OSTBAYERISCHE TECHNISCHE HOCHSCHULE REGENSBURG

Schleibinger Geräte
Building Materials Testing Systems

Rheology of Building Materials, Workshop
-
Circular construction – Effect of recycled mineral powders on rheological properties of cementitious materials

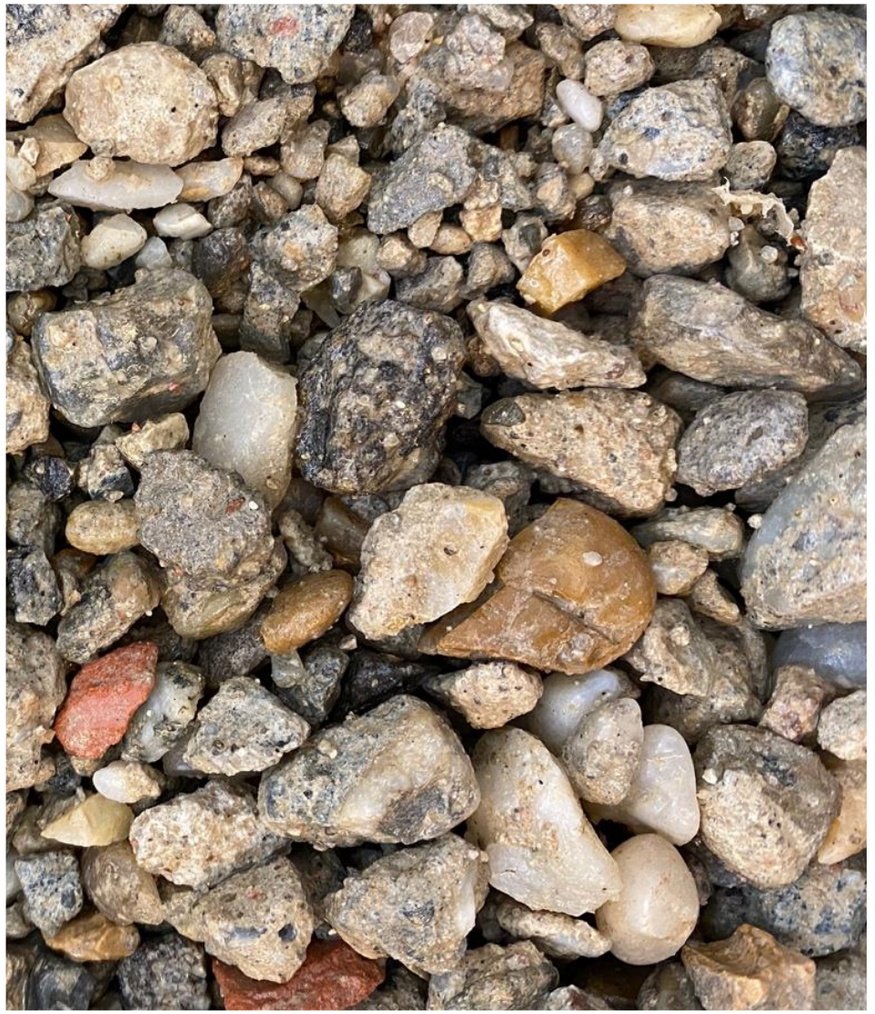
02.03.2023

OTH-Regensburg, Regensburg, Germany
Schleibinger Geräte Teubert u. Greim GmbH, Buchbach, Germany

Materials

Recycled Concrete Aggregates (RC)
in combination with natural Aggregates

RC: - Water Uptake 7.32 %
- Water suction: 2.2 M.-%
- Grading Curve 2/16



Materials

Mixture compositions

	Grain 0/4, kg	Grain 4/8, kg	Grain 8/16, kg	Recycled grain 2/16, kg	Limestone powder, kg	Cement, kg	Water, w/z = 0.44, l	PCE, 1,7 % bwc, g	Suction water, g
Mix 1, reference	23,020	11,510	11,816	-	3,951	13,500	5,940	229,5	-
Mix 2 with 40 % recycled material	13,812	6,906	7,090	16,456	3,951	13,500	5,940	229,5	411,4

