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New Technological Advances in Rheology

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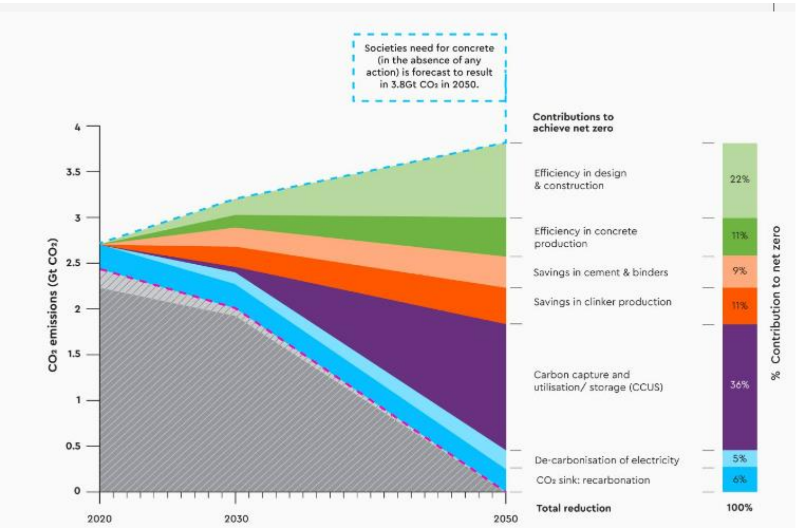
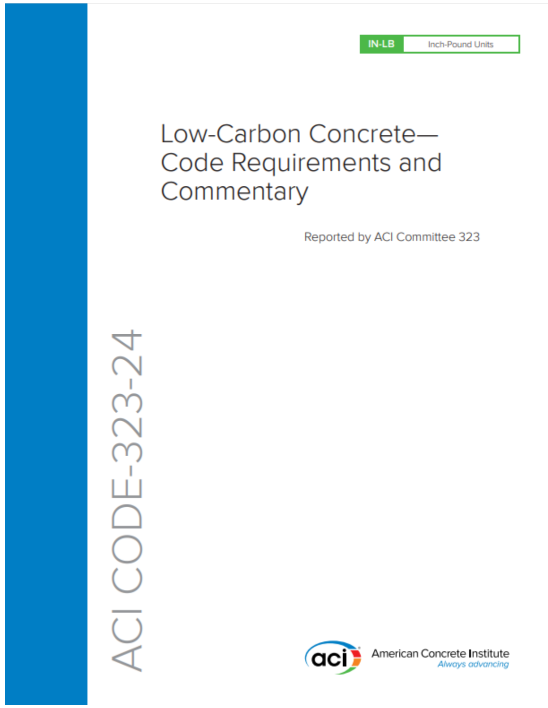
CONSTRUYENDO CONFIANZA

Agenda

- Sustainability Initiatives
  - Important Driver
- Importance of Low Viscosity of Concrete
  - Overview of Rheology
  - Cases Studies
- What is next in terms of technology?

Adoption of Sustainable Initiatives as Driver





1. Type IL/IP/IT/GU blended cements

(currently 5-15% limestone, >30% GU cements)

2. Fly Ash & Calcined clay and other SCM's

(reduced supply/higher cost)

3. Lower cementitious content while maintain durability requirement

(sustainability initiatives)

4. Closer aggregates

(sources not used before Low GWP)

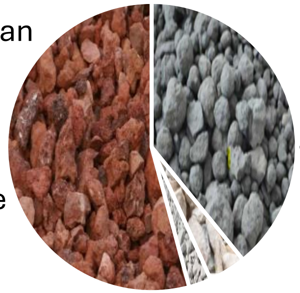
Source: *Global cement and Concrete Association & ACI Code 323-24*

1. Cements continue to change

OPC – ASTM C150 Clinker, Gypsum and Limestone

Type 1L - ASTM C595 Clinker, Gypsum and Limestone (higher content)

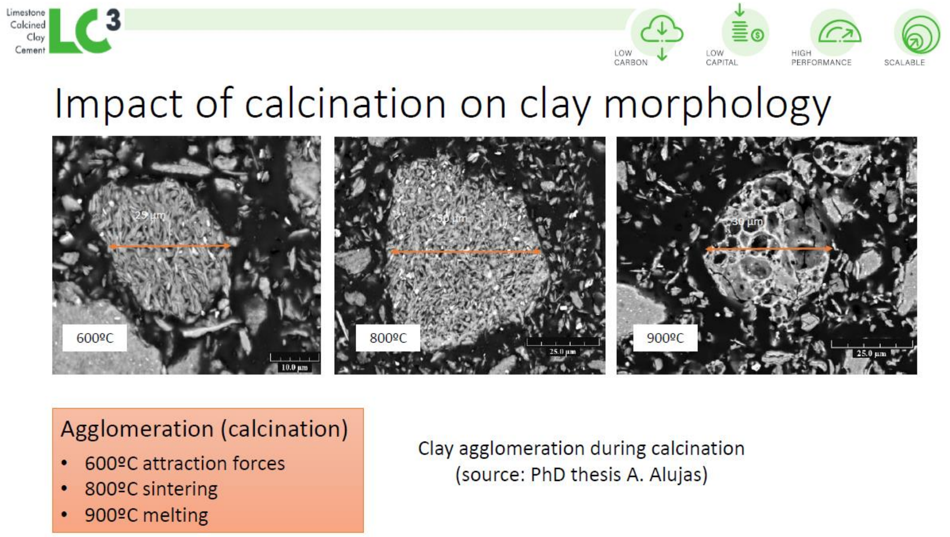
ASTM GU -Clinker, Gypsum, Limestone, and Pozzolan

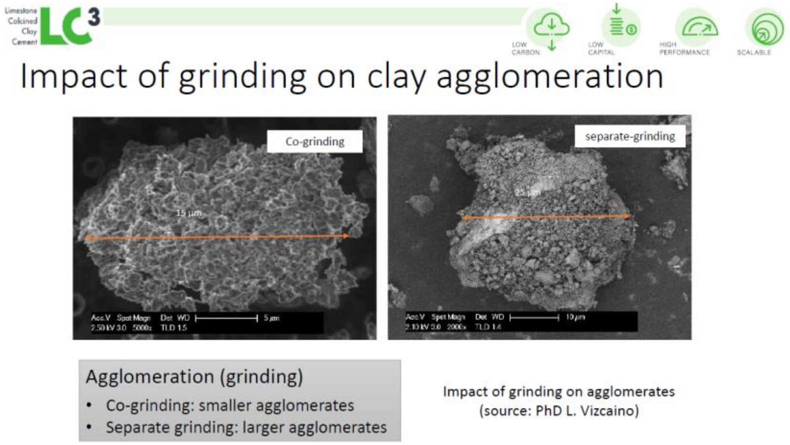


Cement 1P25 – ASTM C595 Clinker, Gypsum, Limestone, and Pozzolan

2. New Supplementary Cementitious Materials (SCM)

Calcined clay – LC3





HIGHER SURFACE AREA

Source: *https://lc3.ch/*

3. Performance and Durability

Industry demand:

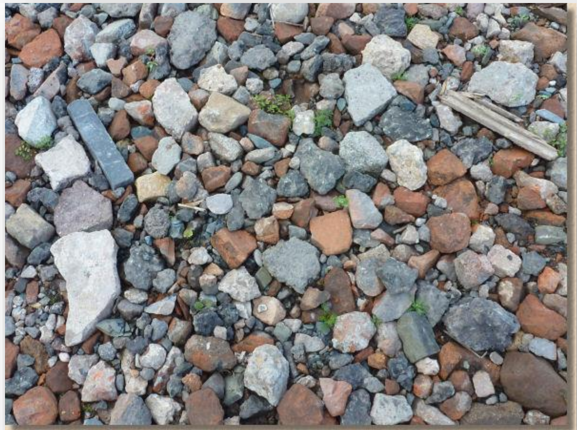
- Low water-cement ratio
- Extend lifecycles of buildings
- Low cementitious content could be one first approach to approach sustainability requirements
- Concrete mix design contain higher proportion of SCMs
  - Reactive materials such as **Natural pozzolan** and **calcined clay** are available in LATAM and NA. As well **Slag** and **Fly ash**.

