Lessons learned from RILEM TC MRP round-robin testing of concrete and mortar rheology in Bethune France, May 2018

Yannick Vanhove, Dimitri Feys, Mohammed Sonebi, Chafika Djelal, Sofiane Amziane, Khadija El Cheikh, Faber Fabbris, Shirin Fataei, Markus Greim, Irina Ivanova, Helena Keller, Kamal Khayat, Laurent Libessart, Viktor Mechtcherine, Ivan Navarrete, Arnaud Perrot, Egor Secrieru

Rheometer RRTs in the past

Concrete rheometer Round-Robin tests executed in 2000 and 2003.

Main findings:

- Rheometers do not measure the same values, with up to a factor 2 difference in results
- Rheometers “rank” mixtures similarly in terms of yield stress and plastic viscosity.

What has changed?

- More flowable mixtures
- Different rheometers
- Interest in different properties
- Better knowledge on measurement procedures and errors

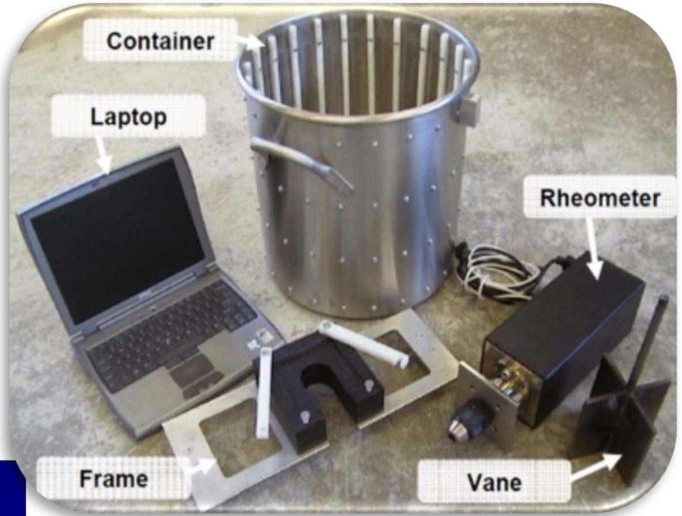
An Old Team

A New Team

Rheometers: Bulk properties

ICAR (4): Vane

Flow curve (4)
Static Yield stress (2)
Interface Rheometry (1)



Viskomat XL: Vane

Flow curve
Static Yield stress

eBT-V: Vane

Flow curve
Static Yield stress

Rheometers: Bulk properties

Rheocad: Vane / Helix

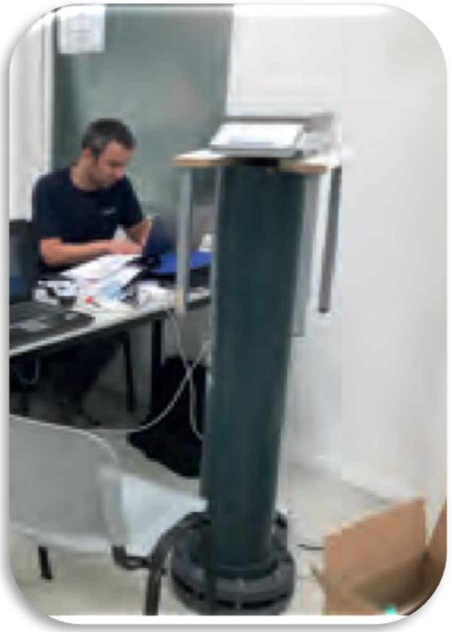
Flow curve (Vane / Helix)
Static Yield stress (Vane)

4SCC: Mixer / Mk-II

Flow curve

Plate test

Static Yield stress
evolution with time



Rheometers: Interface properties

Sliper

Interface

Interface tool for ICAR

Interface

Plane/Plane tribometer

Friction at interface

Targeted Mixtures

Concrete 1: SCC	Reference	SF = 600 mm / VF = 20 s
Concrete 2: SCC	Lower Yield Stress	SF = 700 mm / VF = 5 s
Concrete 3: SCC	Higher Viscosity	SF = 550 mm / VF > 30 s
Concrete 4: Flowable	Less Powder	SF = 600 mm / VF = 20 s
Concrete 5: Flowable	Higher Yield Stress	SF = 400 mm / Slump = 230mm
Mortar 1:	Reference	SF = 750 mm / VF = 3 s
Mortar 2:	Higher Viscosity	SF = 650 mm / VF = 5 s
Mortar 3:	Higher Yield Stress	SF = 550 mm / VF = 3 s

***No conventional mixtures were evaluated**

Organizing an RRT for Concrete Rheology

Need equipment: local, shipped, transported

Need concrete: preferred single batch, state-of-the-art producer, open to demands from the team

Need space and people: international collaborators, local helping hands

Need sponsors: industrial and academic, (inter)national and local

Need organizers: a team who can do all the legwork to make the RRT successful. Thanks to U. Artois: Yannick Vanhove and Chafika Djelal.