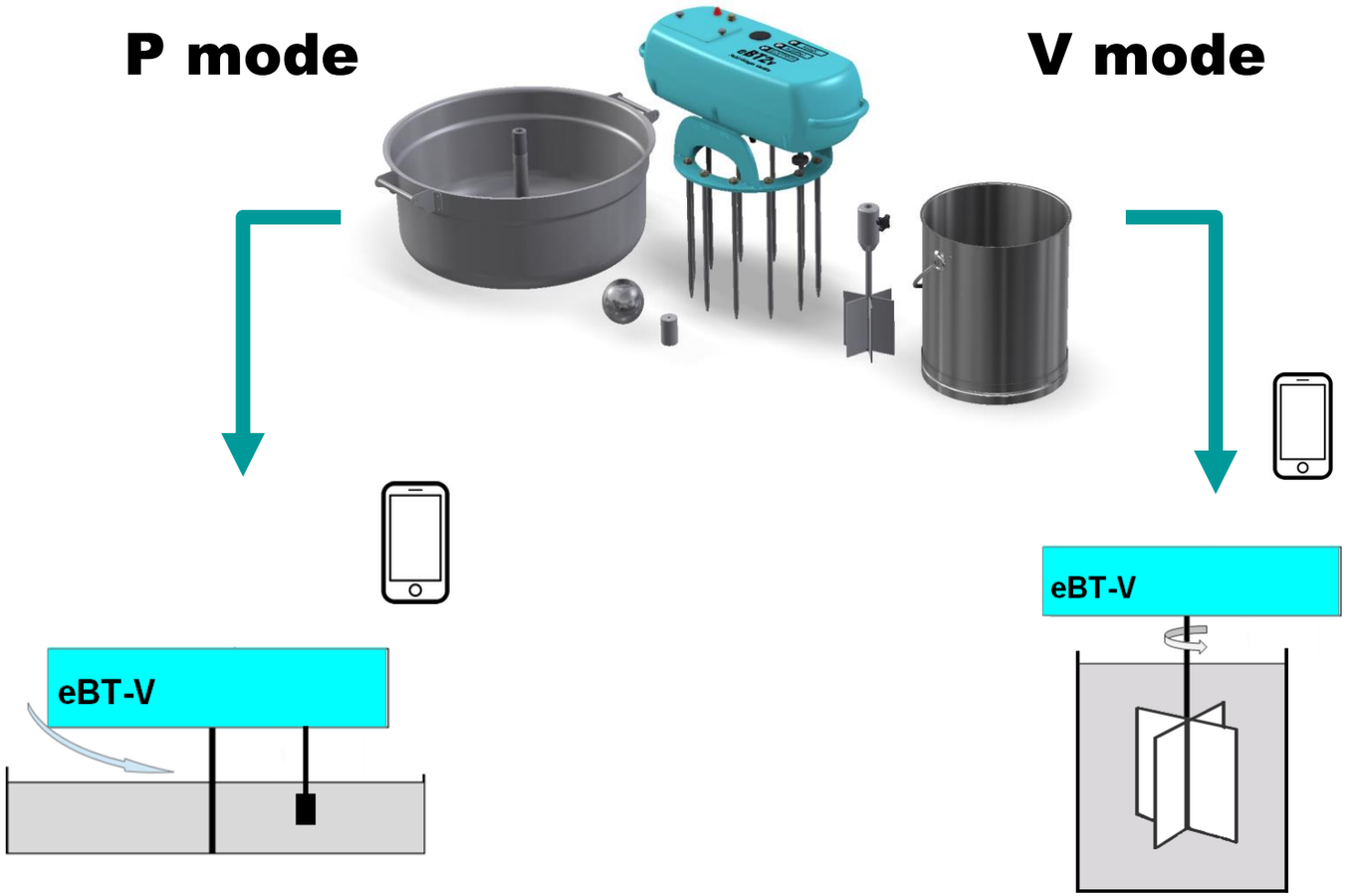
Measurement equipment

- Flow cone test for concrete
- Mobile rheometer for fresh mortar and concrete, eBT-V
- SLIding PipE Rheometer, SLIPER

