ADMIXTURES FOR LC3 CEMENTS

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LEAD WITH SAFETY

EVERY 17 MINUTES SOMEONE IS INJURED BY FURNITURE, A TV, OR AN APPLIANCE TIPPING ONTO THEM…

- Securely install anti-tip furniture safety kits where needed
- Observe warning label in all new furniture
- Confirm new furniture is manufactured in compliance with a stability standard
- Identify and document possible existing “hidden hazards”

SAINT-GOBAIN

This presentation is intended for educational purposes only and does not replace independent professional judgment. Statements and opinions are those of the presenter.

BACKGROUND

NEW MATERIALS AND EXISTING MATERIALS USED IN NEW WAYS

Concept courtesy of Larry Sutter

The Existing Players

- Portland cement
- Coal ash
- Slag cement
- Natural pozzolans
- Silica fume

Supporting Cast

- Aggregates
- Admixtures

The New Players

- Alternative cementitious materials
- Alternative supplementary cementitious materials
- New binder systems (i.e. blends, engineered materials)

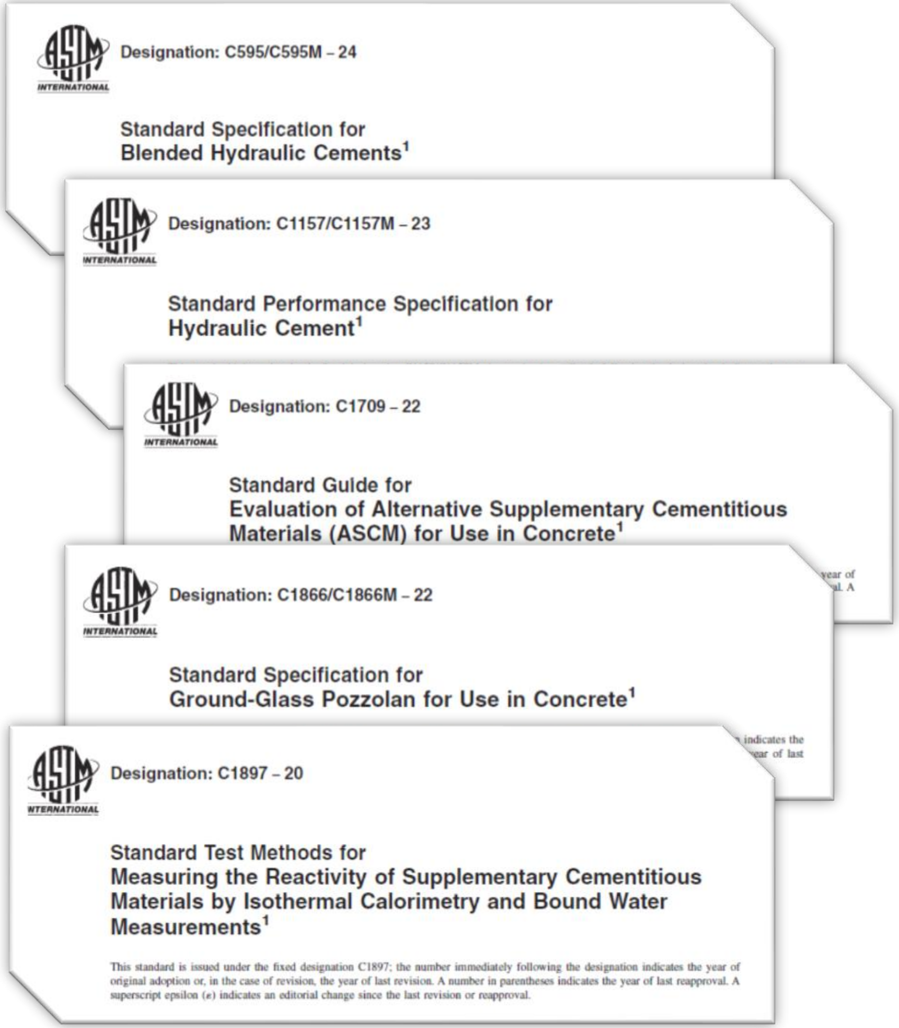
The New Supporting Cast

- New admixtures

WHAT ABOUT SPECIFICATIONS FOR USE OF THESE IN CONCRETE?

List courtesy of Larry Sutter

- Performance specification for SCMs (in progress)
- Allowing limestone as a blending component in blended SCMs under ASTM C1697 (in progress)
- Specification changes for natural pozzolans (in progress)
- Type IL – changes to permit blends using more SCMs (in progress)
- Type IC - new type of blended cement in ASTM C595 to allow for increased clinker reduction (in progress)
- New specification for alkali activated cements (completed)
- New specification for cements that set by carbonation (completed)



17+ YEARS AGO…

KAREN SCRIVENER:

“THIS MATERIAL HAS THE POTENTIAL TO CUT CO_2 EMISSIONS RELATED TO CEMENT BY MORE THAN 400 MILLION TONNES A YEAR.”

WHY THE NAME “LC3”?

LIMESTONE

CALCINED CLAY

CLINKER

MARKET DRIVERS

CALCINED CLAY
→ ONE OF THE ANSWERS

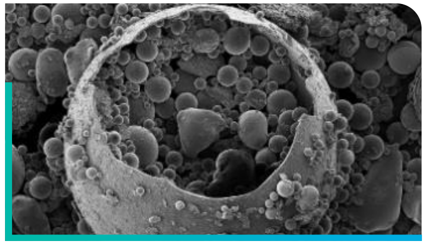
SCM FOR CO_2 CONTENT REDUCTION

- Increased use of SCM to reduce cement and concrete CO_2 content
- Expected decrease of traditional SCM availability – byproducts coming from other industrial process
- Need for an SCM in high availability to pursue global decrease of CO_2 in concrete

"TRADITIONAL" SCM'S

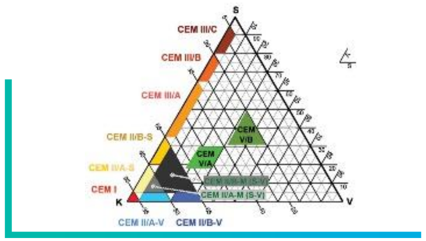
LIMESTONE	GGBFS	FLY-ASH	NATURAL POZZOLAN	BURNT SHALE





NEW SCM'S AND COMBINATIONS

CEM II/C, CEM VI, LC3	CALCINED CLAY	CARBONATED FILLERS	BASALT ROCK	STEEL SLAG…






40 CEMENT PRODUCERS IN 25 COUNTRIES WORKING ON LC3

- Cement manufacturers recognize the calcined clay potential in concrete production.
- Calcined clay is emerging as a significant player in the construction industry, offering a lower carbon alternative to traditional portland cement.