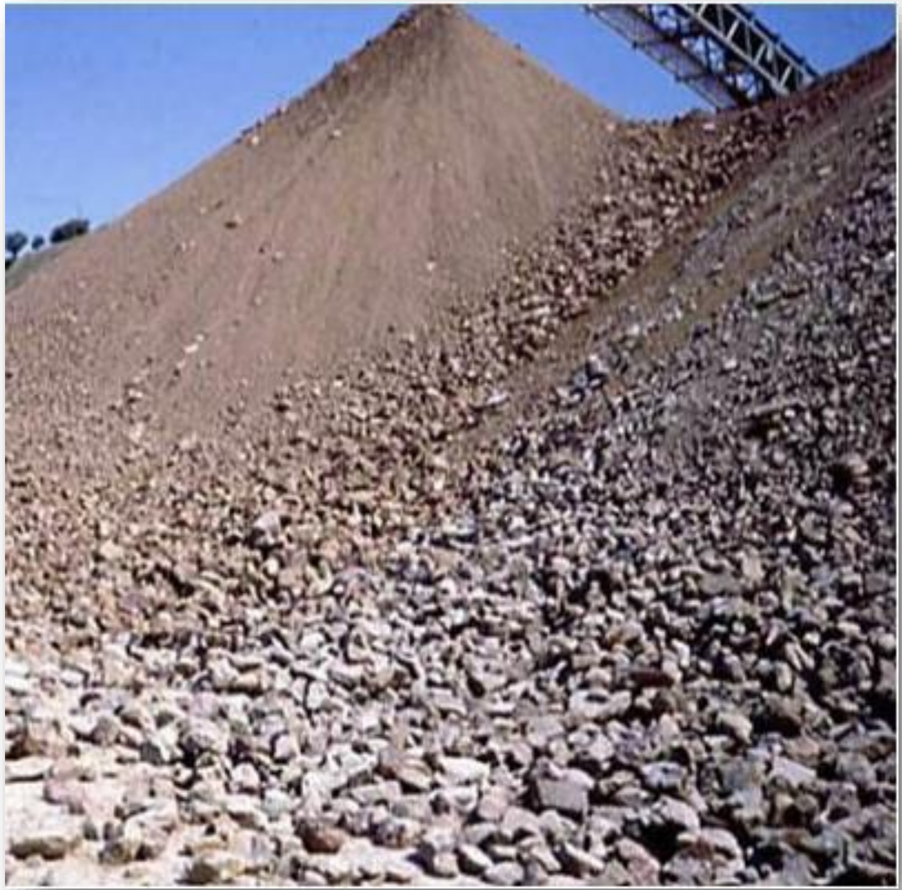
4. Aggregates

Which challenge does the industry faces?
- Availability of easy to work materials

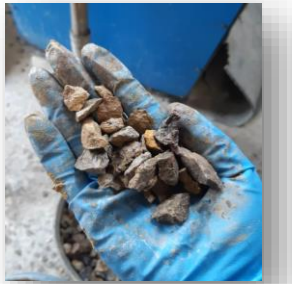
4. Aggregates availability

Reality in LATAM



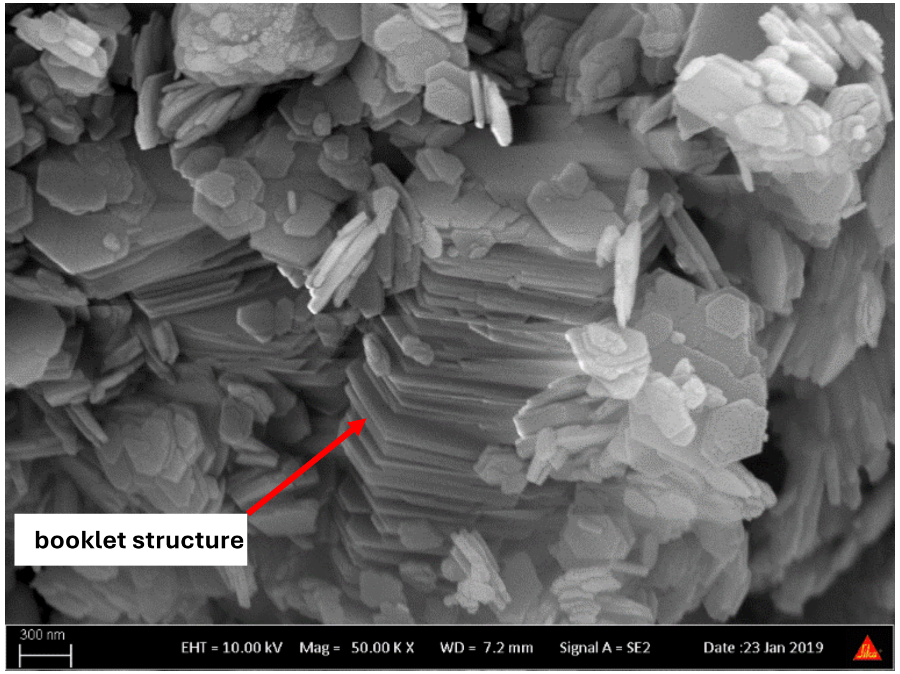


4. Aggregates play an Important Role in Concrete

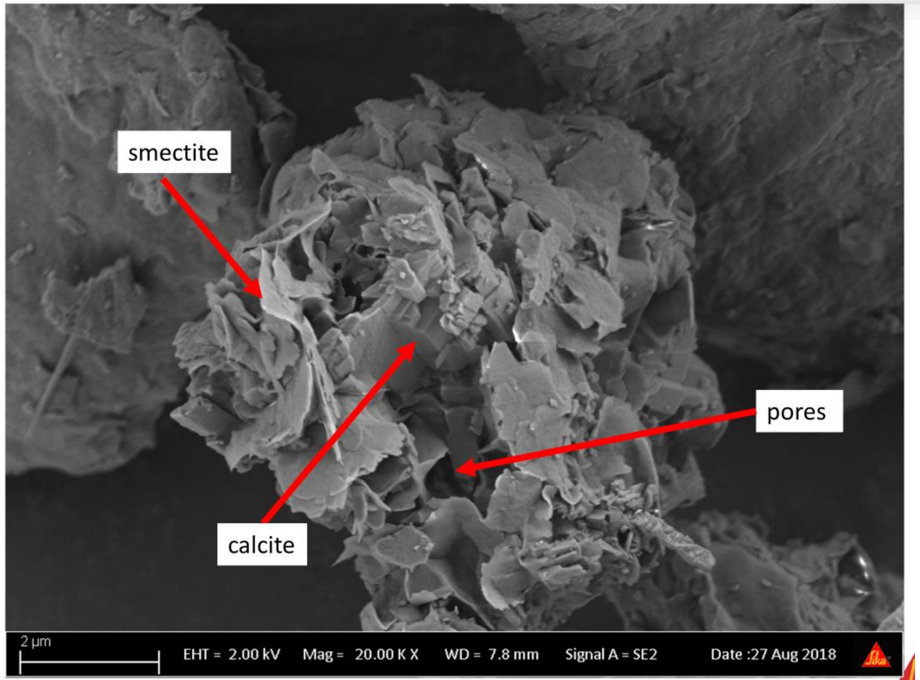


UNDERSTANDING INDIVIDUAL MINERALS

Kaolinite



Bentonite



Driving the need to decrease concrete Viscosity

Industry challenges

Type IL/IP/IT/GU blended cements (currently 5-15% limestone, >30% GU) *Expected to increase as high as 45% - LC3	Viscosity increase/water demand
Fly Ash & CC, and other SCM's (availability and distance)	Viscosity increase, mobility
Quality aggregates (increased demand/cost and GWP) *More frequent use of man sand & crushed, angular aggregates	Water demand, viscosity, mobility
Lower cementitious content (sustainability initiatives)	Stability, cohesiveness, finishability

