Correcting Your Own Mistakes: An Effective Instructional Method on Errors in Cement Paste Rheometry

Dimitri Feys

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Overview

Introduction of the class

Discussion of errors in cement paste rheometry

Project part 1

Project part 2

Lessons learned

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The Class

Class title: Understanding the Rheology of Cement-based Materials

Audience: Graduate students

Duration: Full semester

Number of students: In person: 9, Distance (online asynchronous): 4

Mode: Flipped – Pre-recorded lectures with discussion and Q&A

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The Class

Class title: Understanding the Rheology of Cement-based Materials

Topics:

- Chapter 1: Introduction to Rheology
- Chapter 2: Suspension Rheology
  - Concepts from physics and chemistry, explaining specific rheological behavior
- Chapter 3: Rheology of Cement-based Materials
- Chapter 4: Measurements
  - Rheometers, Procedures, Calculations, Errors
- Chapter 5: Complex Phenomena

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The Class

Evaluations:

Two oral exams with 24-48 h preparation (20 and 30%)

The project (50%)

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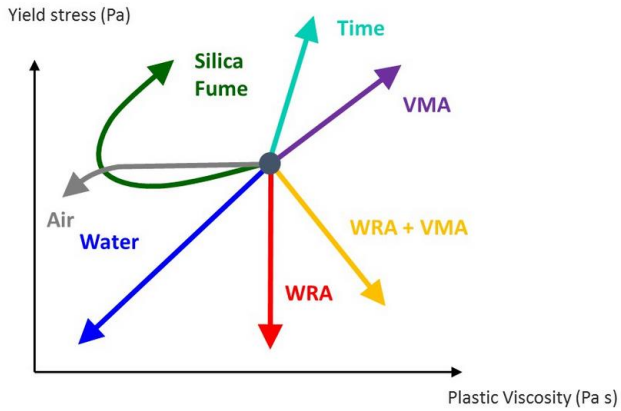
Cement Paste / Mortar / Concrete Rheometry

Purpose of rheometry: measure constitutive equation of fresh cement-based material. (i.e. shear stress vs. shear rate).

- Expectation: Linear with a yield stress
- Thixotropic: Shear- and time dependent



Effect of the following constituents

- Increase w/cm: decrease yield stress, viscosity, thixotropy
- Increase HRWRA dosage: decrease yield stress, thixotropy
- Replace cement by silica fume: increase yield stress, viscosity, thixotropy
- Replace cement by fly ash: it depends

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Cement Paste / Mortar / Concrete Rheometry

Errors in rheometry for cement-based materials

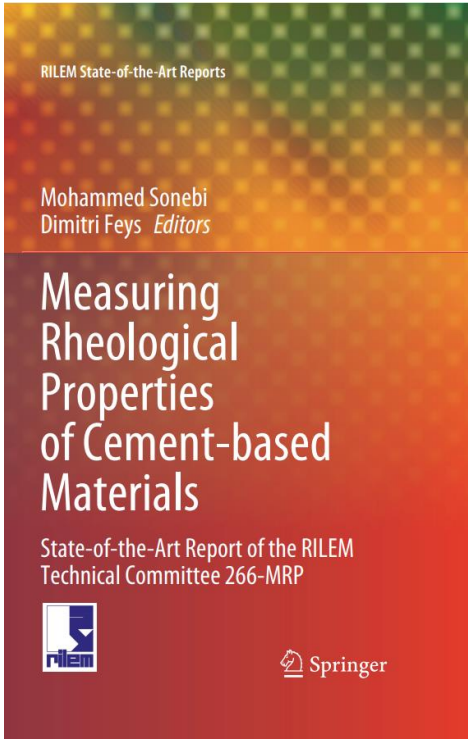
Source(s): 1 – Experience

2 – RILEM TC 266 MRP STAR: Chapter 5

50 min pre-recorded lecture, all based on the STAR report.

For each error:

- Source of error
- Consequence of error
- Detection and prevention



Cement Paste / Mortar / Concrete Rheometry

Error	Likelihood for class	Detection?	Correction
Friction	Unlikely	Really stiff, vertical walls, pressure dependence	Different concept of rheology
Non-steady state	Almost certain	Decreasing stress at constant shear rate	Longer pre-shear period
Plug flow	Less likely	Stress at Ro < yield stress	Mathematical
Particle migration	Probable	Extremely difficult	Shorter duration, more viscous mixtures
Pressure effects	Probable	Happens with vanes	None needed, seems to work
Transformation eqs	Almost certain	Rheometer working like a black box	Apply applicable eqs
Air	Probable	Difficult, apart from air measurements	Work on SCC consistency
Wall effects	Probable	Difficult, need comparison with other measurements	Roughness on geometry

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Project Part 1

Posted end of September, due early November.

Coincides with end of Chapter 2, Chapter 3.

Device: MCR 72 (robust rheometer).

Quick training on device functionality.

Project Part 1: Mistakes Galore

Four groups, each measuring the effect of a variable & repeatability.

Measure yield stress, viscosity, thixotropy over 1 hour.

No knowledge about measurement and calculation procedures
(or tell them to forget all they know). Allowed / Encouraged to make mistakes.

Submission: small report with procedures, results, calcs, interpretations and conclusions

What are they judged on: “Nothing yet,” part 2 matters.

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Project Part 2: The Rectification

Start: Early November, Due: Just before finals (early December)

Goal: Identify and correct errors you have made

- Identify error and its cause
- Consequence and effect on measurement
- Recalculate if possible
- Advise on additional observations during experiment
- Suggest new procedure

Try out on reference, maximum 1 additional adjustment

Examine effect of your variable and is it different from part 1?

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Project Part 2: The Rectification

Submission:

- Excel files with old and new measurements.
- Record a video presentation with the group on lessons learned.
- Defend your procedure during the final exam.

Evaluation based on:

- Corrections performed
- Assessment of errors
- Understanding of consequences
- Discussions on repeatability and influence of your factor in video
- No judgment on perfection, but on further identification of possible shortcomings.

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Part 2: The Rectification

Error	Likelihood for class	Detection?	# groups
Friction	Unlikely	Somewhat easy	
Non-steady state	Almost certain	Easy	Considered: 4/4 – Corrected: 4/4
Plug flow	Less likely	Easy	Considered: 4/4 – Corrected (if needed): 4/4
Particle migration	Probable	Extremely difficult	Considered: 4/4 – Adequately corrected: 2/4
Pressure effects	Probable	Assumed	Considered: 2/4 – 1 group changed geometry
Transformation eqs	Almost certain	Easy	Considered: 4/4 – Adequately corrected: 3/4
Air	Probable	Difficult	
Wall effects	Probable	Difficult	

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Lessons Learned

Pro's:

- Effective way of having students experience measurements (learning by doing)
- In terms of time commitment, it's not excessively demanding. This project is an extension of theoretical material, and students are capable of handling this without major assistance. Can we extrapolate?
- Students put significant effort in this work!
- Very good reception from in-person students

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Lessons Learned

Cons:

- Need suitable and robust equipment
- Requires a certain level of maturity from students (grad students)
- Outcome strongly dependent on involvement of students
- Risk for some students dominating the group, especially those who already performed measurements.
- Challenging to include distance students.

  Suggestions reported in evaluations

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