- Wide variety of calcined clays available worldwide with different chemical and physical characteristics

CALCINED CLAY PRODUCTION

- This process entails making the clay more reactive to replace part of the clinker used cement production, thereby reducing the environmental footprint of building materials.

- The use of calcined clays, particularly kaolinite, in concrete offers a sustainable alternative to traditional materials.

CLINKER

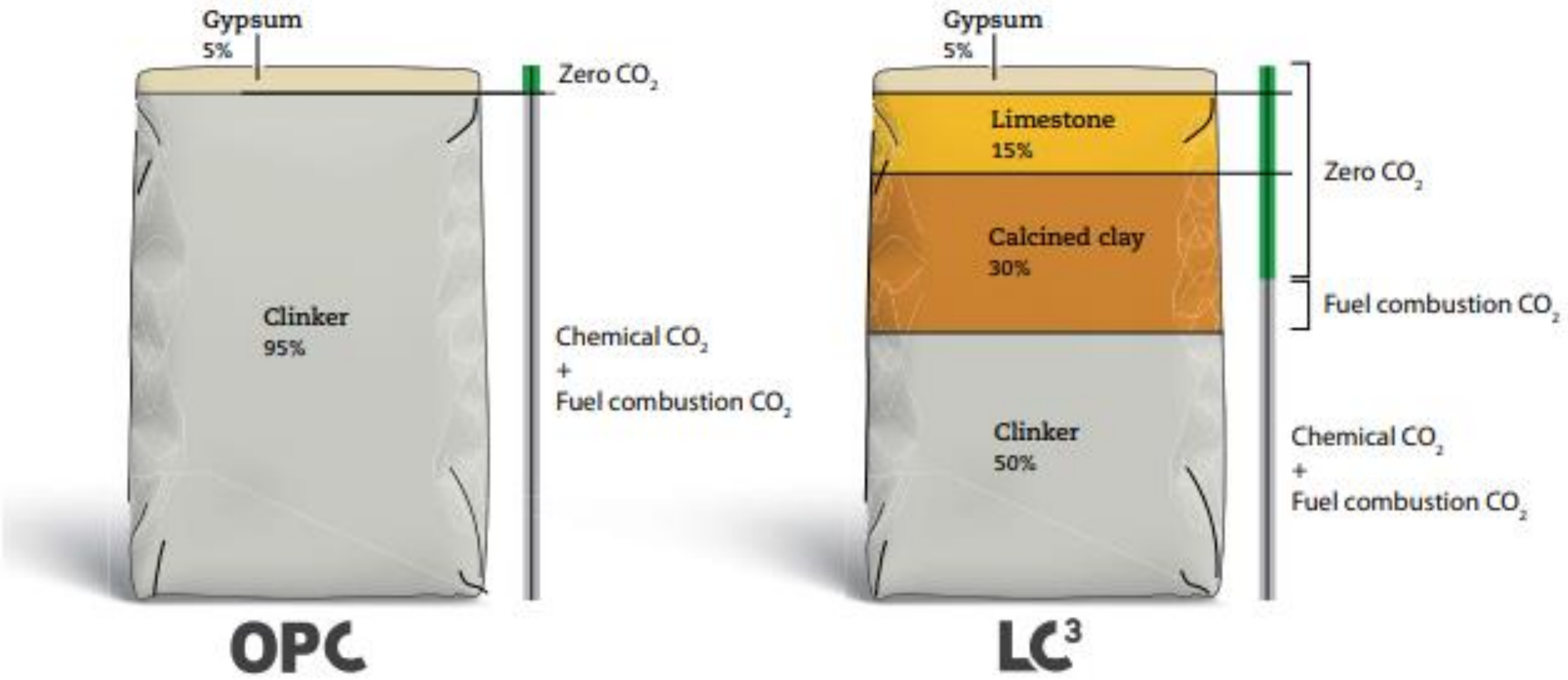
Calcination Tº: **1450ºC**
Portland cement: **810** kgCO_2eq/ton of cement

CALCINED CLAY

Calcination Tº: **750ºC**
CC based cement: **490** kgCO_2eq/ton of cement

LC3 MEANS CO_2 REDUCTION

~40% COMPARED TO ORDINARY PORTLAND CEMENT



Source:
https://www.weforum.org/stories/2023/10/this-new-material-could-change-how-we-make-cement-forever-and-cut-500-million-tonnes-of-emissions-by-2030/

