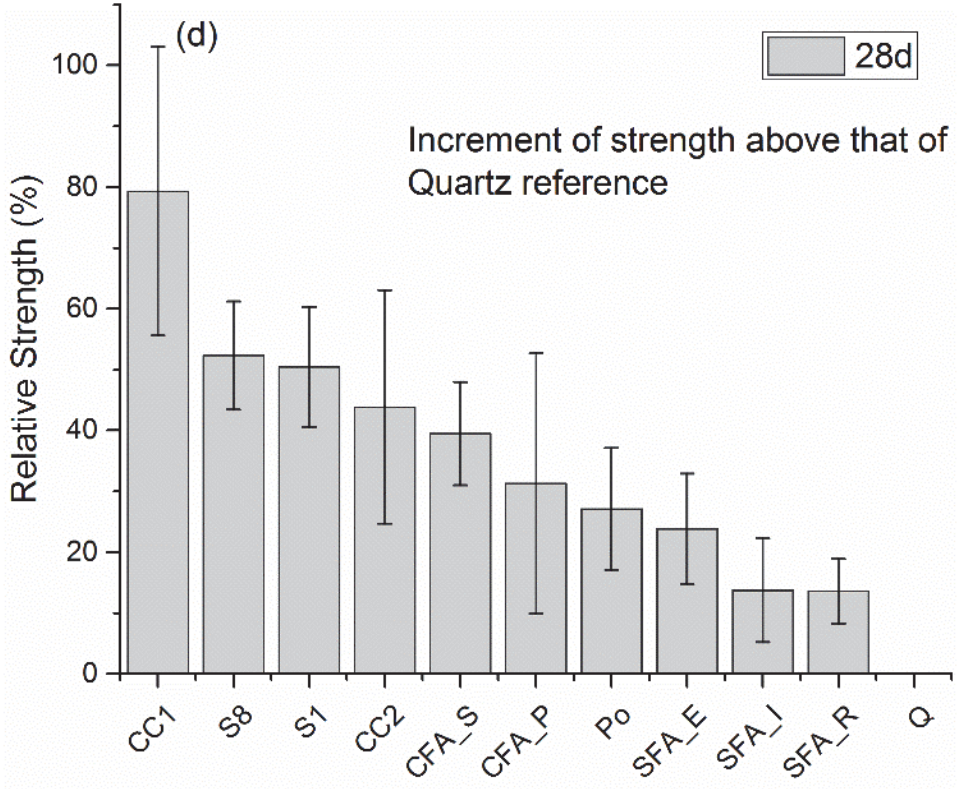
- Mass evolution after thermal treatment at 350°C for for 2 hours
- Only requires a balance and an oven



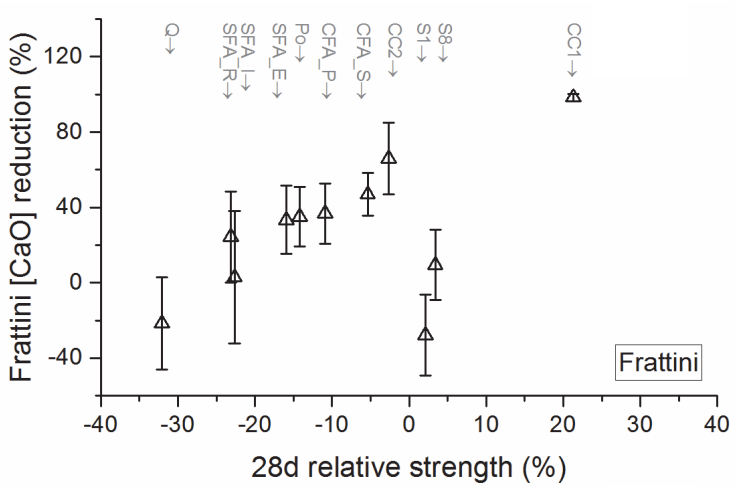
Results: Strength test as reference (30% substitution)

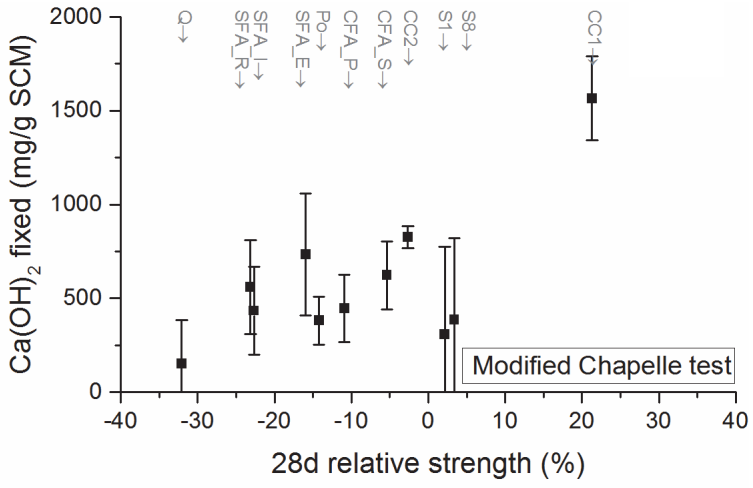
- 6 cements used in 6 different labs
- Significant differences, even though all cements used for the blends are CEM I 42.5 R

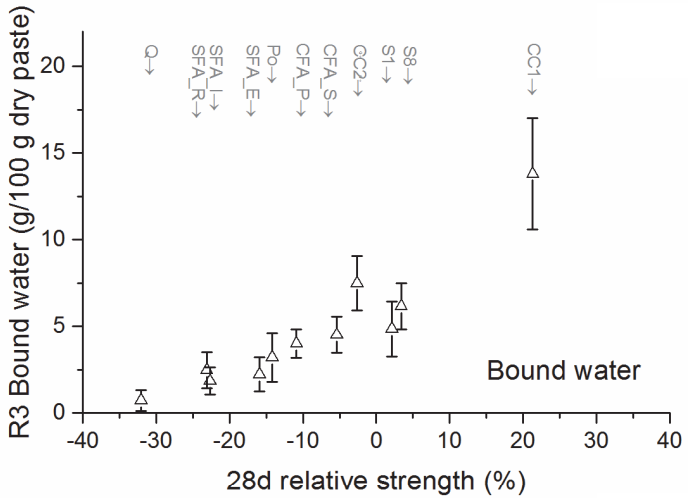


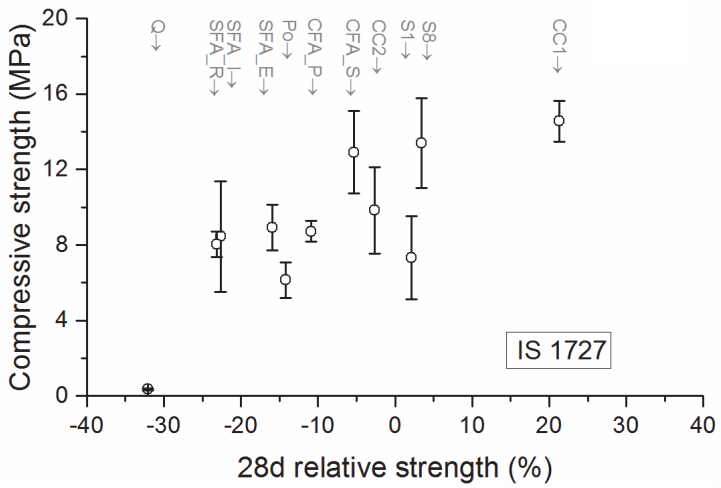


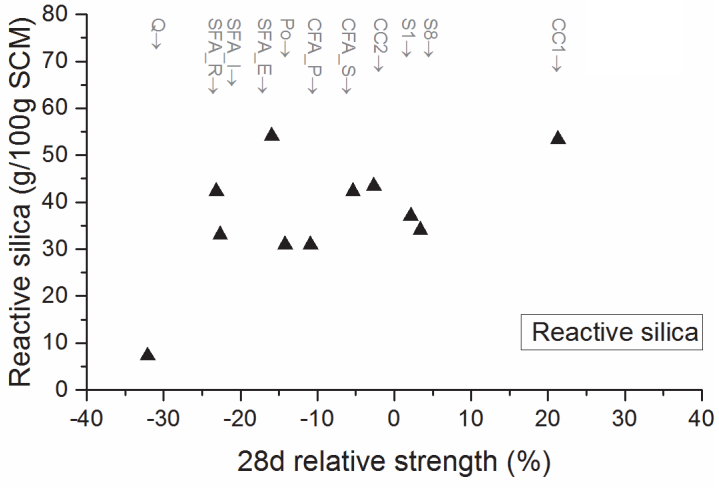
Correlation between reactivity tests and strength