Mobile rheometer, eBT-V

P mode:
- **SCC, zerro-slump concrete…**

V mode:
- **SCC, HPC, UHPC…**

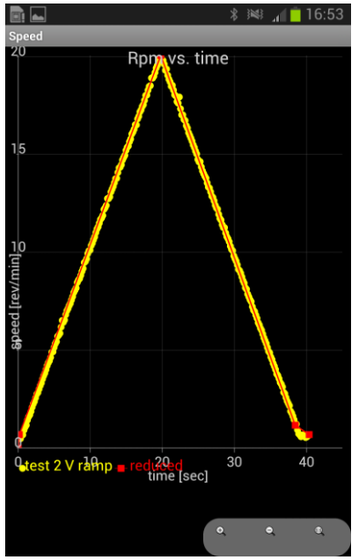


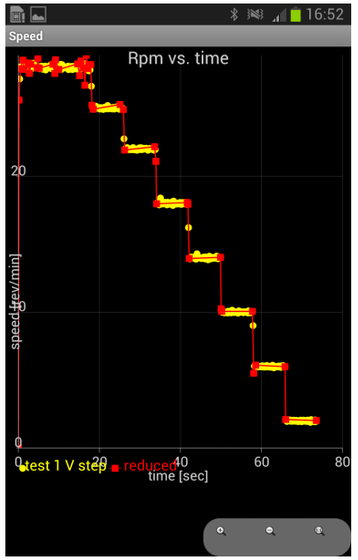
Mobile rheometer, eBT-V

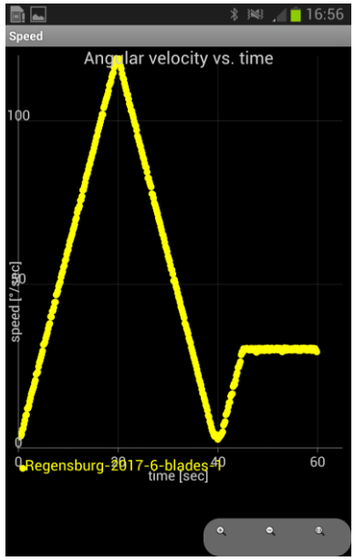
Max. particle size: up to 32 mm
Sample volume: approx. 15L / 20 L / 40 L
Torque: 0 … 10 Nm
Rotational velocity: 0,001 … 40 rpm

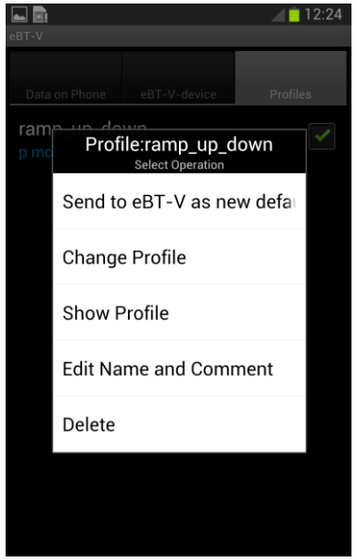
free profile design:

- ramp profiles
- step profiles
- constant speed profiles
- combined ramp and step profiles





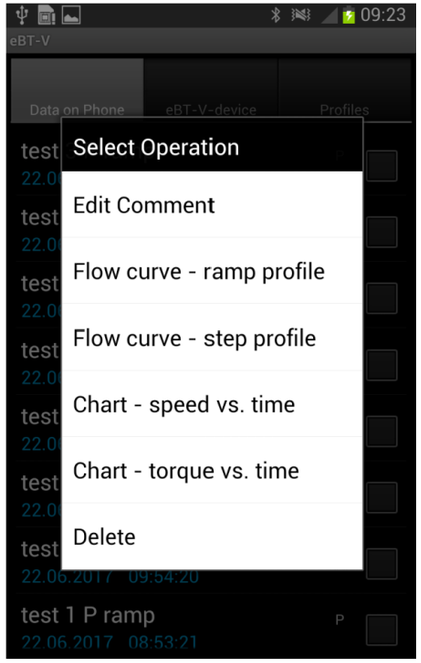


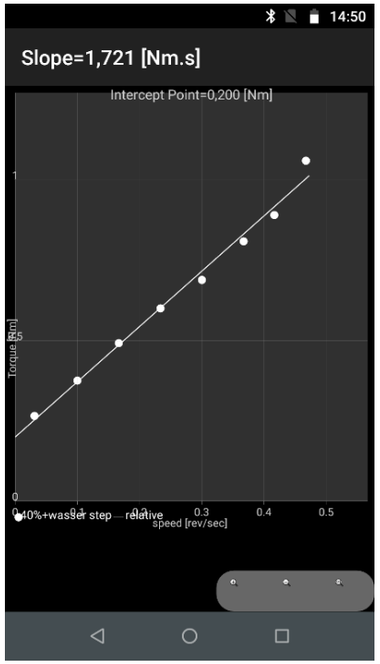


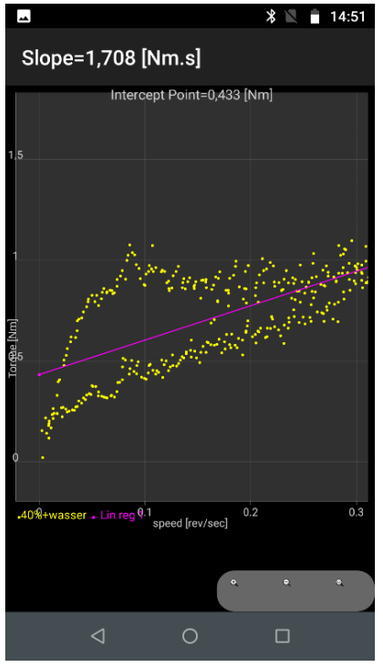
Mobile rheometer, eBT-V

Measuring results on the phone:

- data display
- comparison of the results
- flow curve analysis (simply way)
- data export