REPLACING CLINKER WITH CALCINED CLAYS

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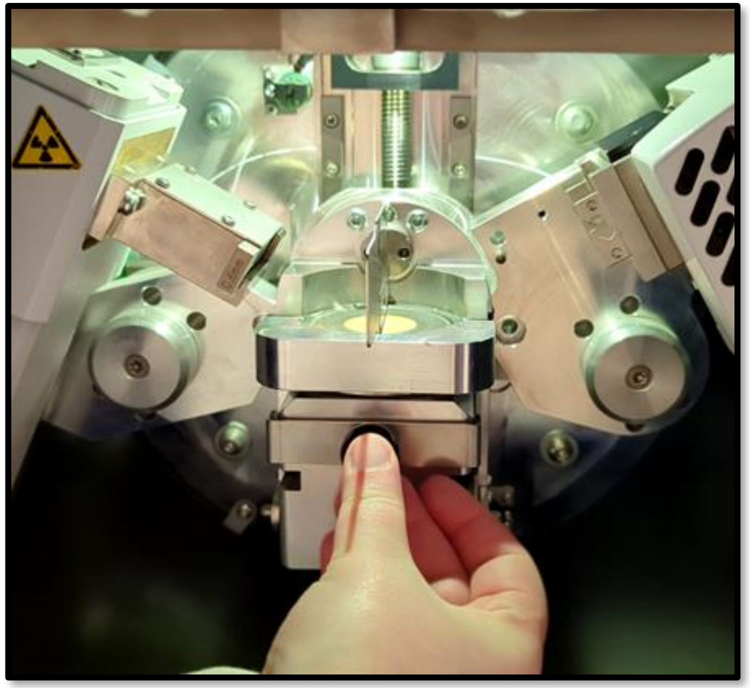
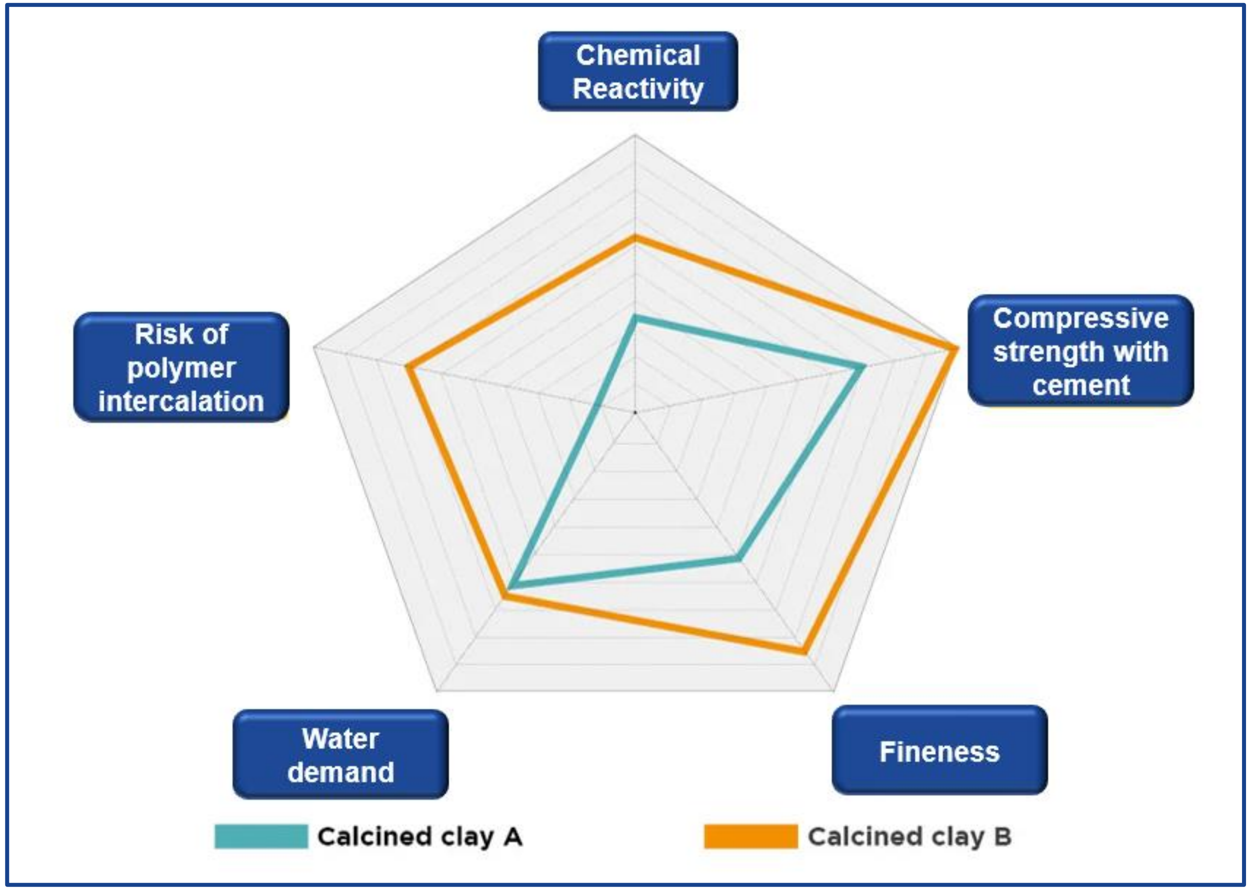
ADMIXTURES FOR CALCINED CLAY BASED CEMENT R&D EXPERTISE

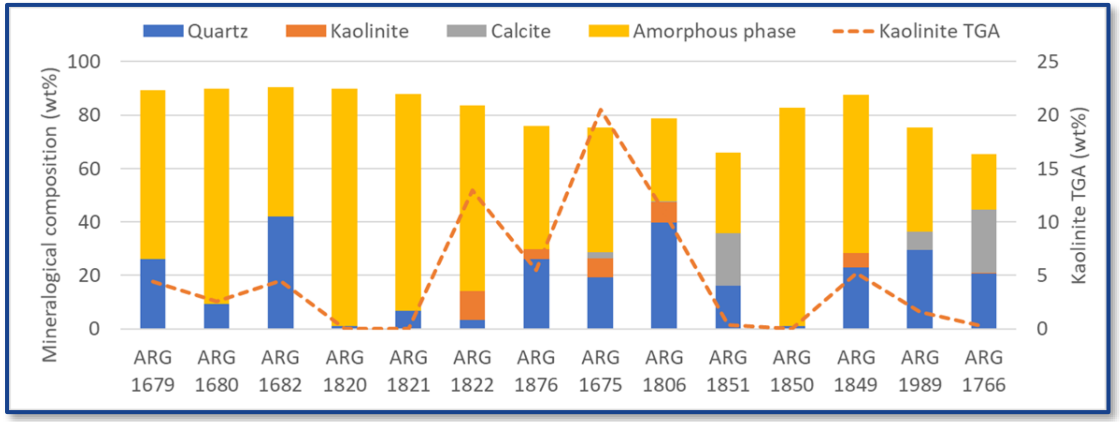
- **Cement expertise and anticipated work on the topic for industrial scale since 2019** with various co-development projects on concrete and cement side.
- **Characterization of numerous calcined clays from worldwide origins with in-house and patented methodologies** to determine the optimal formulation for each potential configuration.
- Optimization of our solutions, building of a large Calcined Clay database to be able to provide **tailor-made solutions.**