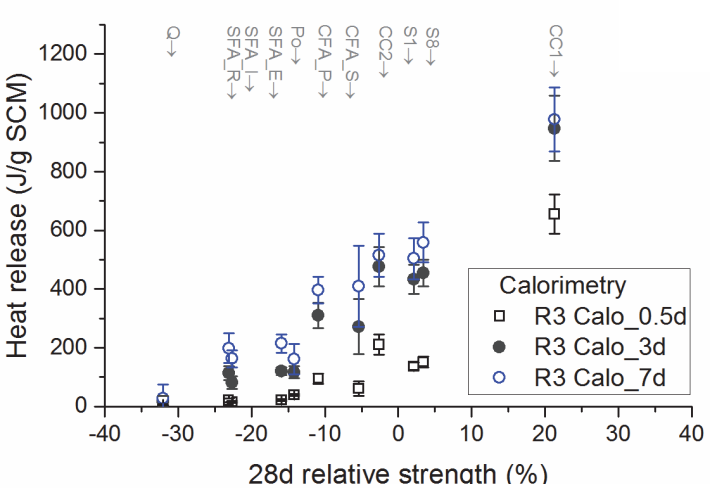








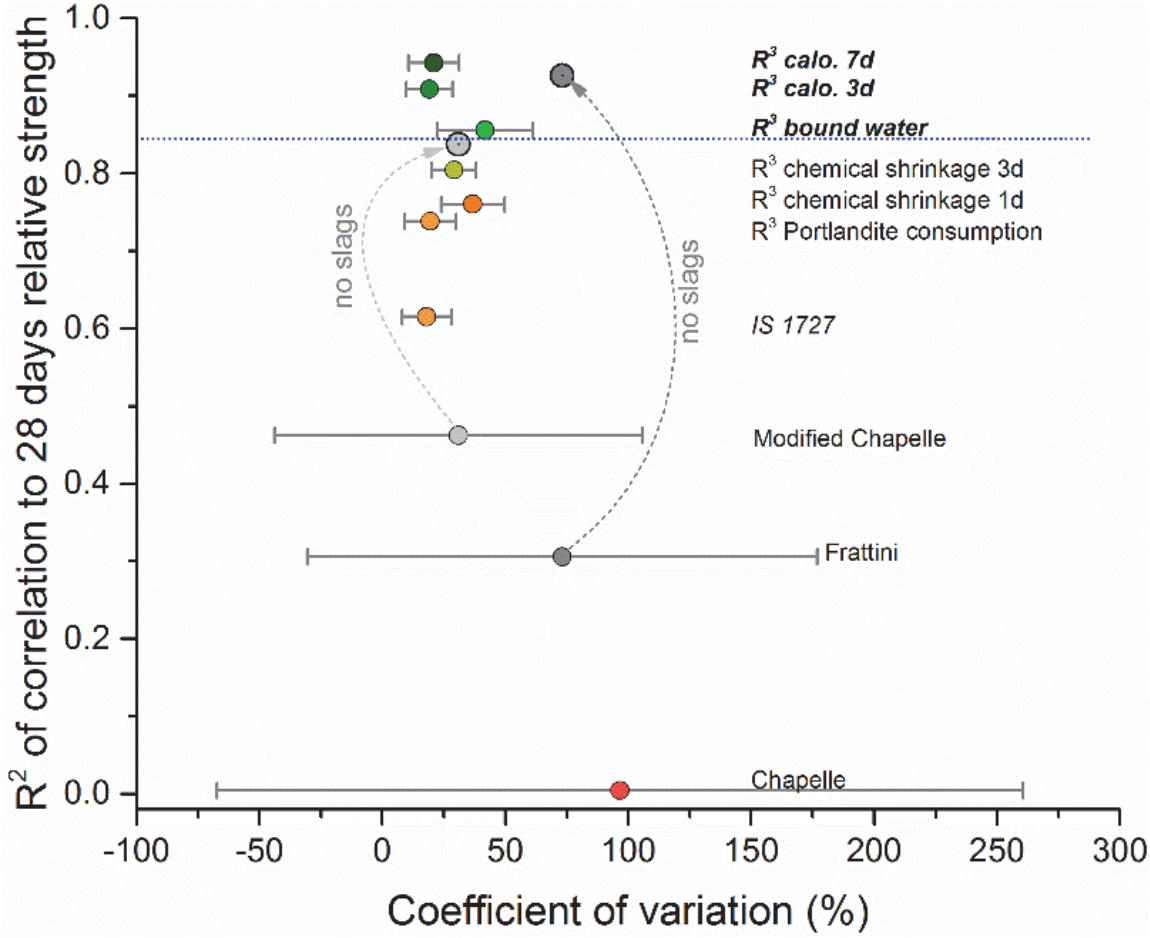




Phase I: Most promising results obtained with the R^3 test

- Frattini and Chapelle tests give poor correlation to strength, with very low interlab reproducibility.
- Improvement of Frattini by excluding slags
- R^3 tests using calorimetry and bound water give high correlation to strength and are the most reproducible

- R^3 deeper investigated in phase II for improving the protocols and the robustness



Li et al (2018)

Materials and Structures (2018) 51:151
https://doi.org/10.1617/s11527-018-1269-x

RILEM TECHNICAL COMMITTEE REPORT

Reactivity tests for supplementary cementitious materials: RILEM TC 267-TRM phase 1

Xuerun Li · Ruben Snellings · Mathieu Antoni · Natalia Mariel Alderete · Mohsen Ben Haha · Shashank Bishnoi · Özlem Cizer · Martin Cyr · Klaartje De Weerdt · Yuvaraj Dhandapani · Josée Duchesne · Johannes Haufe · Doug Hooton · Maria Juenger · Siham Kamali-Bernard · Sabina Kramar · Milena Marroccoli · Aneeta Mary Joseph · Anuj Parashar · Cedric Patapy · John L. Provis · Sergio Sabio · Manu Santhanam · Laurent Steger · Tongbo Sui · Antonio Telesca · Anya Vollpracht · Felipe Vargas · Brant Walkley · Frank Winnefeld · Guang Ye · Maciej Zajac · Shizhe Zhang · Karen L. Scrivener

- Phase I work:
  - Comparison of existing of novel methods
  - Test on a wide range of SCMs
  - Correlation with reference mortar strength

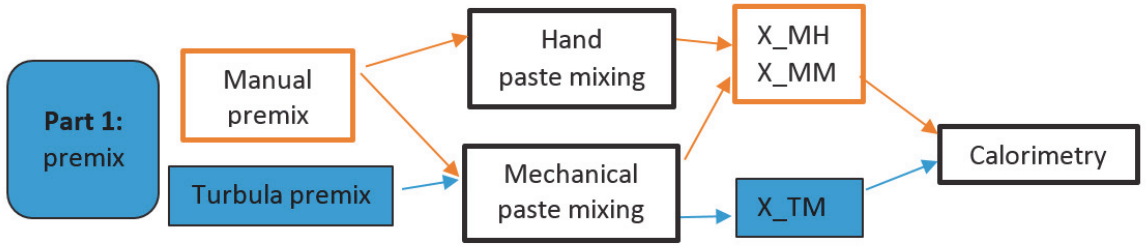
- Phase II: Test robustness of protocols
  - Identification of key parameters
  - Improve the protocols

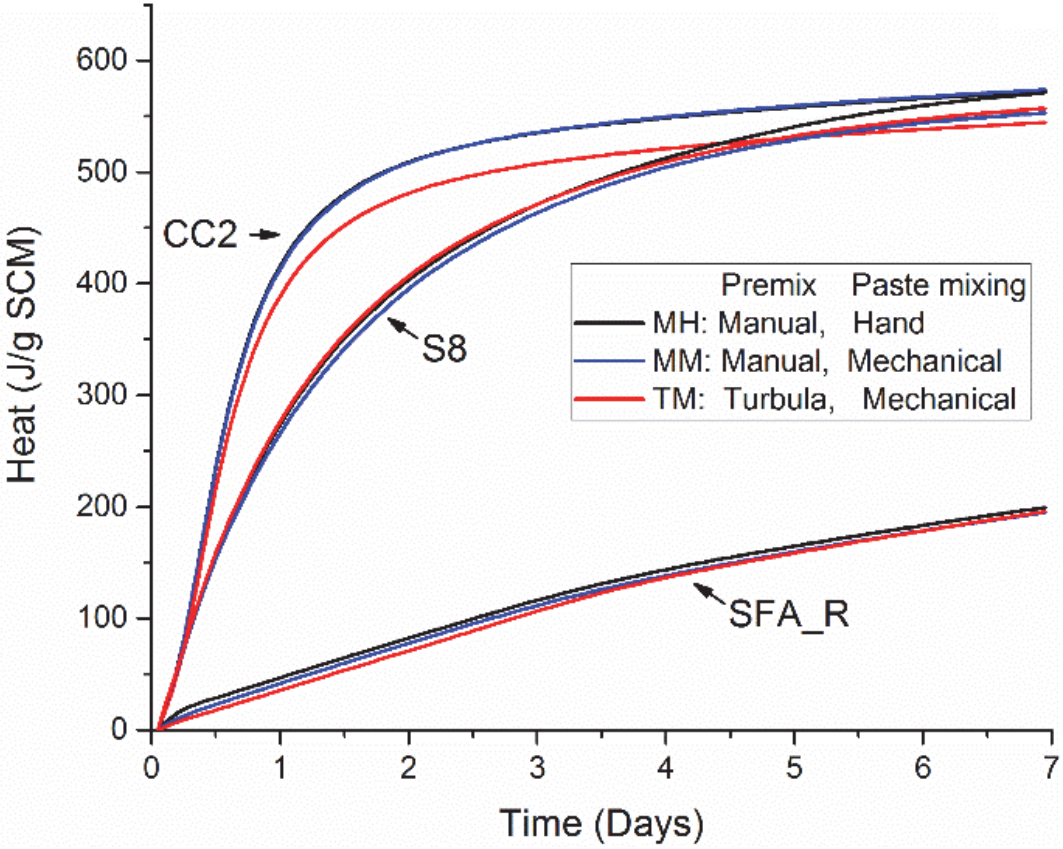
Investigation of the robustness and reproducibility of R^3