Organizing an RRT for Concrete Rheology

RRT Goal: Compare Rheometers

What do you want to measure?
- Flow curves
- Structural build-up
- Interface properties

Scope?
- Variety of mixtures, multiple measurements per mixture
- Maintain reliability and validity of the measurements

Outcome?
- Comparing rheometer results
- Interpretation of findings

Organizing an RRT for Concrete Rheology

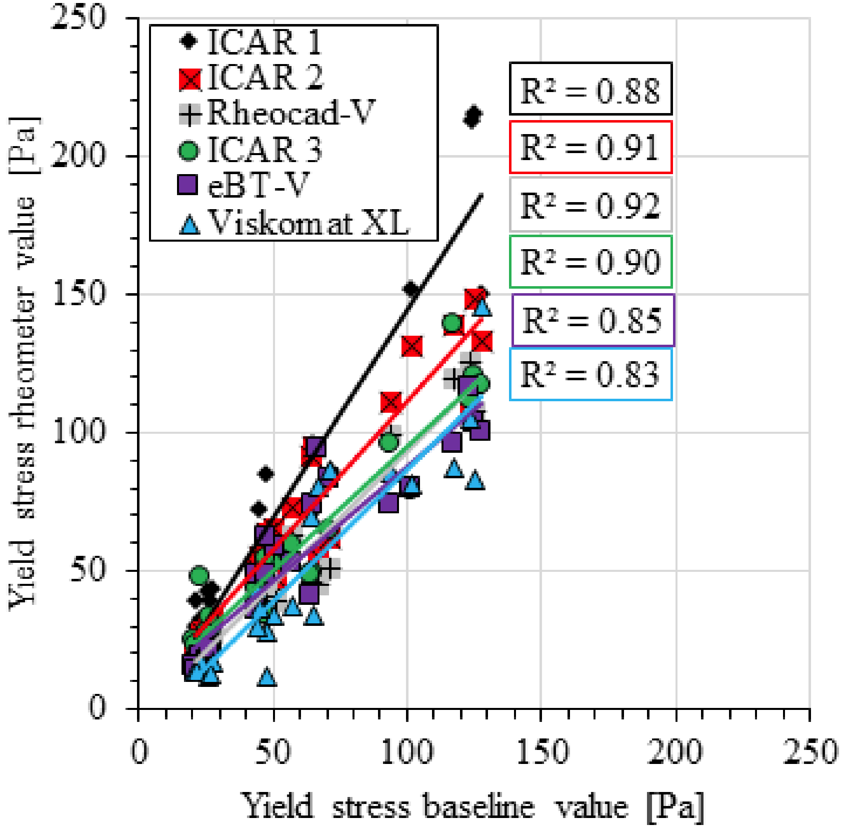
The little details that matter:

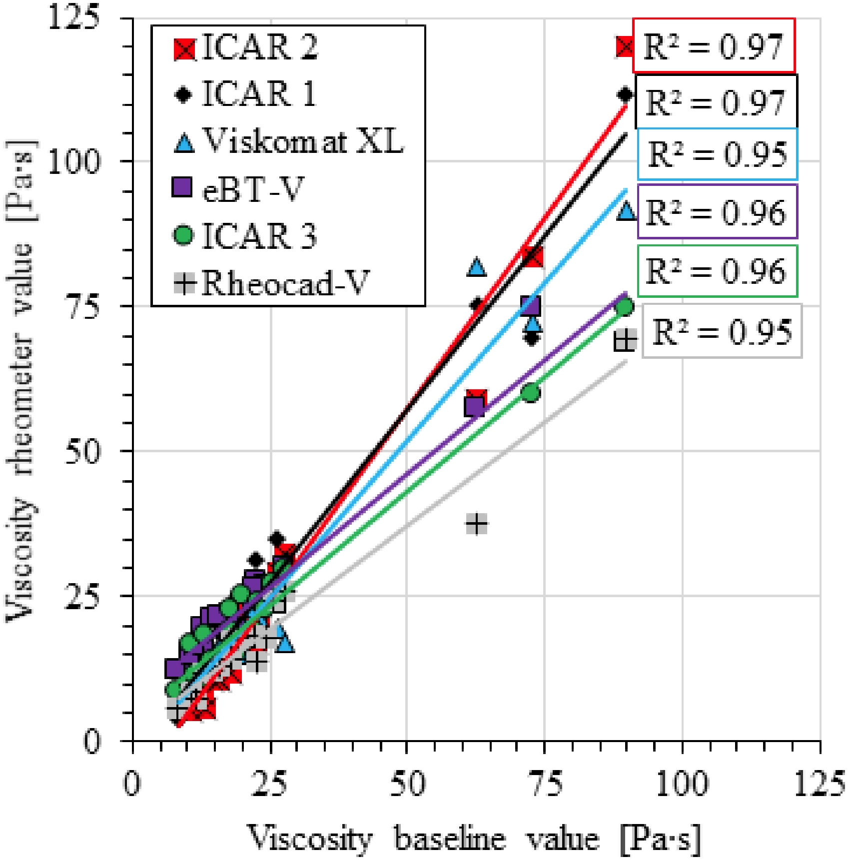
- Batch uniformity
- Matching procedures and measuring protocols
- Precise assignment of tasks
- Timing of events
- Agreement on analysis procedure
- Common statements towards interpretation