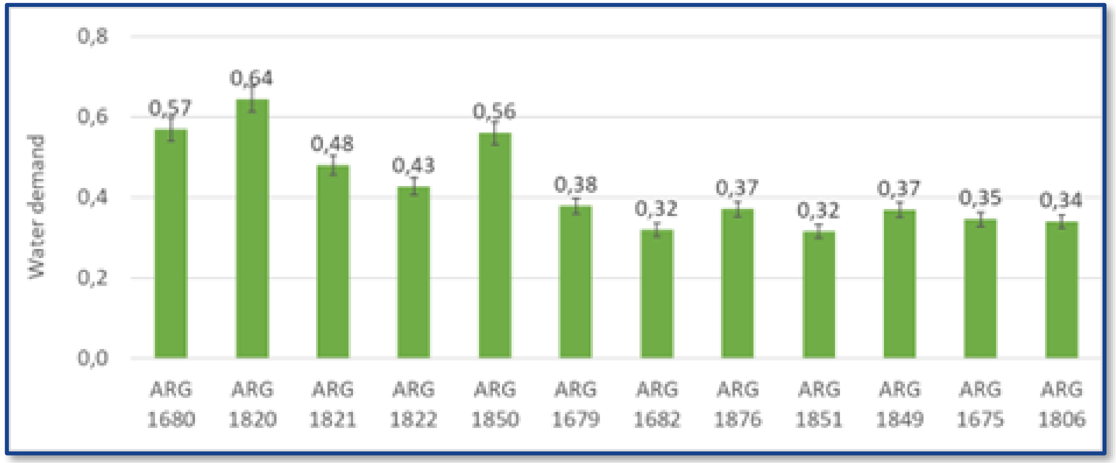


CONCRETE PERFORMANCES CHALLENGES

WIDE VARIETY OF CALCINED CLAYS







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CONCRETE PERFORMANCES CHALLENGES