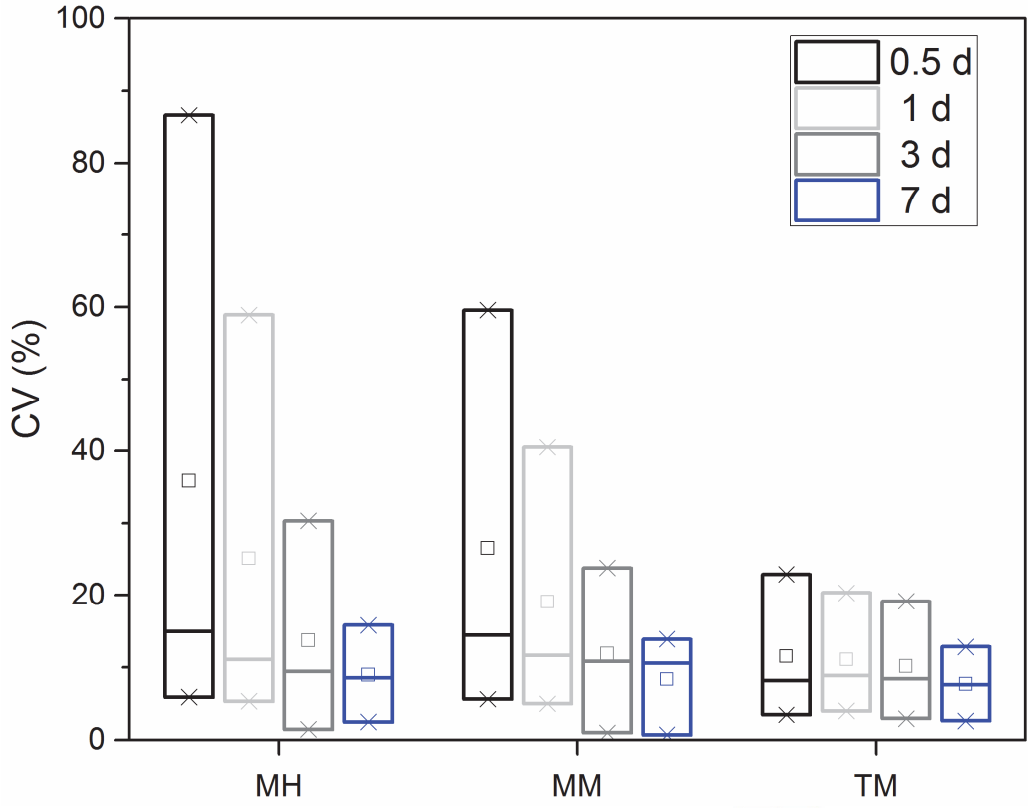
- R^3 Heat release
  - Premixing and mixing conditions
  - Mix design composition
  - Water bath

- R^3 Bound water
  - Drying procedure

Premix and mix conditions

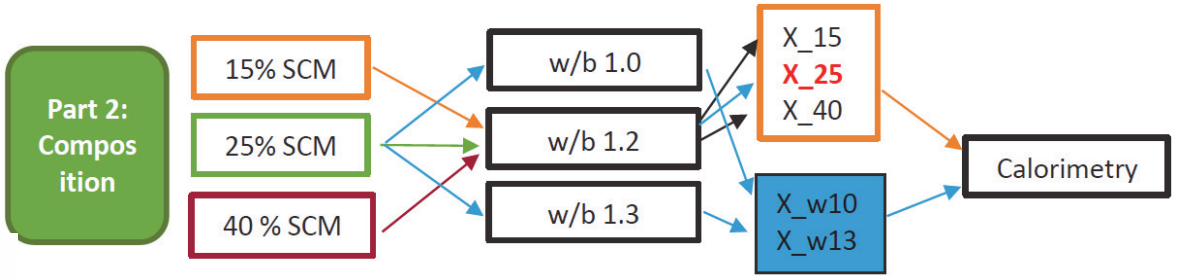


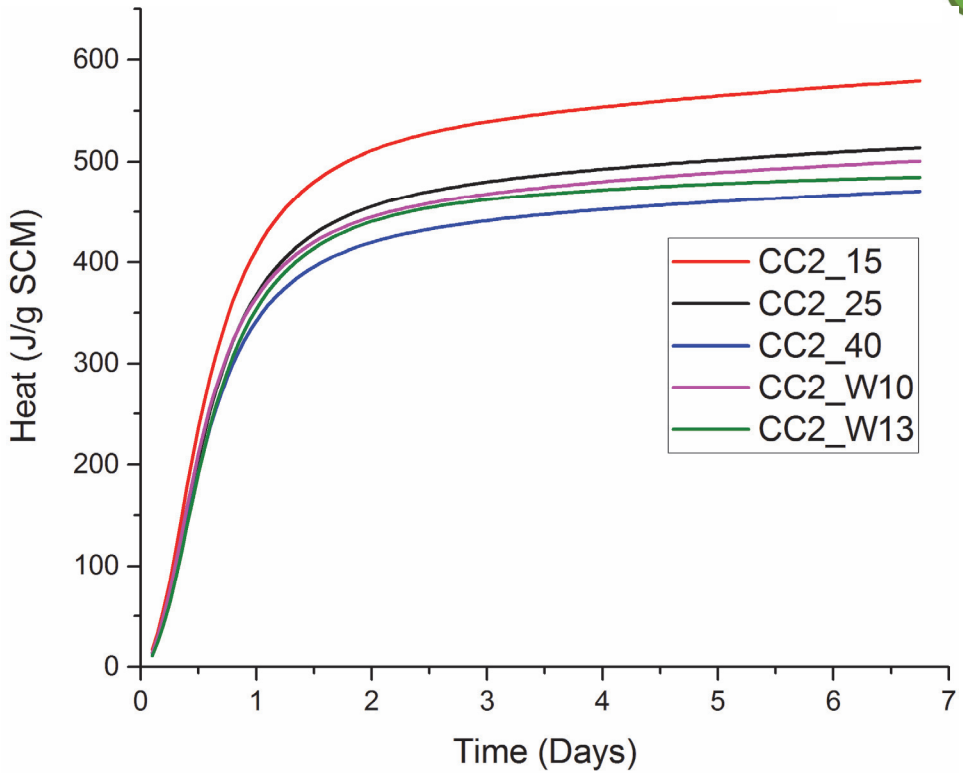




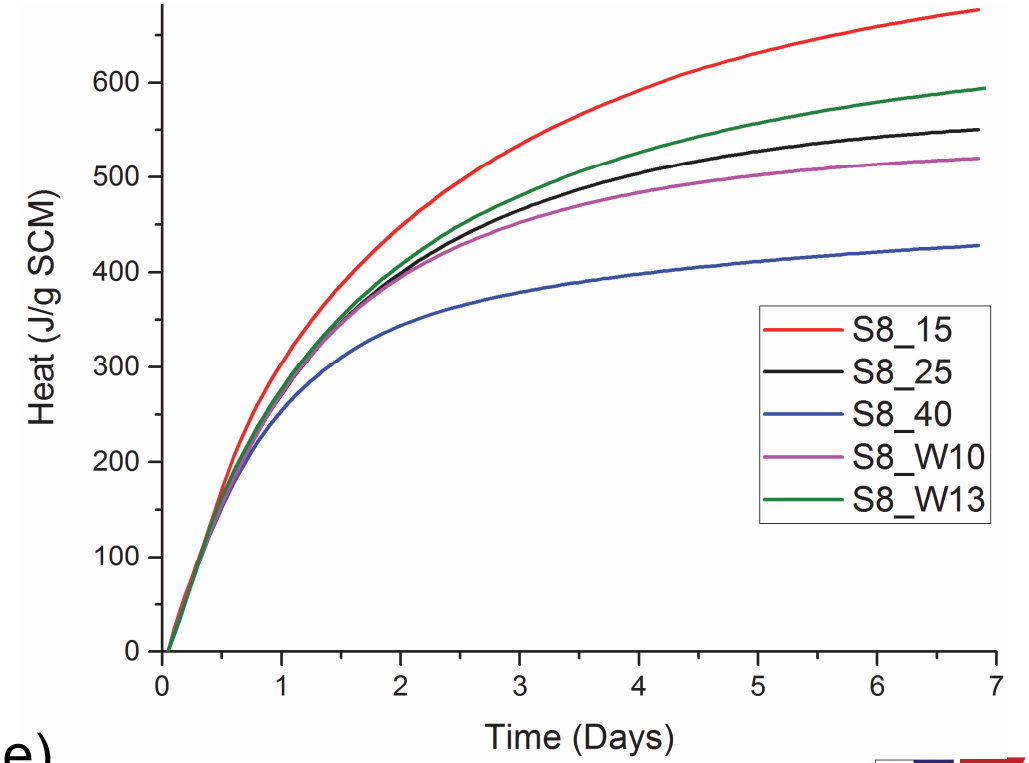
Mix composition change

(5 participants)





Accumulative heat of CC2 (average)



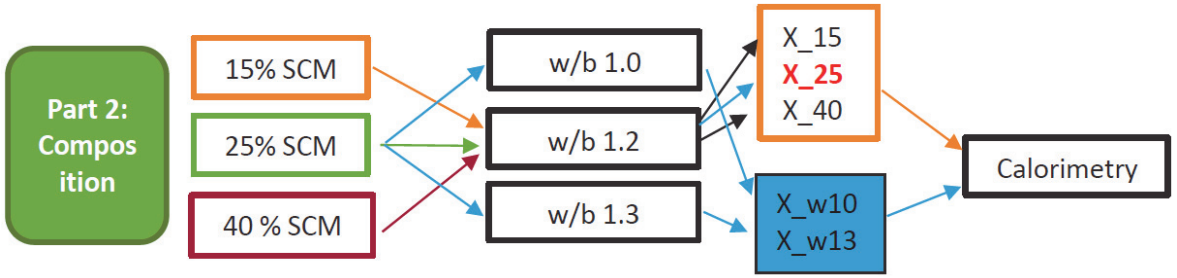
Accumulative heat of S8 (average)