Driving the need to decrease concrete Viscosity

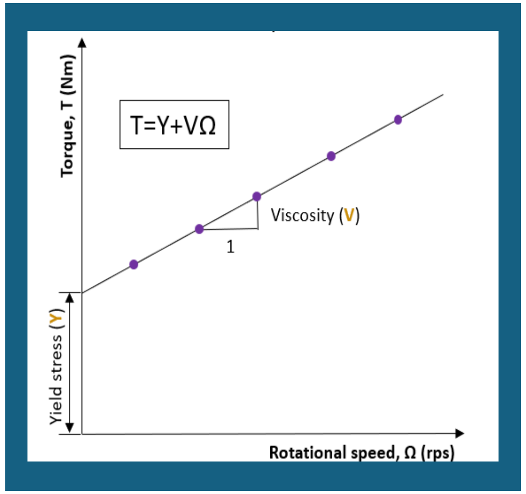
Importance on applications

Finishing

Finishing

Pumping

Understanding Concrete Viscosity is Key



New cements

Additional or New SCMs

Performance & Durability required

Challenging Aggregates

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Importance of Low Viscosity

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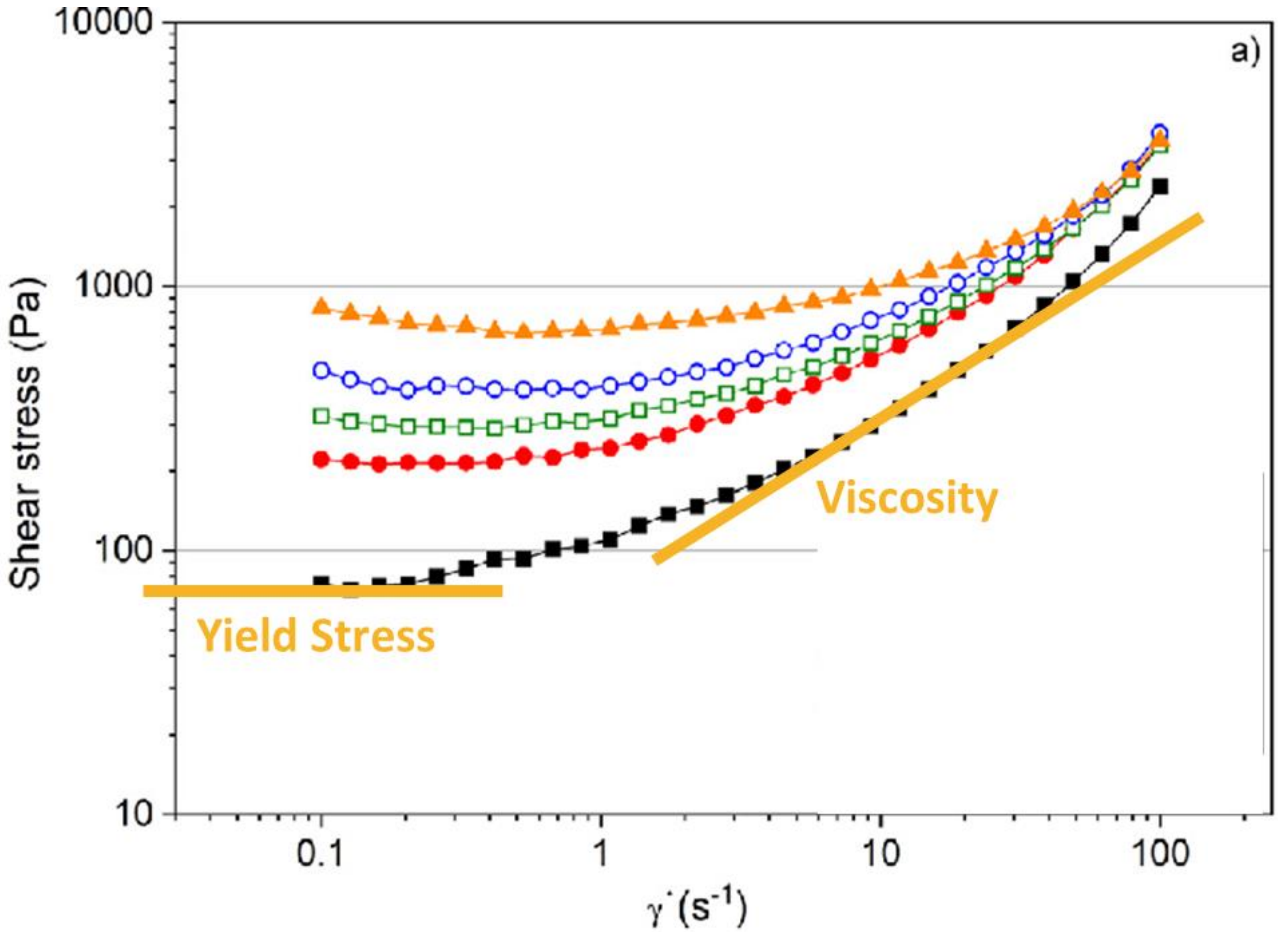
ENABLING LOW CO2 CONCRETE

SOFTNESS · LOW VISCOSITY. FROM GUT FEELING TO NUMBERS

Softness in reality!



Softness in theory!