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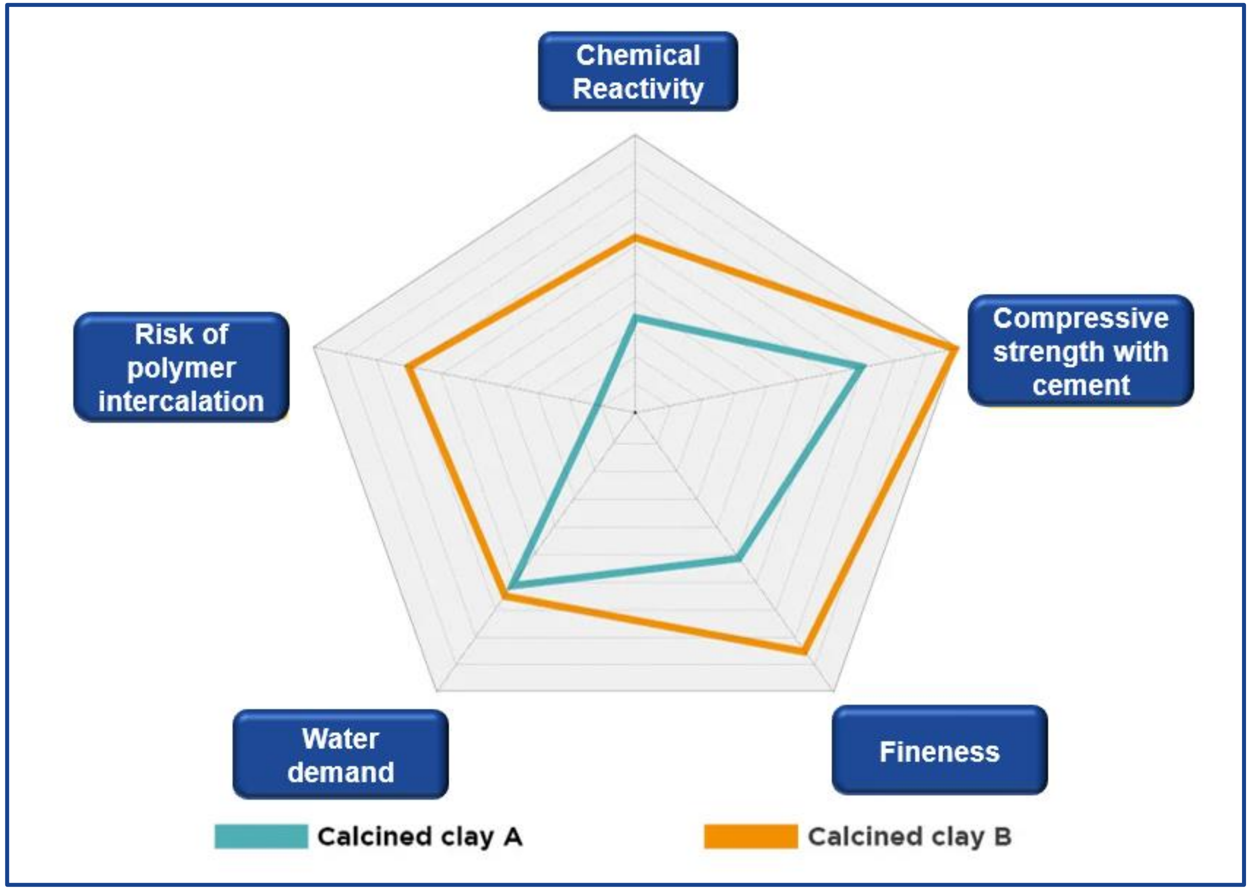
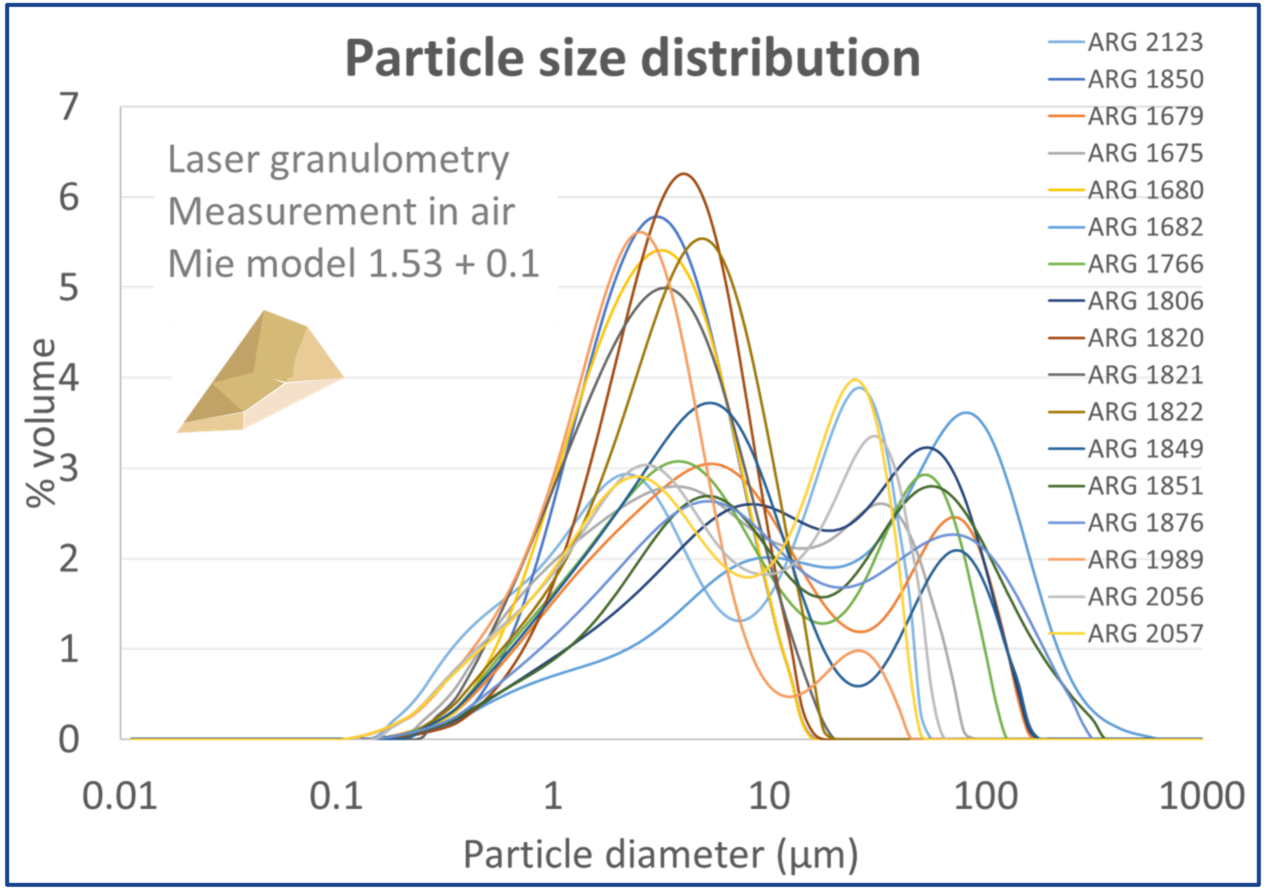
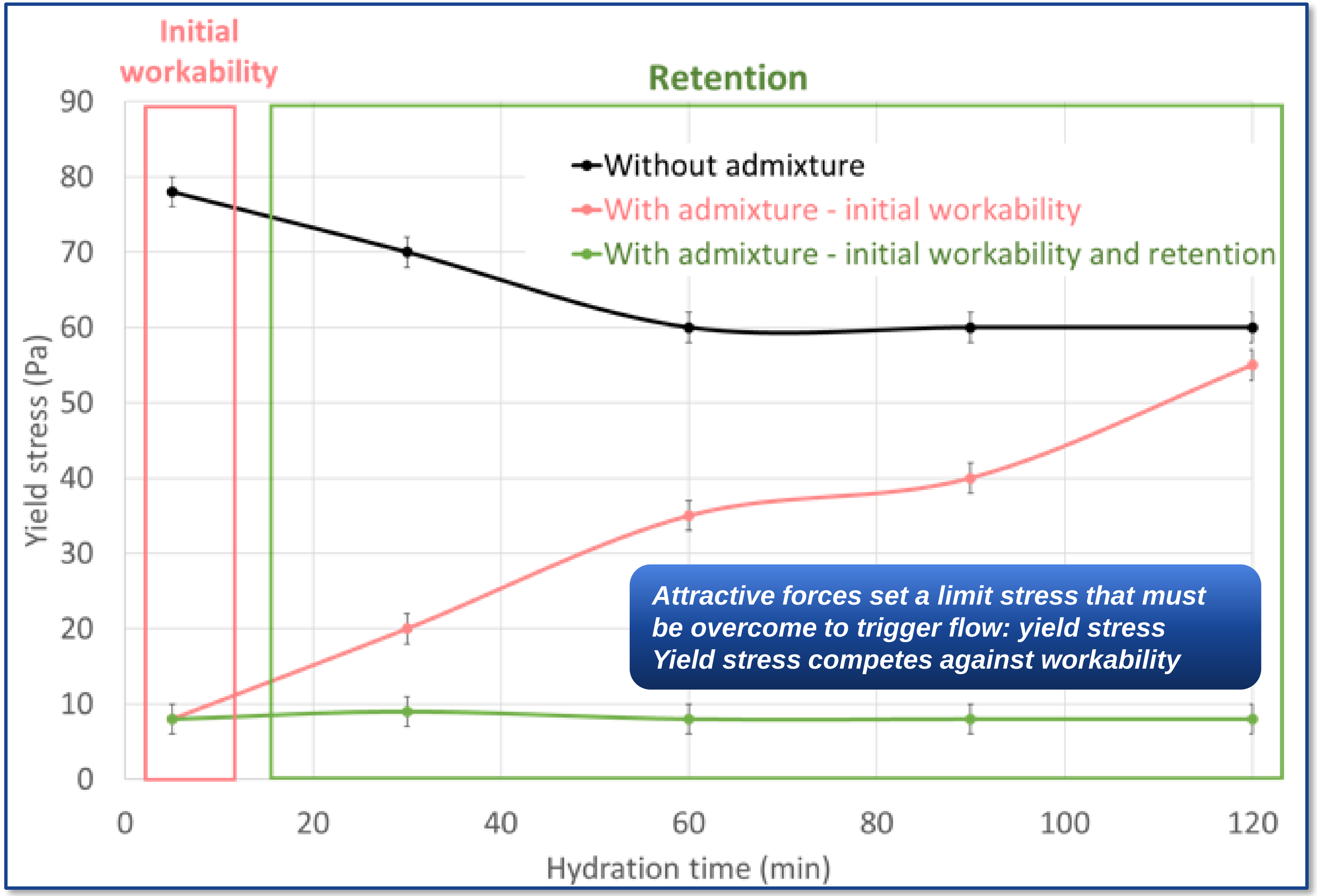