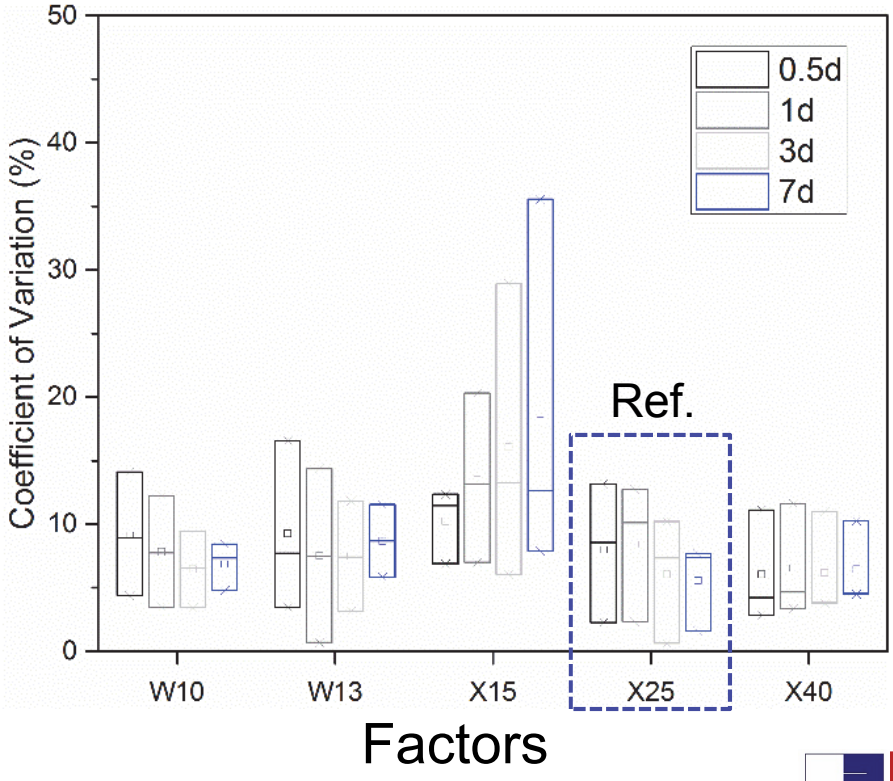
Mix composition change

(5 inputs)

	R3_7d				
R2	X15	X25	X40	W10	W13
Mortar_28	**1.00**	**0.98**	**0.88**	**0.97**	**1.00**
Mortar_90	0.49	0.38	0.18	0.35	0.56
CV (%)	*18.7*	*5.6*	*6.4*	*6.9*	*8.7*

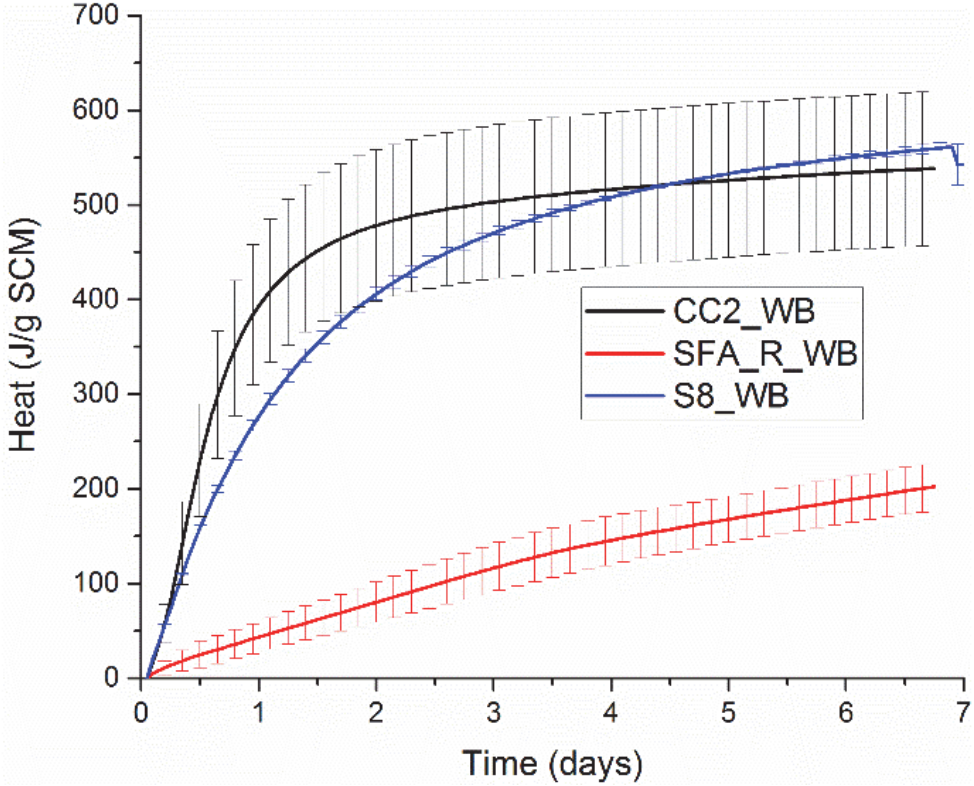
Initial mix



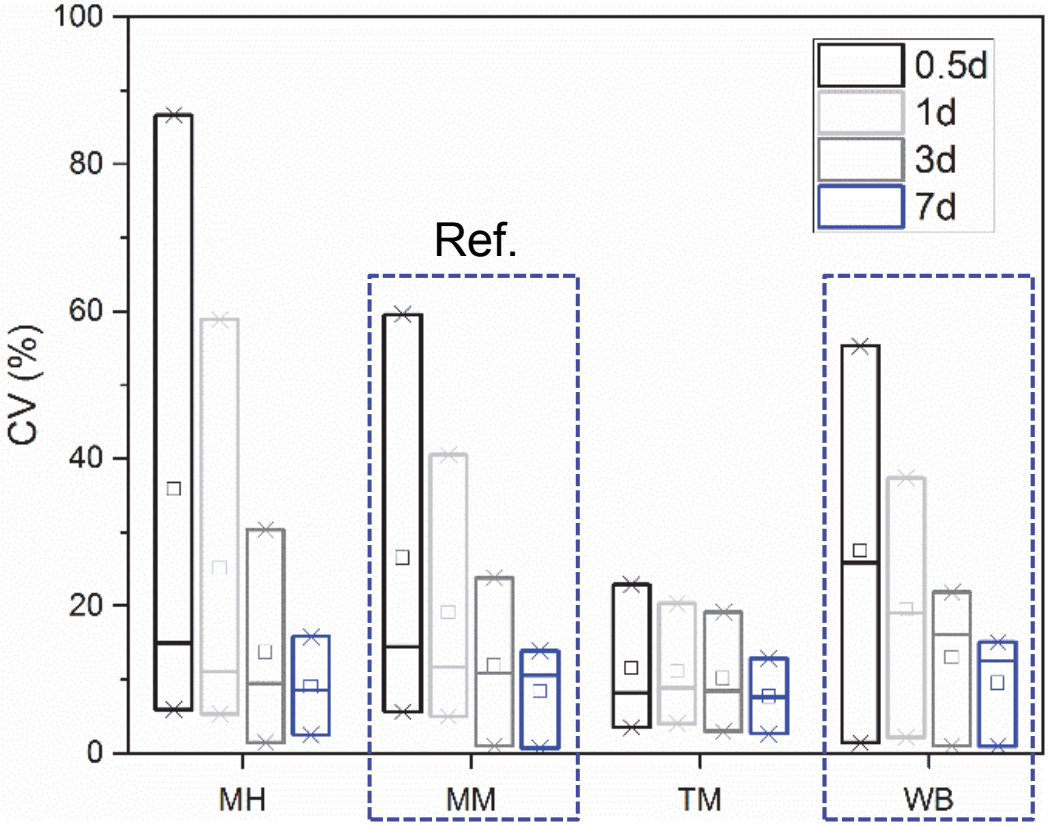


Water bath during casting

(5 participants)



Accumulative heat (average)