Understanding Concrete Rheology

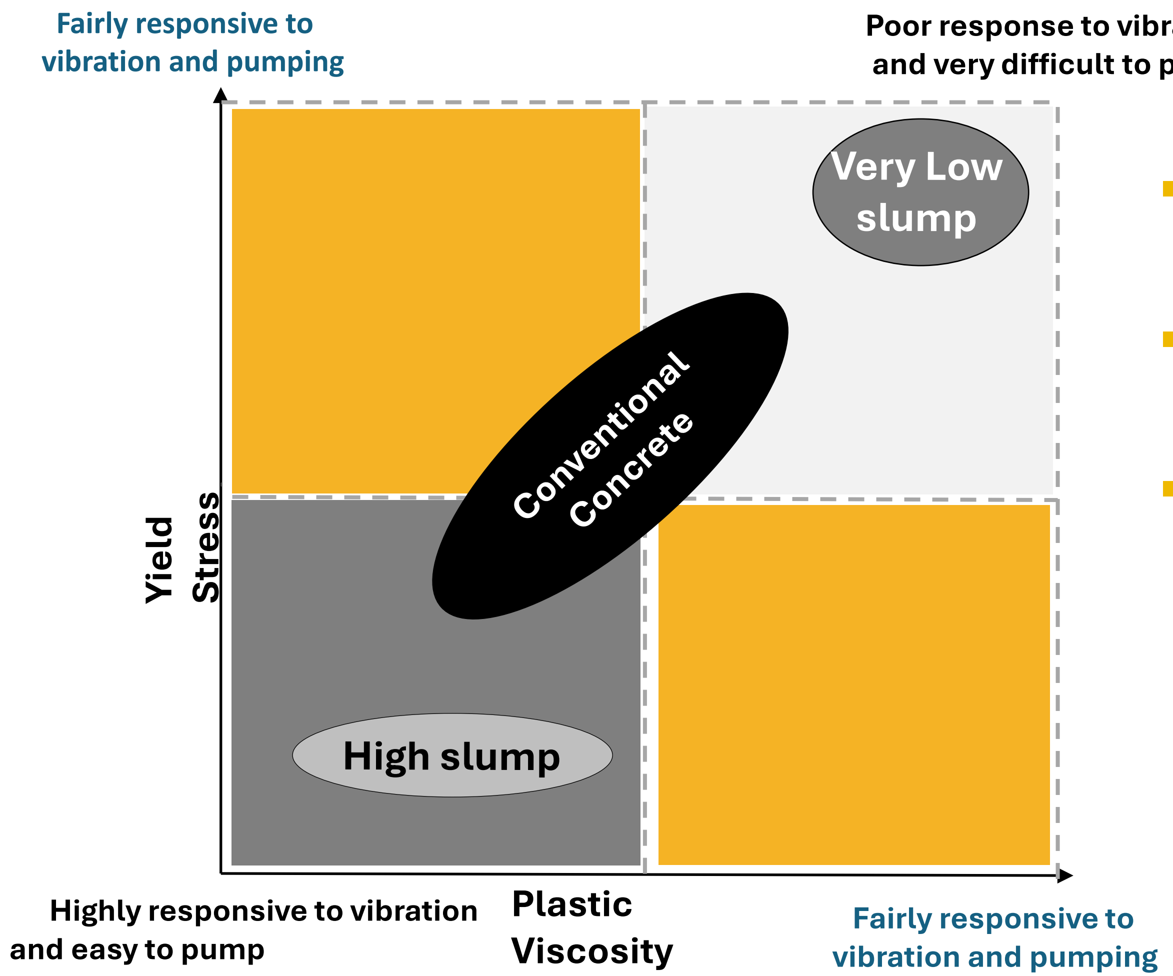
Rheology – study of how the matter deforms and flow

Yield Stress and **Plastic Viscosity** are the key parameters to describe concrete rheology

- **Yield Stress** – Related to the force required to initiate the flow
- **Plastic Viscosity** – Describes the resistance of concrete to flow
  - Two different concrete mixes can have the same yield stress but different viscosity, or the same viscosity but different yield stress

ICAR - Practical tool for measuring concrete rheology

Concrete Rheology



- Every concrete has its own rheological characteristics.
- Applications is key to define the target rheology needed on a project.
- Materials used in concrete mix designs is key as well.

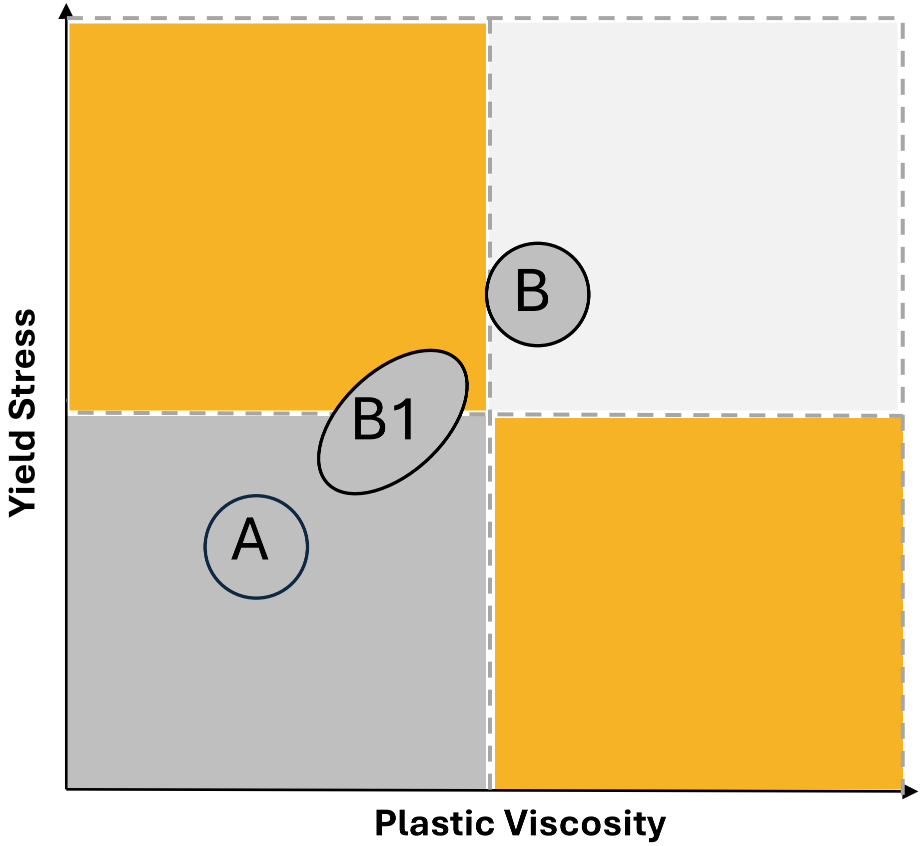
Methods to Alter the Rheology of Concrete

- **Water**
  - More water reduces viscosity and yield stress (**can be detrimental to concrete**)
  - Less water increases viscosity and yield stress (**not helpful for rheology**)
- **Paste**
  - More paste reduces yield stress but can increases viscosity (**careful with shrinkage**)
  - Less paste increases yield stress (**challenge for rheology**)
- **Aggregate Type & Ratio**
  - Optimized gradation reduces yield stress and viscosity (**improved rheology**)
- **Different Cement Types** – Type IL, Type I/II, Type III, GU, HE, IP, LC3, etc.
  - Chemical composition, particle size and distribution, water requirement, etc.
- **Different SCM's** – Fly Ash, Slag, Metakaolin, Calcinated Clays, etc.
  - By varying combinations and amounts, viscosity and yield stress can be tailored according to the desired performance

Methods to Alter the Rheology of Concrete

- **Air Entraining Admixture**
  - Lowers viscosity and slightly reduces yield stress (**improved rheology**)
- **Plasticizer/Superplasticizer**
  - Variable effect on viscosity and can significantly reduce yield stress
- **Viscosity Modifying Admixture**
  - Reduces segregation by increasing viscosity & yield strength
- **Rheology Modifying Admixture**
  - Lowers yield stress and viscosity without the detrimental effects of other options and support the mix optimizations.