Flow Curve Analysis

Need to stay as objective as possible:

Reference values determined based on complex weighed average procedure



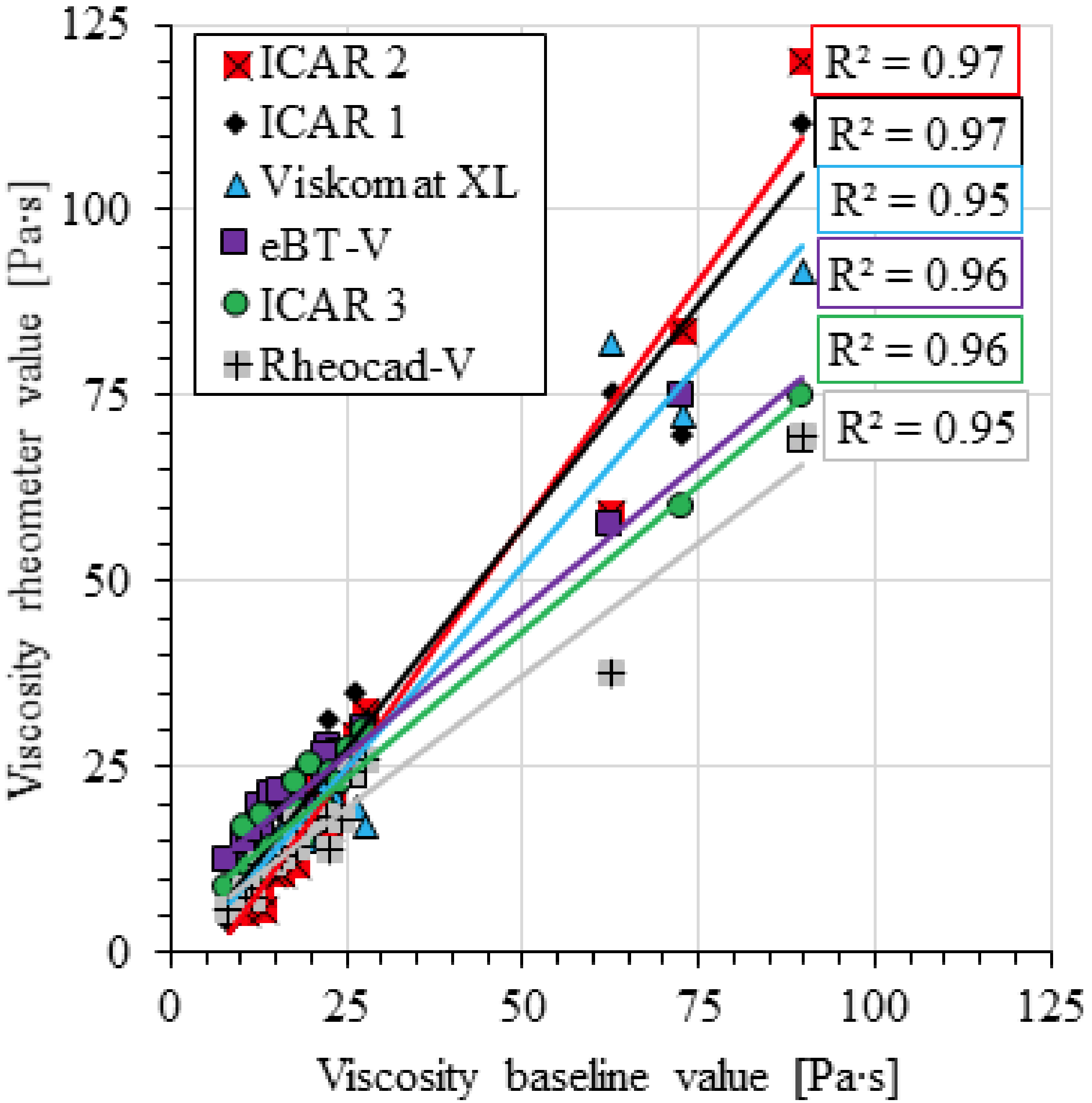


Flow Curve Analysis

Strong correlations between rheometer values and the baseline.

Differences up to a factor 2 observed.

Attributed most likely to calibration settings in torque and rotational velocity.



Flow Curve Analysis

All rheometers have similar deviations around best-fitting curve with baseline.

Differences in deviations depend on mix design:

- YS: coarse aggregate and YS/PV
- PV: magnitude of PV

A more extensive measuring procedure can lead to excessive shear-induced particle migration, compromising the assessment of rheology of concrete