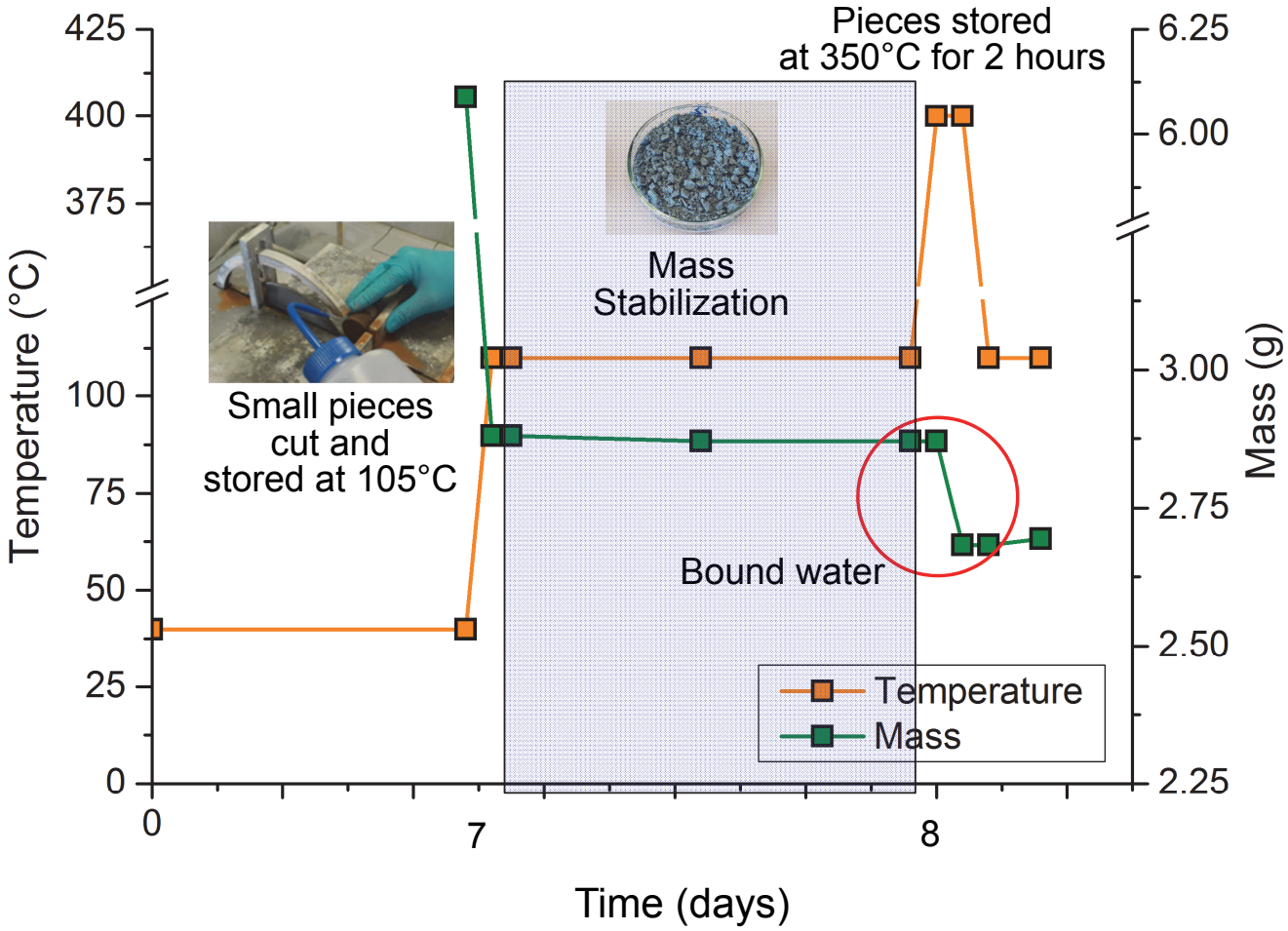


Investigation of the robustness and reproducibility of R^3

- R^3 Heat release
  - Premixing and mixing conditions
  - Mix design composition
  - Water bath

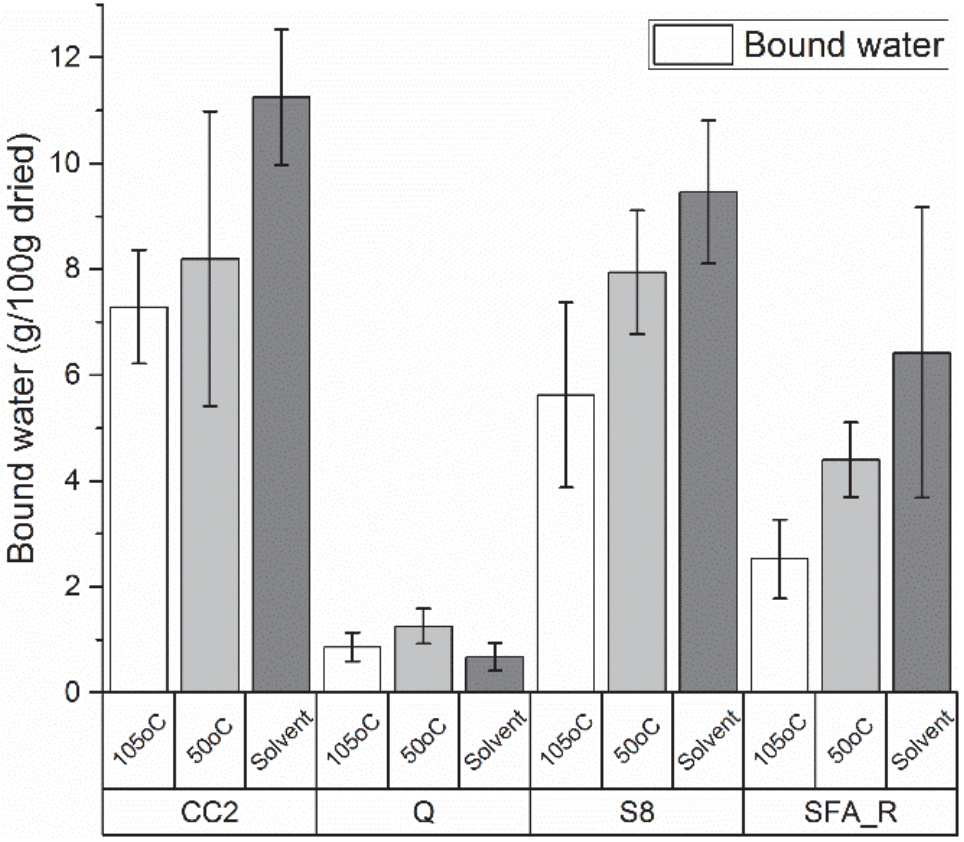
- R^3 Bound water
  - Drying procedure

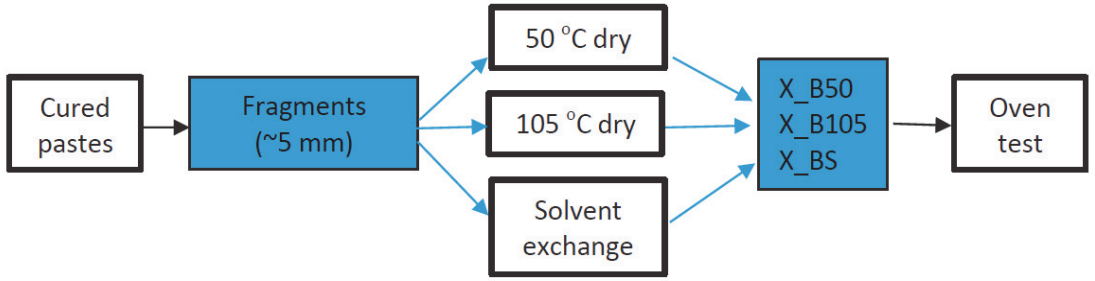
Drying step investigation

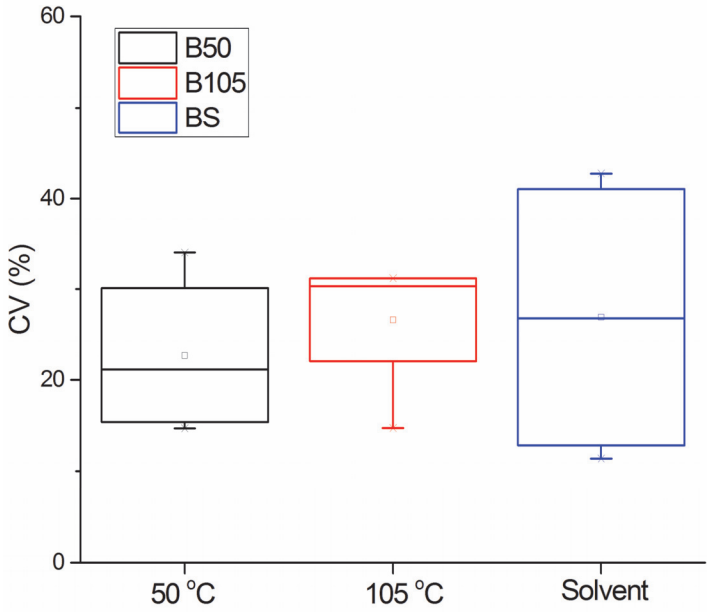


Bound water – different drying procedures

(7 participants)

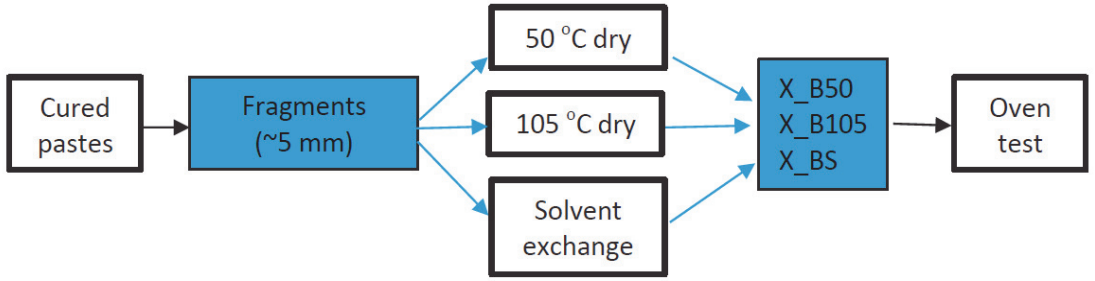






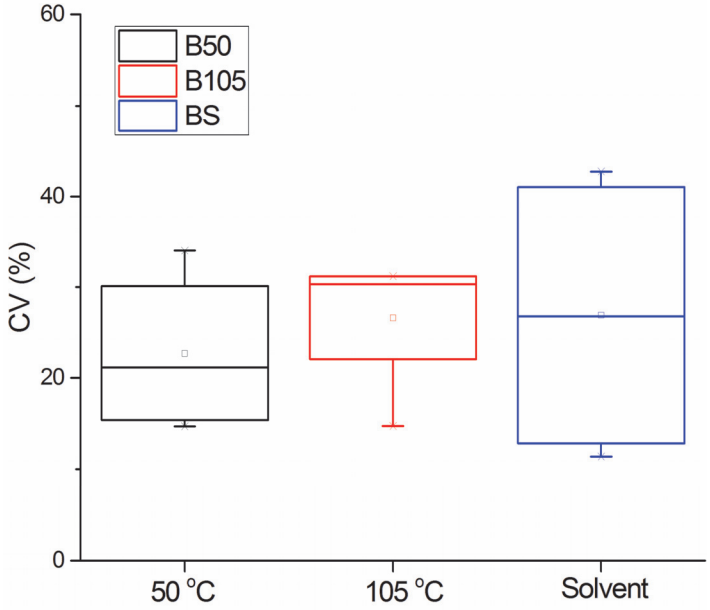
Bound water – different drying procedures

(7 participants)