Concrete Rheology

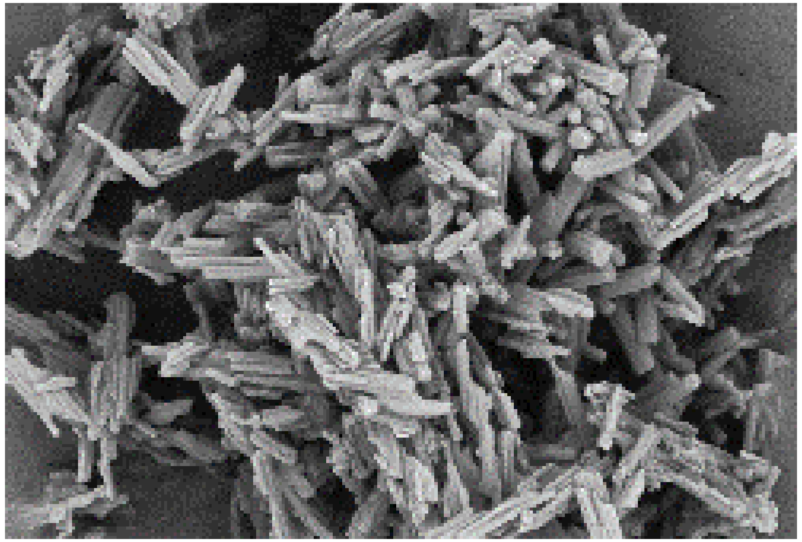


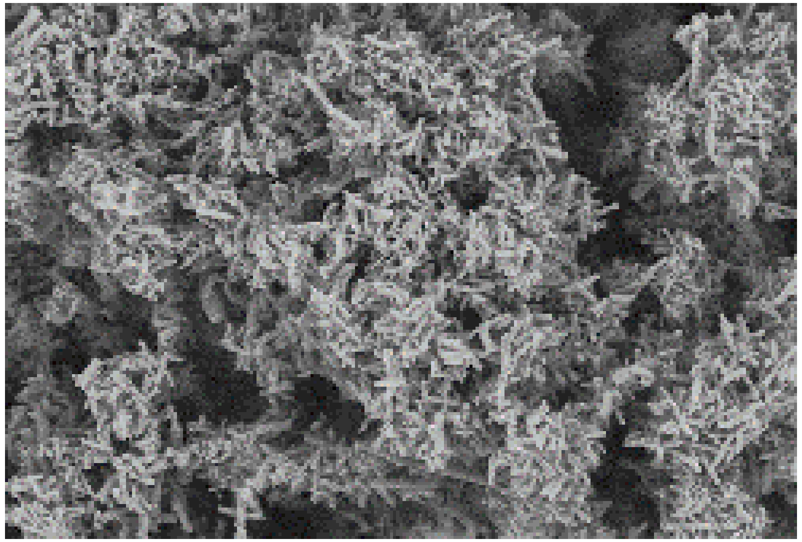
Rheology of **SCC mix:**

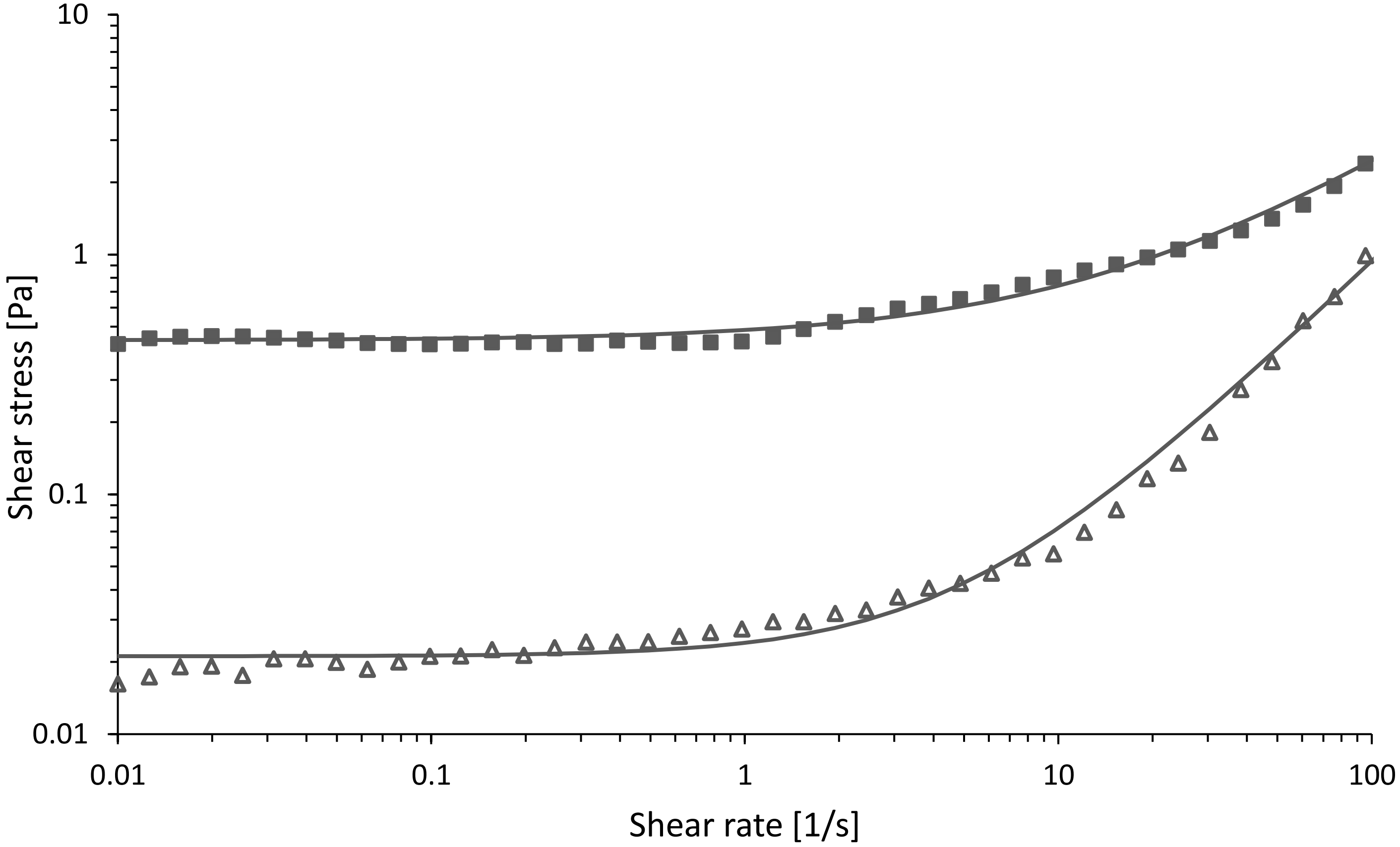
- **Zone A**: Represents a well optimized mix design with quality aggregates that are well graded and proportioned, etc.
- **Zone B**: Represents a poorly optimized mix design with poorly graded and proportioned aggregates, etc.
- **Zone B1**: Represents a mix design from Zone B with the same raw materials, including some optimization and the addition of a rheology modifying admixture