Necessity to develop specific admixture solutions

ADMIXTURE FOR CONTROLLING RHEOLOGY

RHEOLOGICAL CHALLENGE



Attractive forces set a limit stress that must be overcome to trigger flow: yield stress
Yield stress competes against workability

- **High initial yield stress at 5 min**
  - ✓ Addition of admixture for reducing yield stress
    - → Control of initial workability
- **Increase of yield stress over hydration time**
  - ✓ Addition of admixture for workability retention

65 wt% cement + 35 wt% calcined clay // W/B = 0.39

Rheometer measurement of shear stress for shear rate from 200 to 0.01 s-1 // Yield stress determination at the minimum shear stress

ADMIXTURE FOR CONTROLLING RHEOLOGY

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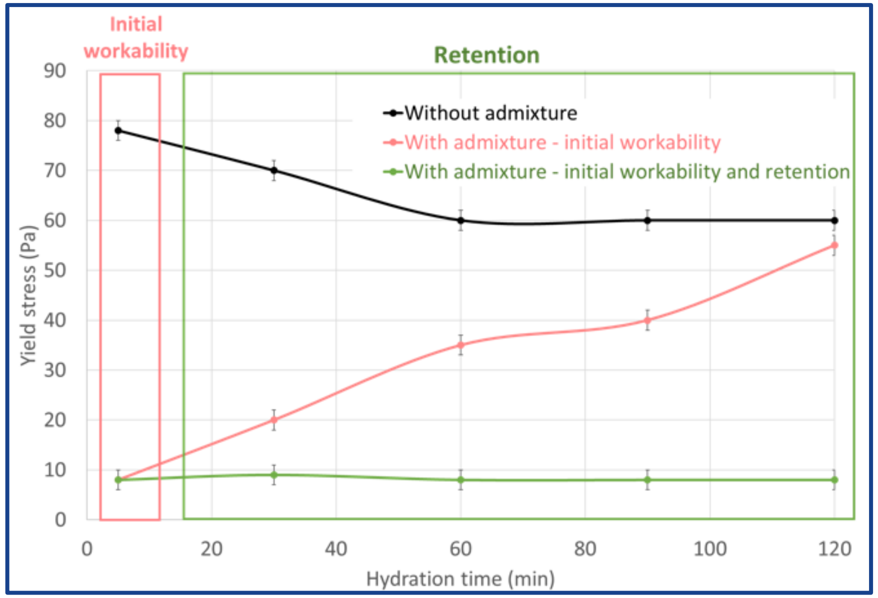
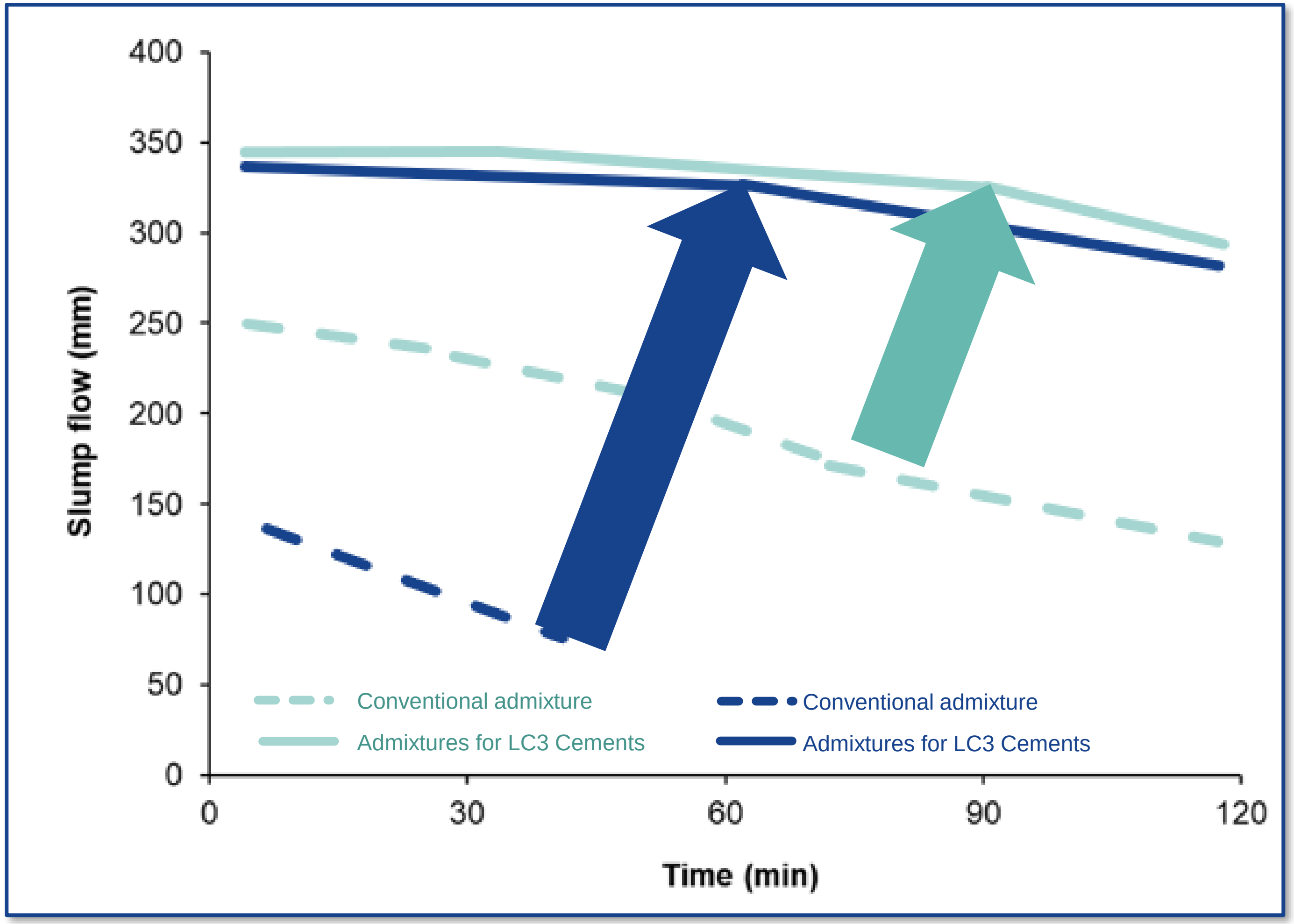