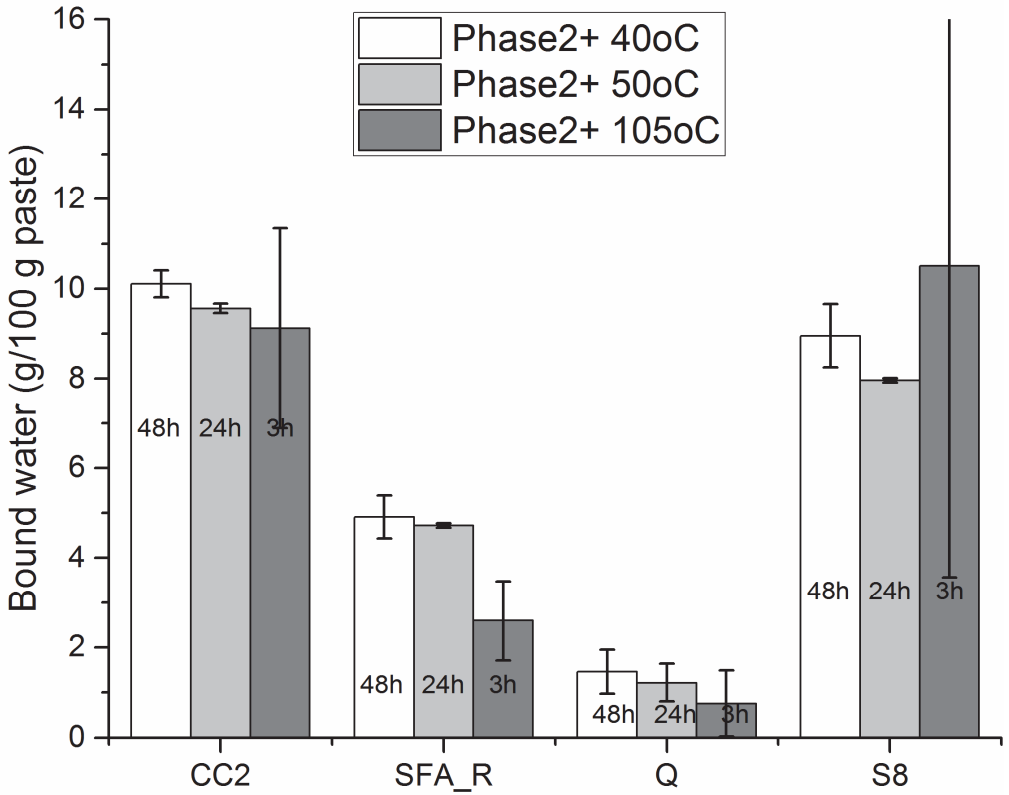


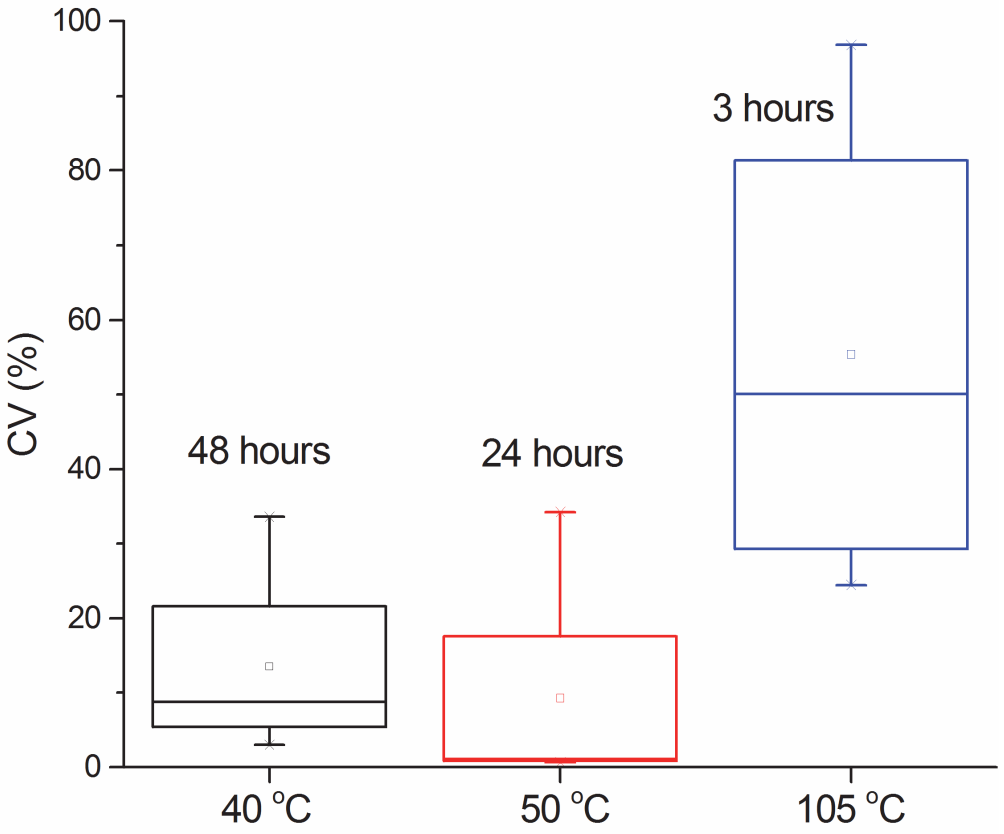
Correlation to relative strength

R2	Boundwater		
	BW_50	BW_105	BW_Sol.
Mortar_28	**0.92**	**0.71**	**0.69**
Mortar_90	0.24	0.05	0.04
CV (%)	*22.7*	*26.6*	*26.9*



Bound water – different drying procedures





Conclusion on phase II

- Finalization of the protocols
  - Heat of hydration
    - Premix or mixing did not show significant impact on the results
    - Recommended to use mechanical mixing if available
    - 25% of SCM in the mix design is a good compromise
    - 1.2 water to binder ratio works well
    - Water bath does not really help
  - Bound water
    - Drying step at 40° C, simpler and better reproducibility
- Standard in preparation for using in phase III

Phase III

- Validation across wide range of SCMs

- Definition of scope of test method – boundary conditions
  - Conventional SCMs and material currently falling outside of standards
  - Dependence on clinker replacement ratios
  - Impact of temperature
  - Water to binder ratio

Flyer

Participation in the RILEM TC 267-TRM reactivity test

The RILEM TC-TRM "Tests for Reactivity of Supplementary Cementitious Materials" concluded that two main methods (R^3 calorimeter and oven technique) are the most promising for evaluating the reactivity of SCMs. The next step is to apply these two methods to a broader and a more substantial number of new and more conventional SCMs.

If you want your material to be tested, requirements are:

- Fill the online form: **Deadline: 31st December 2018**
- Quantity of SCM: **50 kg of dry ground homogenized SCMs to be sent to EPFL (Switzerland) before the end of April 2019**
- Fineness of SCM: **d_{50} < 20 µm**

What we offer:

- **SCM characterization**
- **Testing of reactivity through mortar test and R^3**
- **Report on the assessment of reactivity**

- Cost: **500 euros for participation + shipping cost**

To visit us:

https://www.rilem.net/group/267-trm-tests-for-reactivity-of-supplementary-cementitious-materials-339

Form for SCM testing RILEM TC 267-TRM

Deadline: 31st December 2018

Name:
First name:
Address:
Zip code:
City:
Country:

Description of your material:

Preparation:

Rough composition / presence of hazardous materials:

Our committee will screen all the application forms and will contact you for the acceptation of your material by the end of January 2019.

To visit us:
https://www.rilem.net/group/267-trm-tests-for-reactivity-of-supplementary-cementitious-materials-339

3rd workshop at EPFL, Switzerland, *April 2017*

4th meeting in Chennai, India, *September 2017*

5th meeting in Leuven, Belgium, *April 2018*

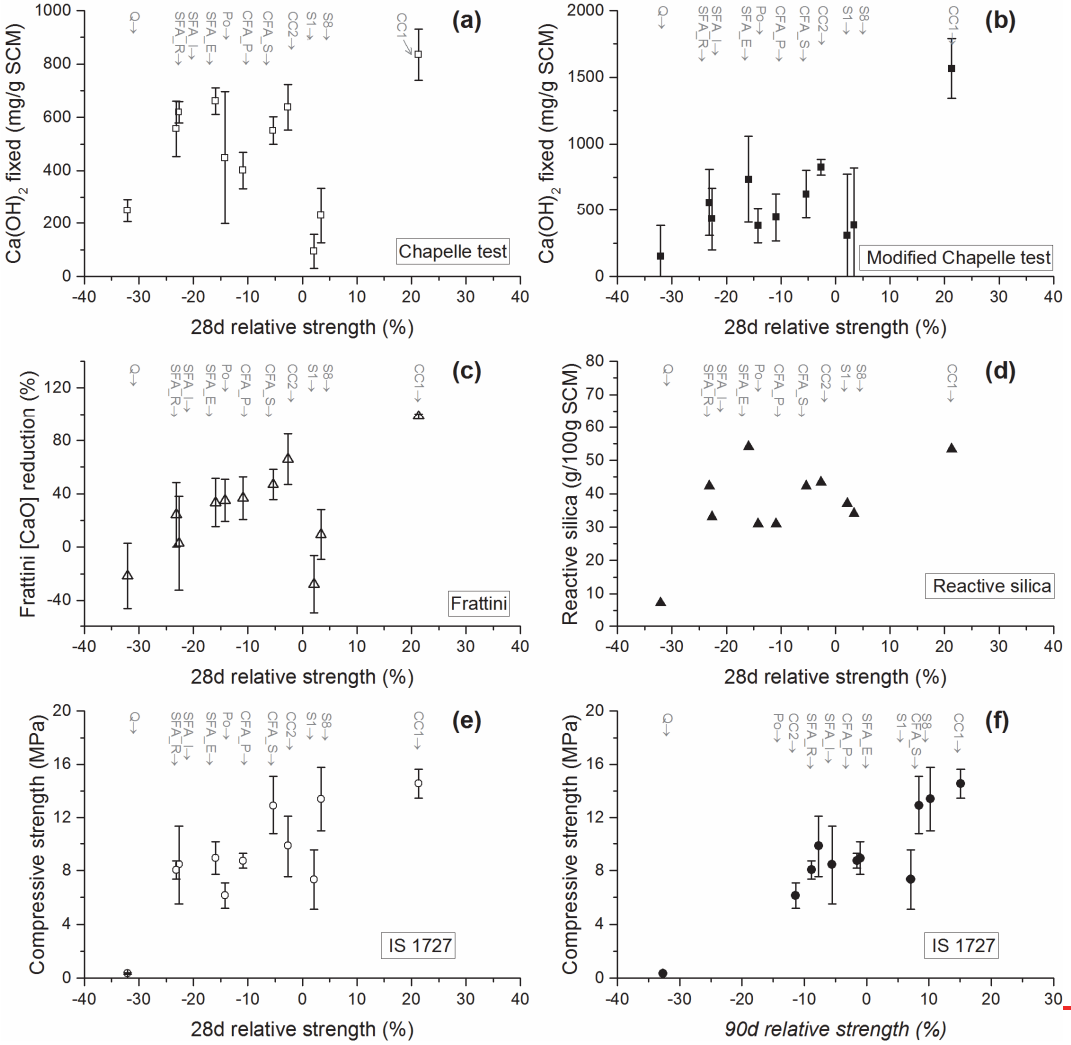
Scan to link to TRM website[1]