	Rel. St. Dev. Δ YS	Rel. St. Dev. Δ PV
ICAR 1	13.6	4.1
ICAR 2	11.3	3.5
ICAR 3	12.2	3.8
Viskomat XL	14.7	4.5
eBT-V	16.0	4.7
Rheocad	10.1	4.8

	St. Dev. Δ YS	St. Dev. Δ PV
Concrete 1	17.7	4.1
Concrete 2	7.5	3.0
Concrete 3	11.4	9.3
Concrete 4	18.7	5.0
Concrete 5	20.7	1.3
Mortar 1	7.2	2.1
Mortar 2	5.4	2.0
Mortar 3	13.9	2.4

Structural Build-up Analysis

Static yield stress measurements

Rheometer test

+ Flow curves: Dynamic yield stress
= static yield stress with no rest

10 minutes

40 minutes

2 measurements

Time (min)

Plate tests

5 minutes

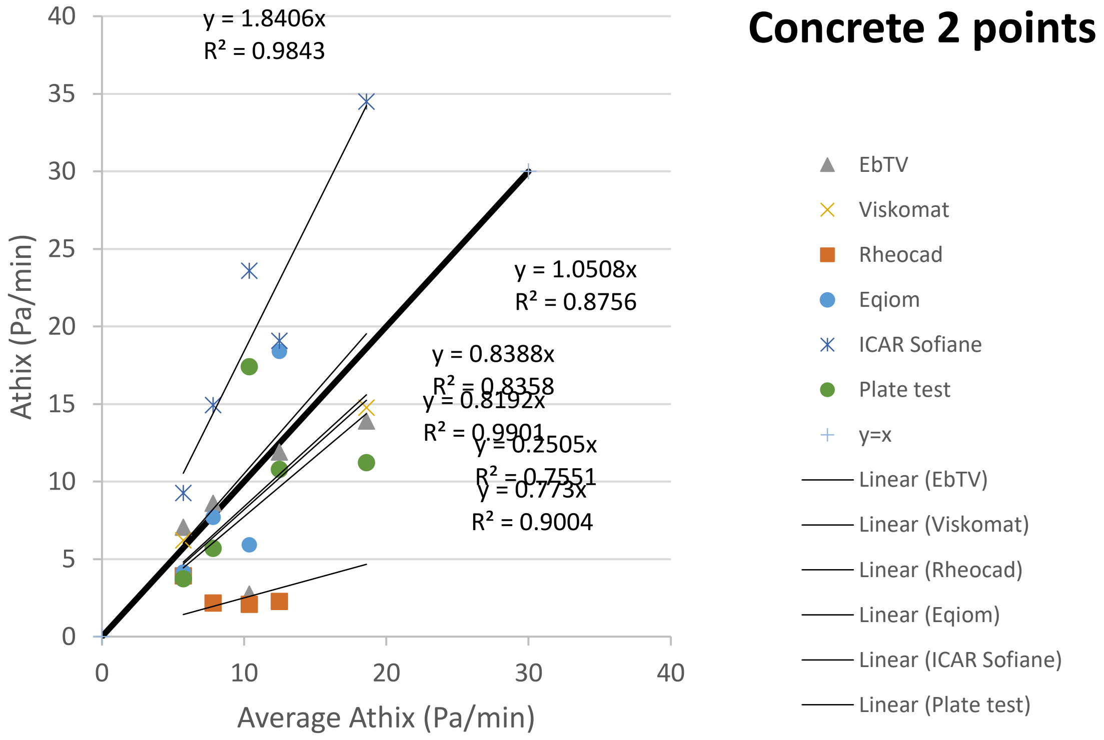
------------------- Continuous measurements-------------------