65 wt% cement + 35 wt% calcined clay // W/B = 0.39
Rheometer measurement of shear stress for shear rate from 200 to 0.01 s-1 // Yield stress determination at the minimum shear stress

***CUSTOMIZED* SOLUTIONS ALLOW TO MEET THE SPECIFIC REQUIREMENTS**

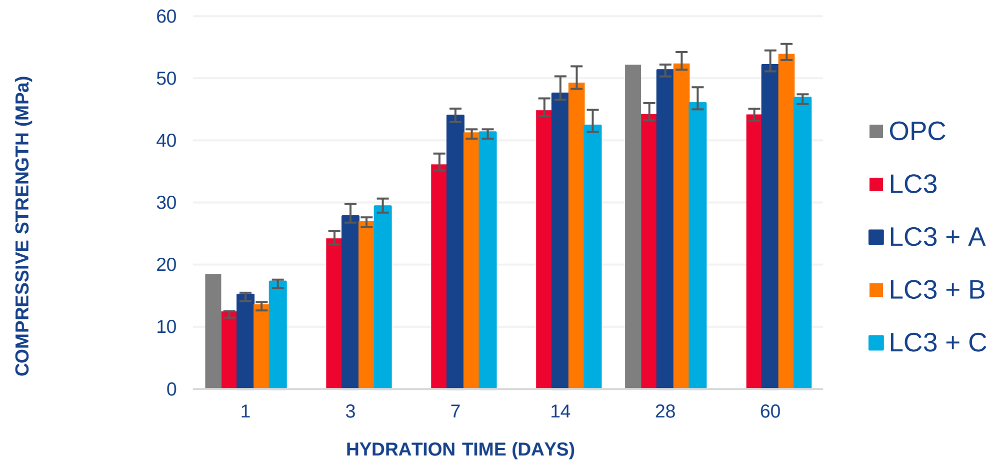


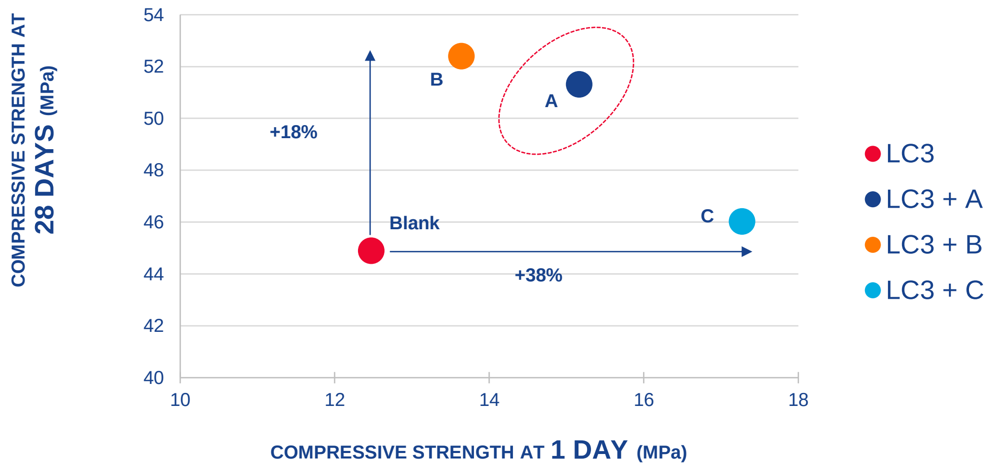
ACTIVATOR – CASE STUDY: LC3

INDUSTRIAL TRIAL WITH LC3-50 CEMENT (30% CALCINED CLAY, 15% LIMESTONE)

ACHIEVED ROBUST INCREASE OF COMPRESSIVE STRENGTHS

- **+ 5 MPa at 1 day (+38%)** with EnviroAdd® “C”
- **+ 8 MPa at 28 days (+18%)** with EnviroAdd® “B”.
- Customized Additive EnviroAdd® “A” met cement plant’s target performance at all ages.