SOFTNESS · KNOW HOW & UNDERSTANDING GENERATION

IMPACT OF HYDRATES MORPHOLOGY ON VISCOSITY







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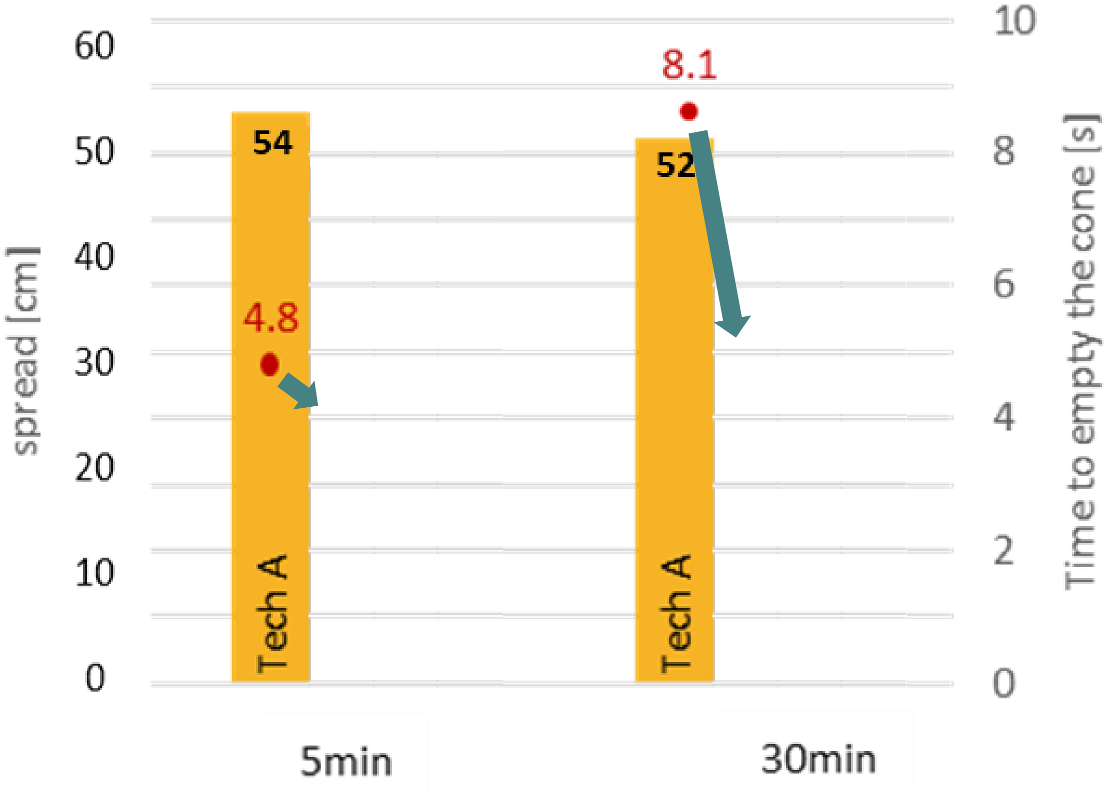
ENABLING LOW CO2 CONCRETE
SOFTNESS · TECHNOLOGY VALIDATION



Reality!

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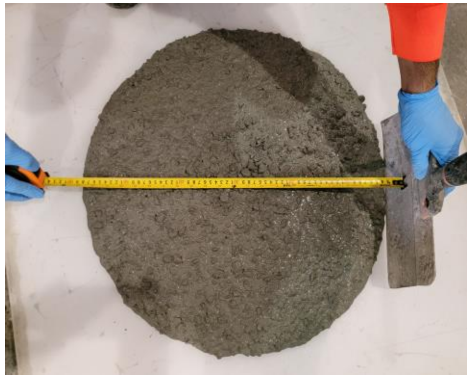
Benefits of concrete with optimum rheological properties

- **Improved concrete pumping operations**
  - Reduced pump pressure results in lower maintenance cost & improved safety
- **Improved concrete placement operations**
  - Less time & energy required during placement and consolidation
- **Improved concrete finishing operations**
  - Easier & faster with better surface appearance
  - Reduced wear of finishing equipment
- **Reduced water and cement = reduced shrinkage & cracking**

Rheology modifying admixtures allows mix design optimization and assists with sustainability initiatives.

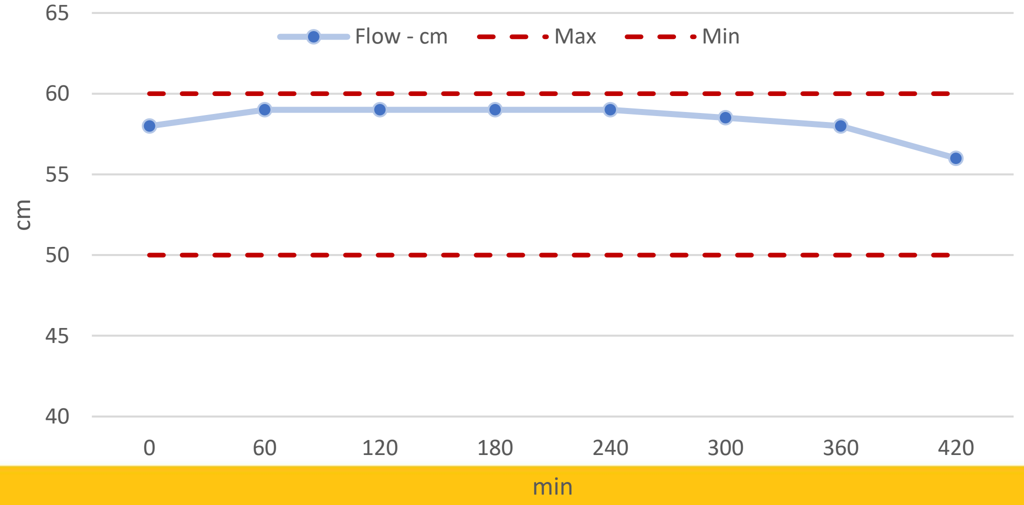
Case 1: Infrastructure Project

Mix Design	Unit	Value	Gs
Cement TII	kg	370	3.10
Puzzolana	kg	70	2.29
Water	kg	180	1
basalt crushing sand	kg	[redacted]	[redacted]
Gravel # 7 - 12.5 mm	kg	[redacted]	[redacted]
Air Content	%	[redacted]	[redacted]
SikaViscocrete 3077	kg	[redacted]	[redacted]
SikaStabilizer 80	kg	[redacted]	[redacted]