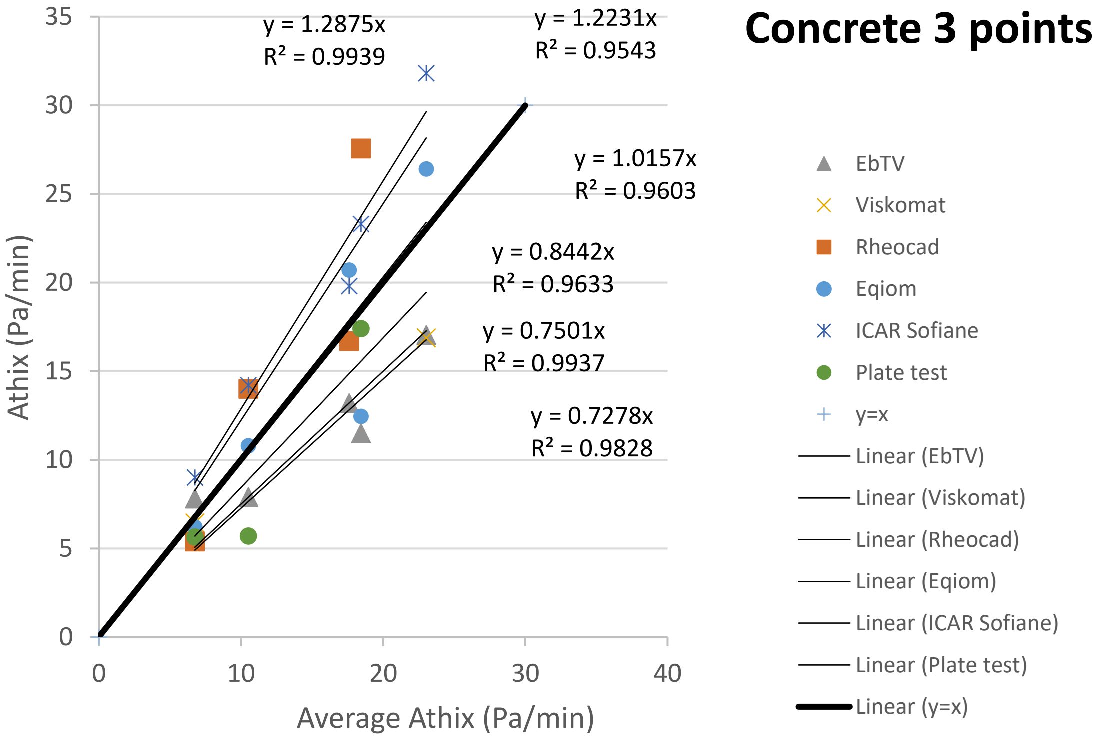
Time (min)

Structural Build-up Analysis

Extra point in assessment of structural build-up is beneficial

A_{thix} compared to averages varies between 0.72 and 1.29





Structural Build-up Analysis

Three thixotropy indices were evaluated

- A_{thix} (slope of static yield stress with time)
- t_c (time to double initial static yield stress)
- Coupled effect (initial yield stress x slope with time)

All indices showed similar trends

Attention should be paid to

- measuring procedure (e.g number of data points)
- data acquisition (e.g. capture points before maximum)
- disturbances (e.g. vibrations, bleeding)

What Can We Do Better?

Calibration:
Either use a reference material, or a simple torque meter, to perform an initial calibration of the equipment. Some differences are most likely attributed to this issue.

Enhanced Scope:
Find a compromise between maximizing validity of the measurements and more variability in concrete mixture types.
Evaluate other mixtures: high yield stress, rapid stiffening
Evaluate other rheometers

Reproducibility:
No repeat measurements performed

What Can We Do Better?

Communication:
Don’t wait until the last day/hour/minute to decide on measuring protocols, mixtures types, …

Learn-on-the-fly:
Although some results were quickly revised during the campaign, a detailed analysis of some data may have been useful to discover some concerns encountered during the analysis phase.

E.g.: Influence of measuring duration on flow curves
Inclusion of third data point for structural build-up

Thank You