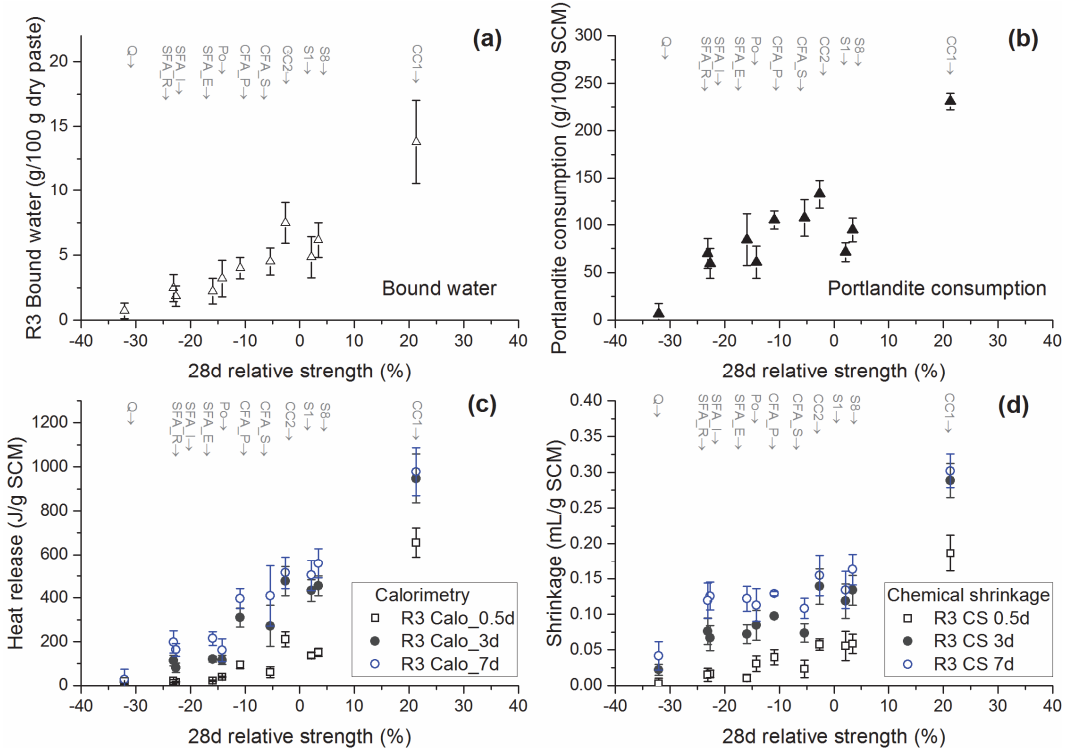
Thank you for your attention

1. https://www.rilem.net/groupe/267-trm-tests-for-reactivity-of-supplementary-cementitious-materials-339

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

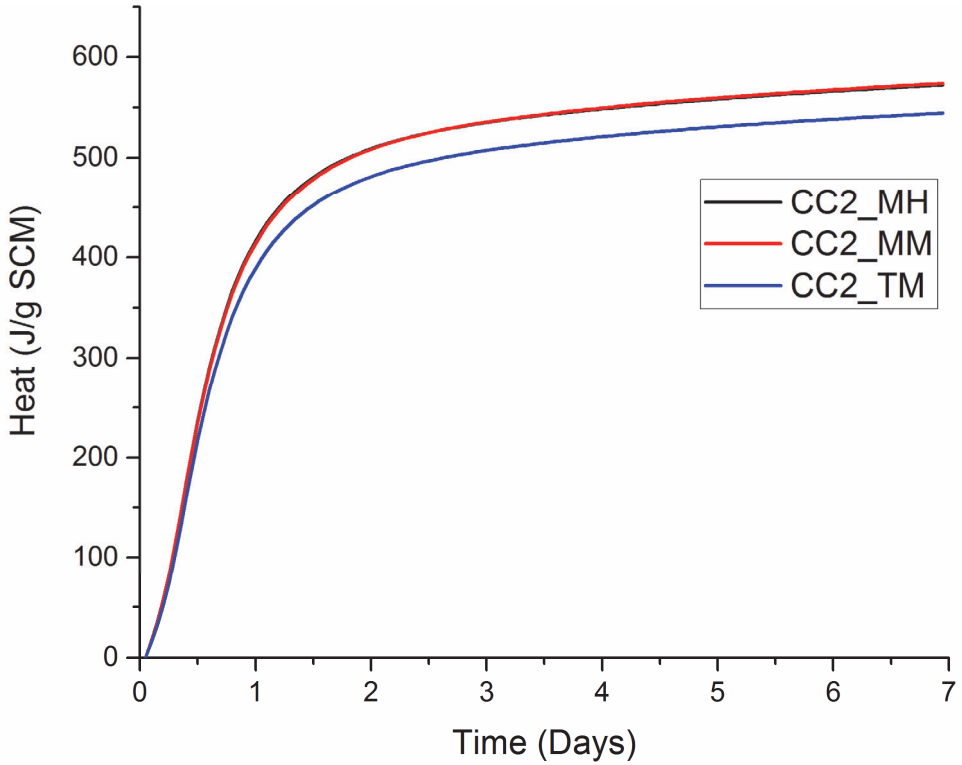
Correlation between reactivity tests and strength