***CUSTOMIZED* EnviroAdd® ACTIVATORS ALLOW TO MEET THE SPECIFIC NEEDS OF LOW-CLINKER CEMENTS**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Impacting factors and properties of limestone calcined clay cements (LC^3)

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This paper details the main factors influencing the performance of limestone calcined clay cements (LC^3). The kaolinite content plays a major role in the rheological properties as well as strength development. Even in the presence of secondary phases, kaolinite can be accurately quantified by thermogravimetric analysis. The performance of LC^3 is slightly influenced by the calcination process of clay, but it can be optimized by using the correct calcination temperature and applying a specific mix design with adjusted sulfate and alkali content. The hydration reactions of LC^3 are fully characterized. They vary slightly from plain cement. There is no significant change in terms of phase assemblage. The main properties of LC^3 are also described. LC^3 blends show a lower creep compliance and a delay in shrinkage strains compared with plain cement. Concerning durability, LC^3 blends show outstanding performance with respect to resisting chloride ingress and expansion from the alkali–silica reaction.

Notation

K	carbonation coefficient
$M_{kaolinite}$	molecular weight of kaolinite
M_{water}	molecular weight of water
$wt\%_{calcined\ kaolinite}$	calcined kaolinite content
$wt\%_{kaolinite}$	kaolinite content
$wt\%_{kaol\text{-}OH}$	water loss during kaolinite dehydroxylation
$wt\%_{kaol\text{-}OH,\ calcined}$	water loss during kaolinite dehydroxylation for incomplete calcination in calcined clay

1. Introduction

Partial replacement of clinker by supplementary cementitious materials (SCMs) in blended cement or concrete is by far the most realistic strategy for lowering environmental impact. Unfortunately, supplies of the most widely used SCMs (i.e. granulated blast-furnace slag and coal fly ash) are limited to around 20% of cement production, and most suitable materials are already used in cement and concrete. Globally, kaolinitic clays are available in very much larger quantities and have excellent reactivity after calcination. Such materials can make a very substantial contribution to reducing the carbon dioxide (CO_2) emission associated with the production of cementitious materials.[1] The clays of interest are not necessarily those with high purity (i.e. high kaolinite content or metakaolin), and clays with a kaolinite content above around 40% also perform well.[2]

Limestone has found its position in the concrete industry as a cement replacement material due to its low price, high availability and low energy consumption during its grinding, enabling its use for adjustment of particle size distribution of cementitious components to enhance the workability and early-age strength of concrete. Furthermore, limestone promotes hydration of clinker by providing a suitable surface for nucleation of hydrates (filler effect) and contributes to hydration reactions in the presence of aluminates.[3,4]

This leads to the interest in cements with a coupled substitution of limestone with calcined clay, which are referred to as LC^3: limestone calcined clay cement.[5,6] The authors previously showed that a strong relationship exists between the strength development of LC^3-50 blends (clinker content reduced to 50%) and the calcined kaolinite content of calcined clay.[2] Moreover, using a clay with only 40% calcined kaolinite gives strength similar to that of plain cement (PC) after about 7 d. This paper presents several important aspects of LC^3 cement and concrete, resulting from several years of research experience at the Laboratory of Construction Materials, École Polytechnique Fédérale de Lausanne, Switzerland. The paper starts by discussing the selection of suitable clays and the way of characterizing them. It continues with the most important processing aspects with the optimization of the calcined clay reactivity affected by calcination parameters. The paper then looks at hydration, mechanical properties and durability of LC^3 systems.

2. Kaolinitic clay characterization

2.1 Determination of kaolinite content

The kaolinite content is a key criterion for the selection of suitable clay. The kaolinite content can be determined by

IMPACTING FACTORS AND PROPERTIES OF LIMESTONE CALCINED CLAY CEMENTS (LC3)

By:
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KEY ITEMS

- The kaolinite content plays a major role in the rheological properties as well as strength development
- Even in the presence of secondary phases, kaolinite can be accurately quantified by thermogravimetric analysis
- The R3 pozzolanic test was developed as reactivity indicator of the calcined clay
- The performance of LC3 is slightly influenced by the calcination process of clay, but it can be optimized by using the optimal calcination temperature and applying a specific mix design with adjusted sulfate and alkali content
- The hydration reactions of LC3 are fully characterized. They vary slightly from plain cement

FINDINGS AND FOLLOW UP…

- The kaolinite content plays a major role in the rheological properties as well as strength development
- A minimum of kaolinite of 40% of clay is necessary in LC3 to reach strength similar to that of ordinary portland cement from about 7 days onward

- Clays with 40 - 50% kaolinite are also better than purer clays in terms of workability.
  - ✓ The optimization of limestone particle size distribution further improves the rheological properties of LC3
- Carbonation of the LC3 system is faster than that of PC
  - ✓ Prolonged curing before exposure can mitigate carbonation.

CLOSING REMARKS

SAINT-GOBAIN

CLOSING REMARKS

- The use of calcined clays makes up a lever to reduce CO_2 in concrete
- There is a broad range of clays
- LC3 cements incorporate calcined clays
- Proprietary (or not) characterization provides for a “clay ID” linked to its performance
  - ✓ Higher water demand reduction
  - ✓ Initial workability or life-time of fresh concrete
  - ✓ Early and long-term strength
  - ✓ Concrete rheology
- Tailor-made product with local calcined clays

THANK YOU!