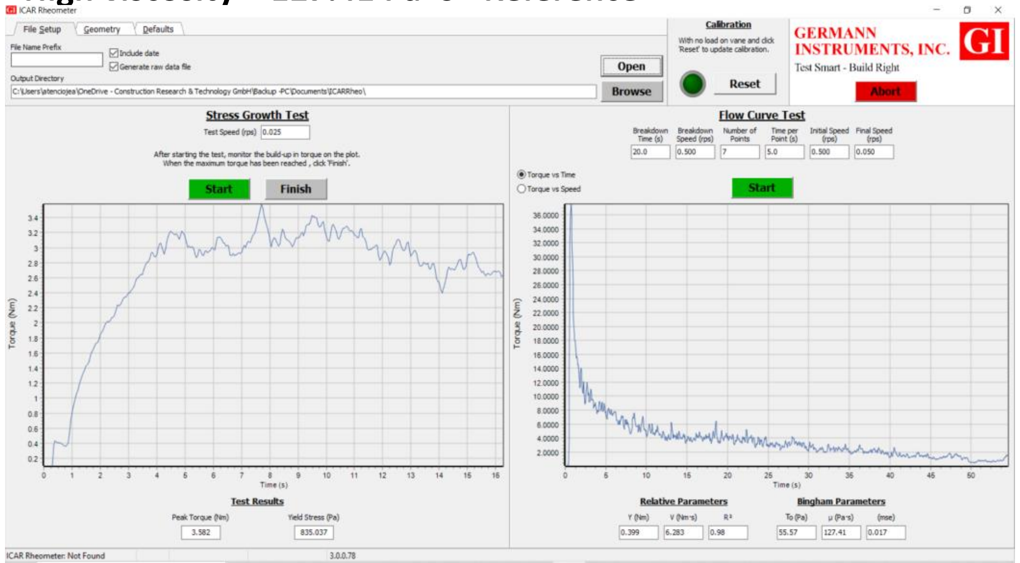
Rel. water/cement **0.41** **2,355**

mix design for piles

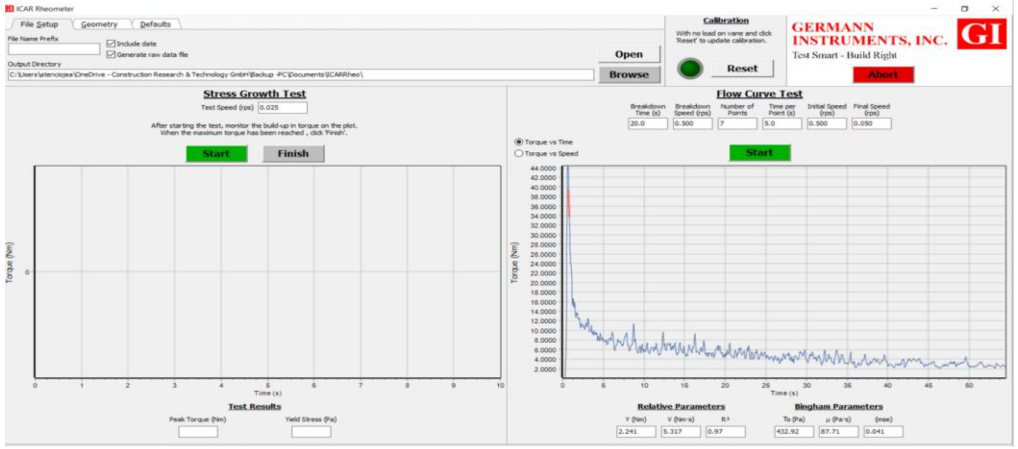


Days	kg/cm2
28	550

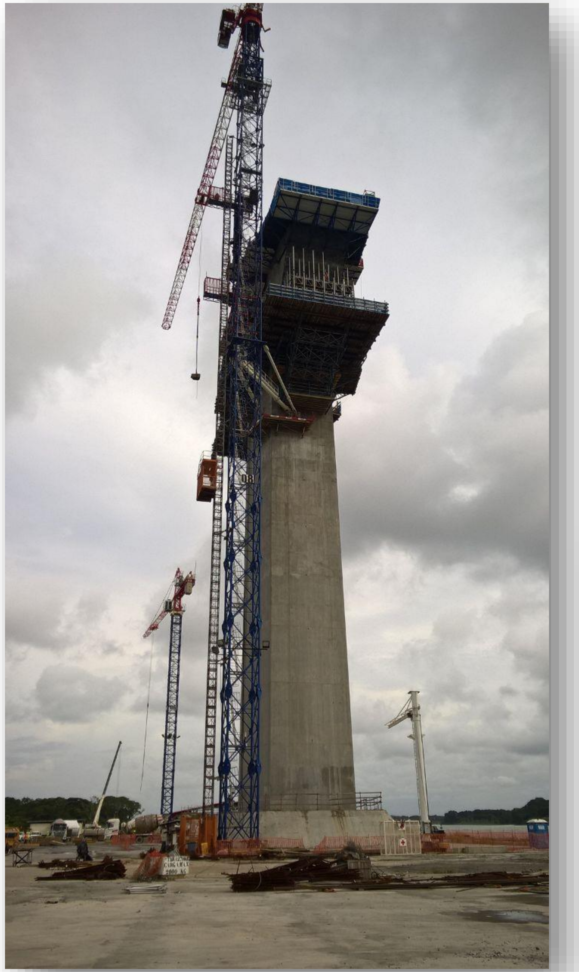
High viscosity – 127.41 Pa*s - Reference



Low viscosity – 87.71 Pa*s – SikaViscocrete 3077



Case 2: 3rd Bridge



RMA technology was a solution to deal with use of manufactured sand, SCM (Silica fume and Natural Pozzolan), w/c = 0.35 to 0.37, Low permeability < 1000 coulomb (RCPT), high amount of reinforcement.

Viscosity measure by T50:

Target = 7 sec

- Reference mix= 10-12 sec
- Optimized mix and RMA = 2-5 sec

Case 3: Repair of Condominium

Repair of Increased Columns Sections

Case 3: Repair Condominium

Increased Columns Sections

- Repair of Increased Columns Sections
- High content of reinforcement
- Column repair required very low viscosity Self Consolidating Concrete (SCC)

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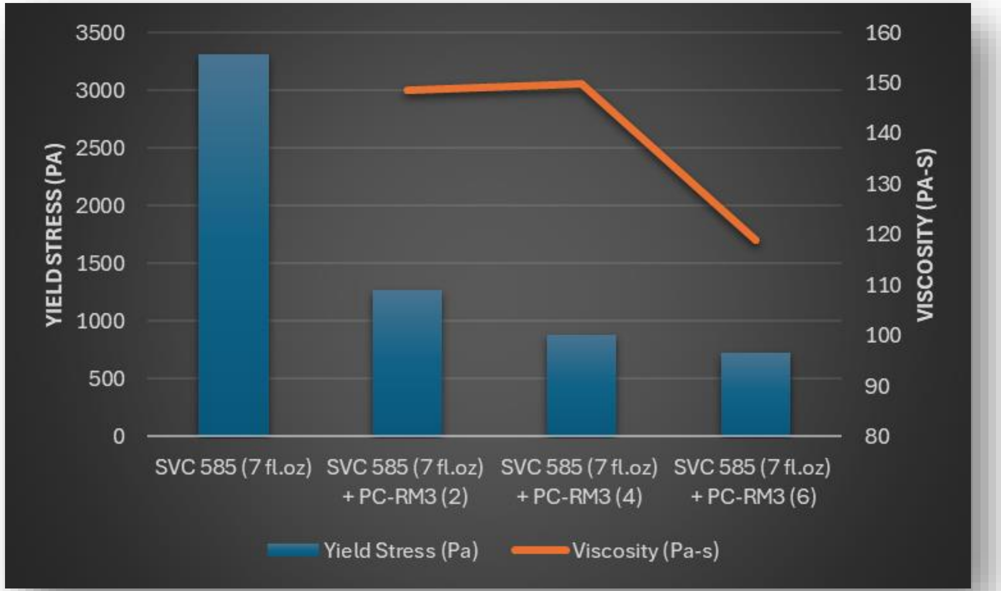
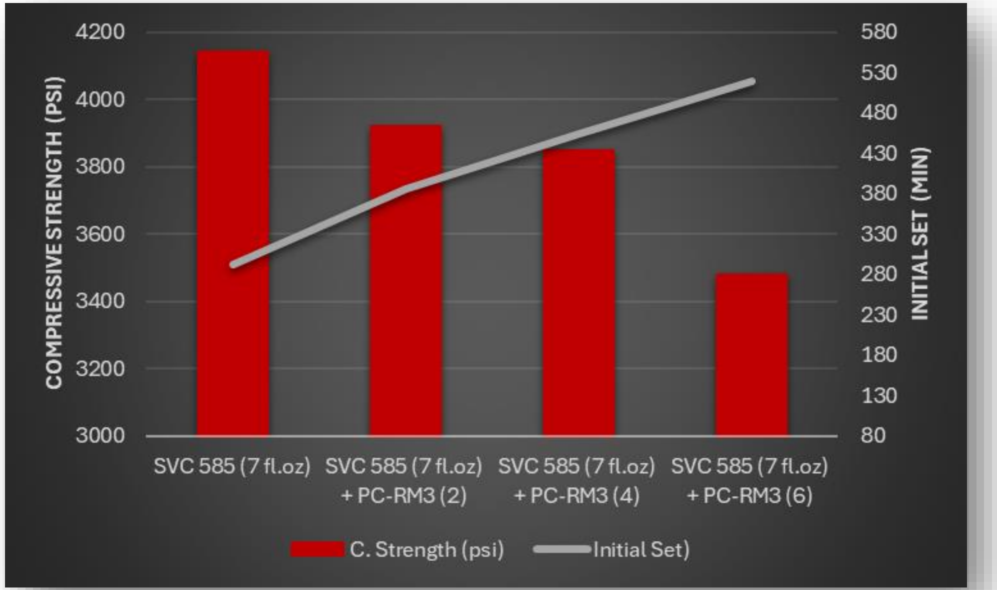
What is next? What are we working on?