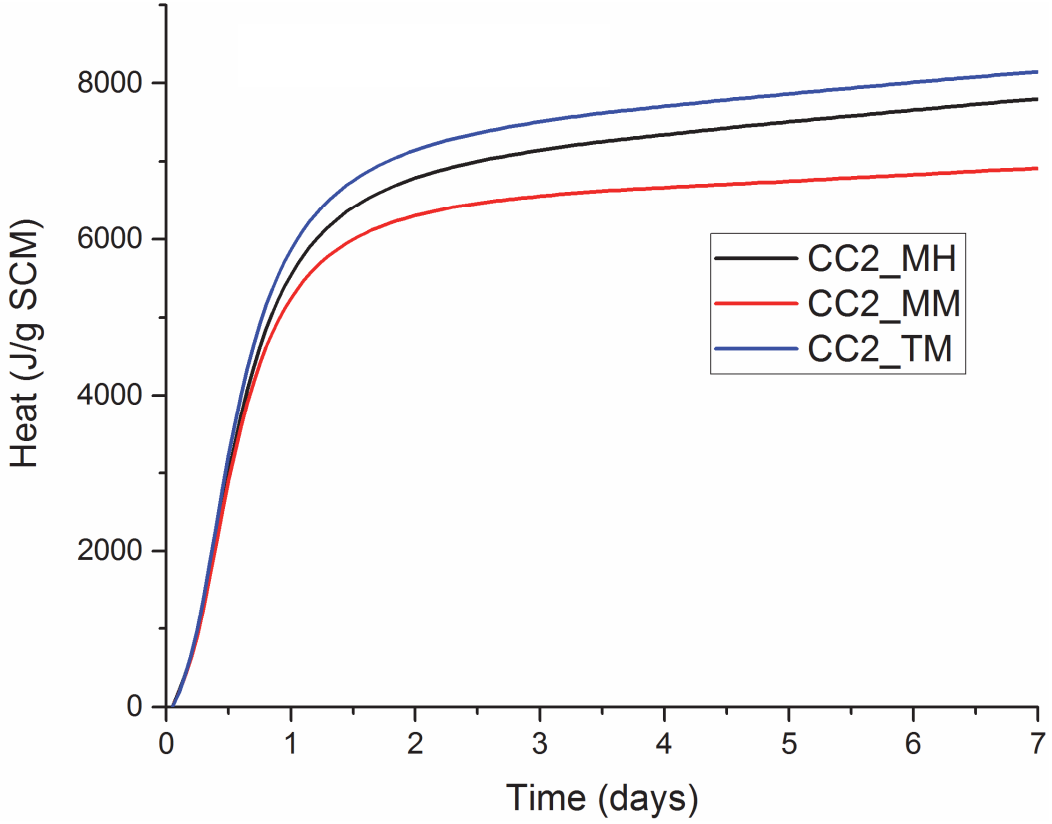




ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

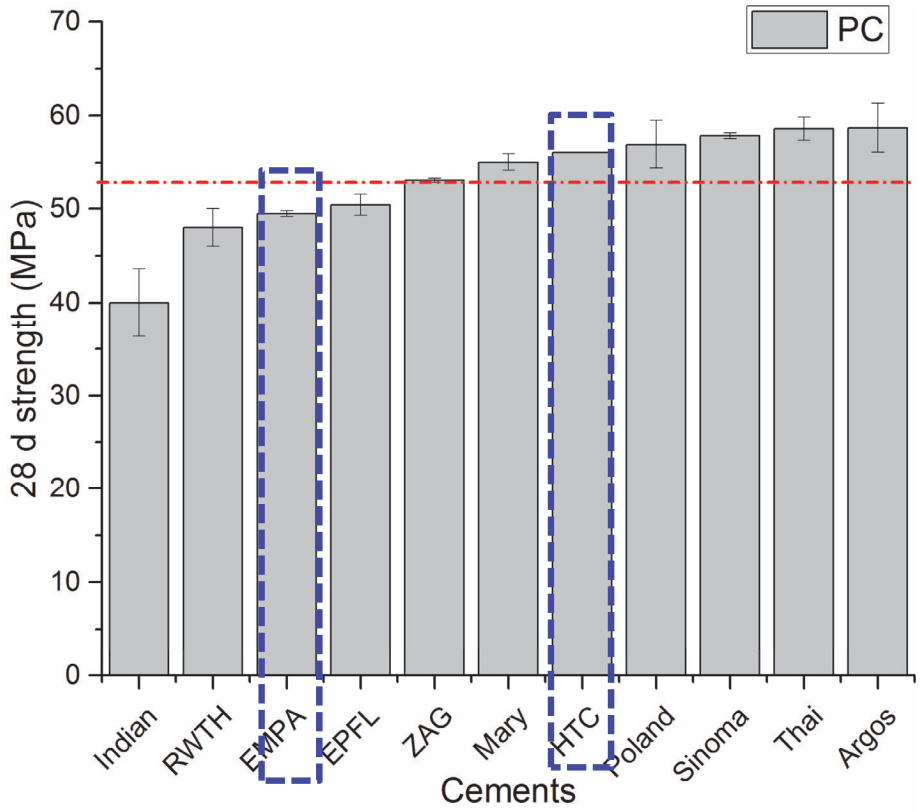
Different calorimeter (U. Toronto - Calmetrix)

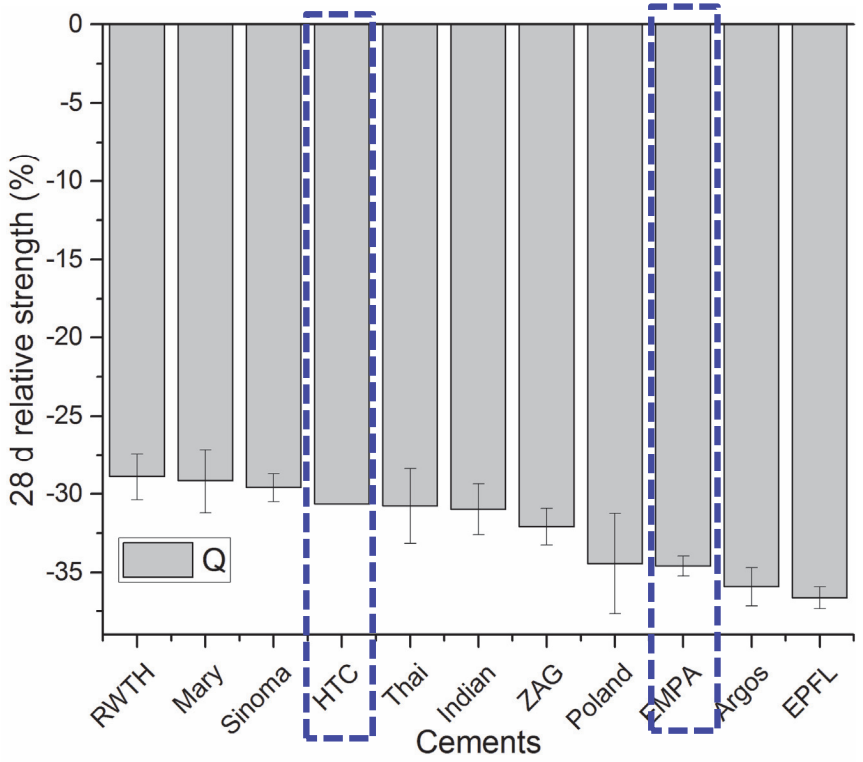




Accumulative heat (average)

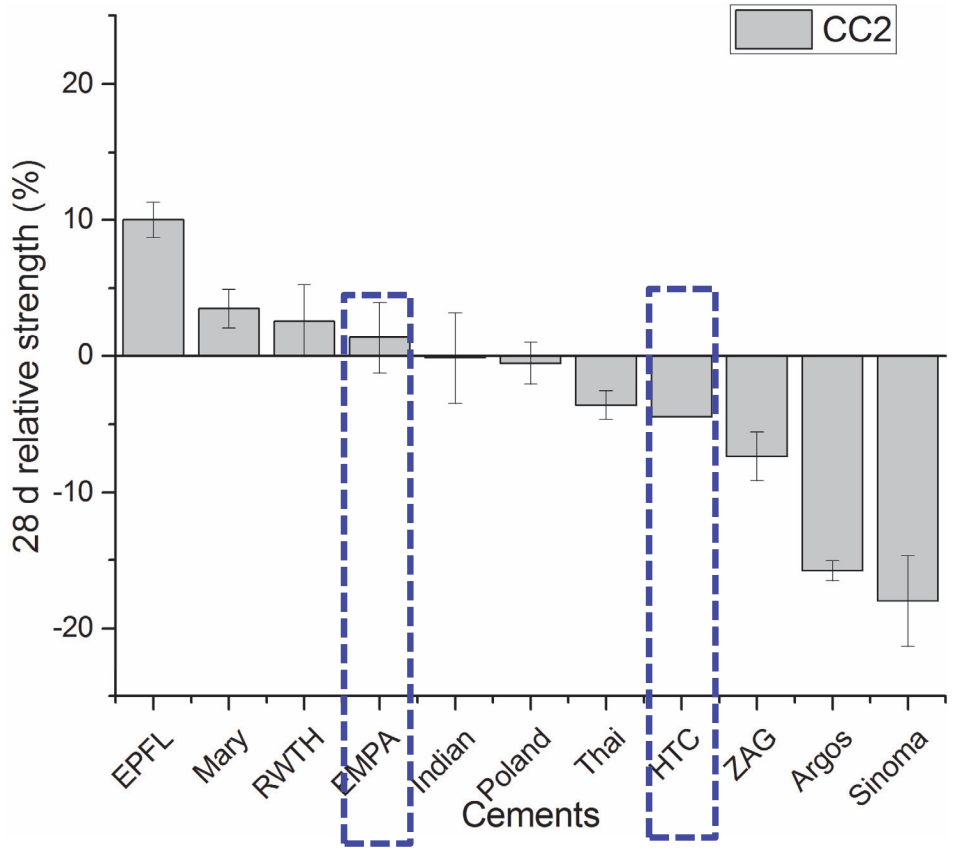
Selection of the cement – PC strength and relative strength for Q



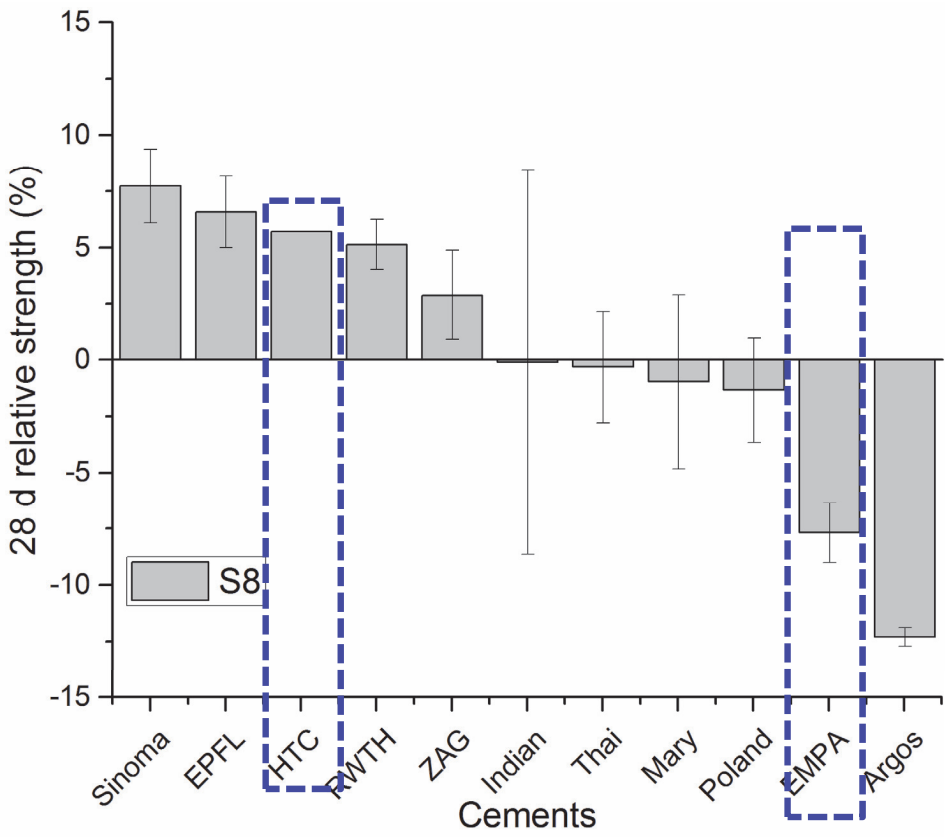


Quartz (Q)

Selection of the cement – relative strength CC2 and S8



Calcined clay (CC2)



Slag (S8)