What else we need to do to reduce concrete technology from PCE?

LOW VISCOSITY CONCRETE PROJECT
MIX@ 0.42 W/C – SVC 585 & PC-RM3





Admixture	Dosage (fl.oz)	w/c	Slump (in)	Air (%)	Yield Stress (Pa)	Viscosity (Pa-s)	Initial Set (min)	Final Set (min)	1 Day- C. Strength (psi)	7 Day- C. Strength (psi)
SVC 585	7	0.42	14	4.1%	3312	225.2	292	513	4140	7120
SVC 585 PC-RM3 (2)	7 2	0.42	17 3/4	3.2%	1274	148.6	386	611	3920	7550
SVC 585 PC-RM3 (4)	7 4	0.42	19	3.3%	887	149.9	454	696	3850	7700
SVC 585 PC-RM3 (6)	7 6	0.42	20 1/2	3.2%	722	118.9	519	785	3480	7900

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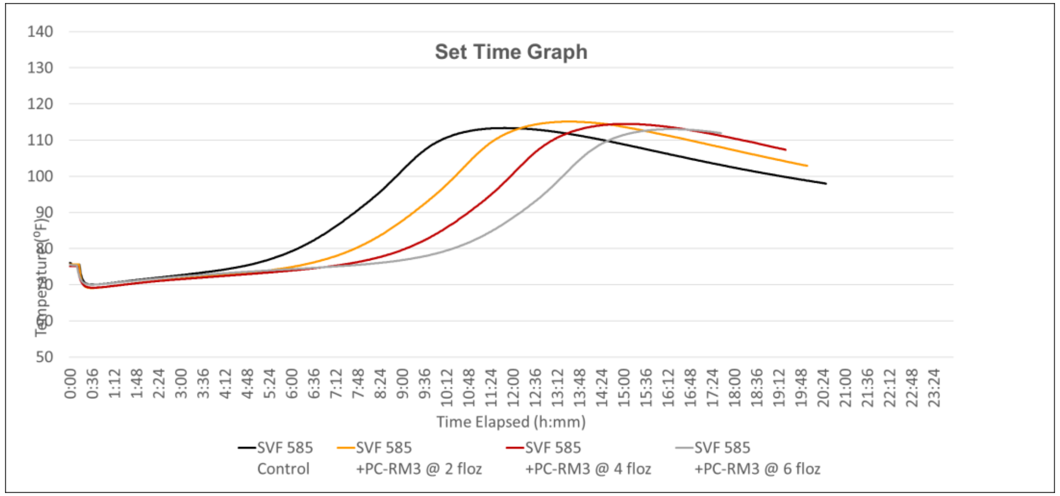
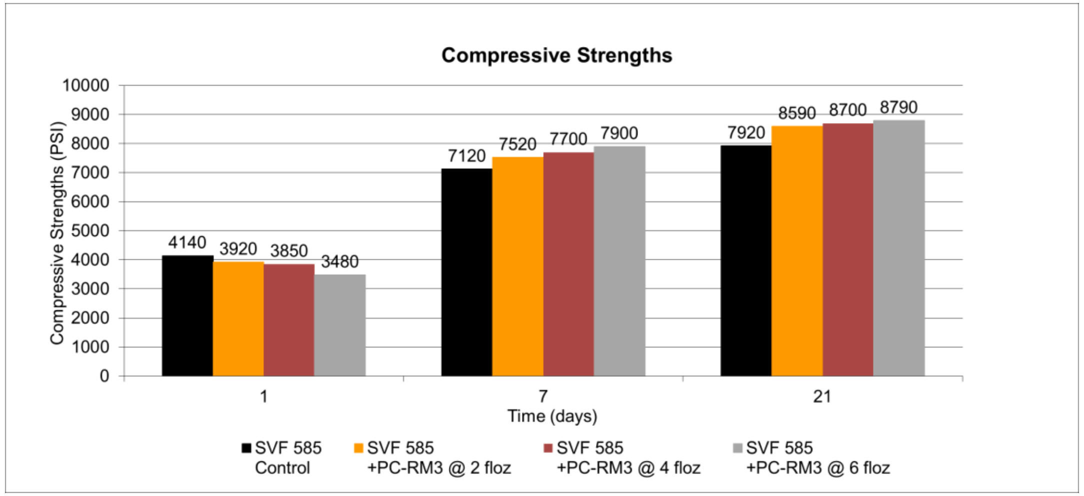
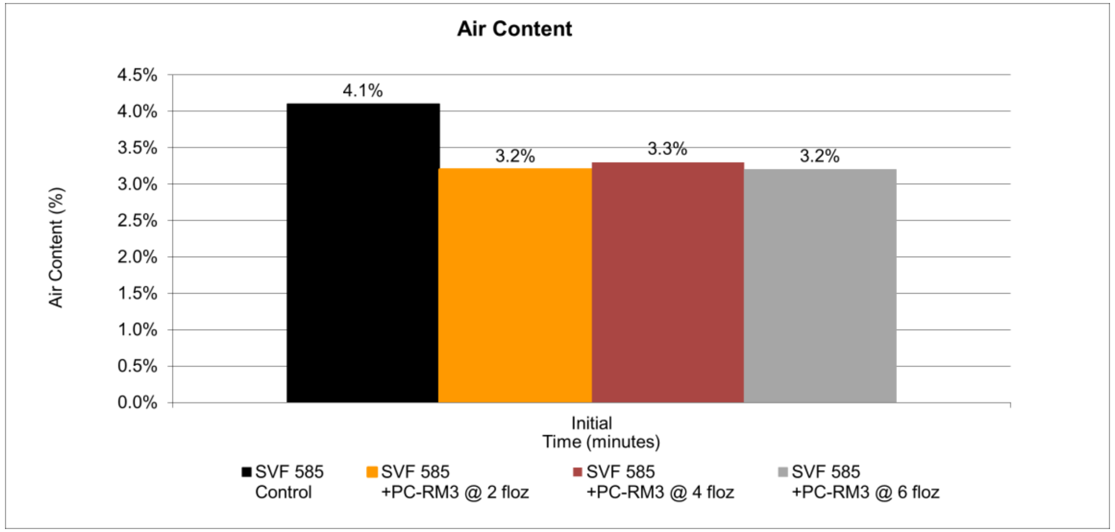
LOW VISCOSITY CONCRETE PROJECT

MIX@ 0.42 W/C – SVC 585 & PC-RM3







INTERNAL

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Summary

- Adoption of **sustainable initiatives** is pushing the industry toward the widespread use of alternative materials.
  - When materials are readily available near project sites, there is a strong tendency to explore the use of other materials.
  - Incorporation of alternative materials can represent performance challenges in concrete, particularly on rheological properties.
- **Reducing Concrete Viscosity:**
  - *Superior concrete rheology improve placements* which reduces the time and cost for placing concrete on site.
  - Everything is possible if we understand the concrete needs
  - ***Sika continue to work toward finding more solutions*** as industry continues to move on the sustainability trends.

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