Measuring pumpability

- economic factors
  - ✓ reduced material consumption
  - ✓ reduced costs

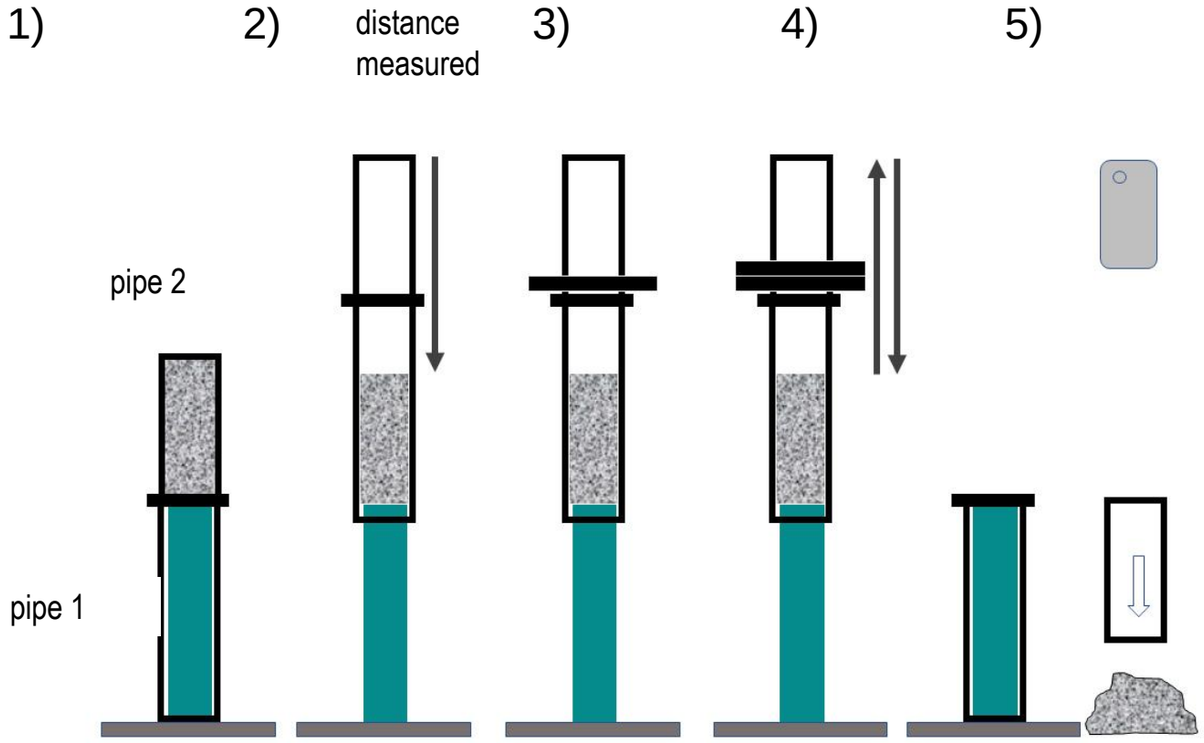
- mobile device
- sample volume approx. 7 L
- correlation to the pumping conditions on site
- use in the laboratory and the construction site

- K.J. Kasten, Gleitrohr-Rheometer: Ein Verfahren zur Bestimmung der Fließeigenschaften von Dickstoffen in Rohrleitungen, Dissertation, Dresden, 2010

Measuring pumpability

Principle of operation:

The measurement consists of several strokes. With each stroke, different speeds and pressures are achieved by adding additional weights.



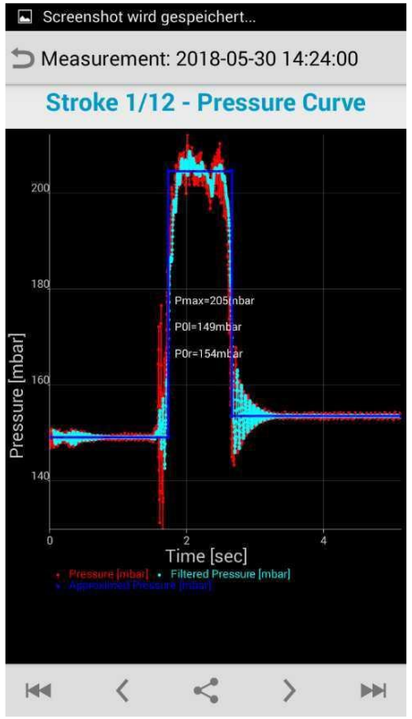
1) The device is assembled and filled with material
2) Pipes are lifted to the top and released to slide down
3) Pipes are weighted with additional weight and are released to slide down
4) more weight added...
5) At the end of testing, material is removed from the pipe
6) Cleaning the device

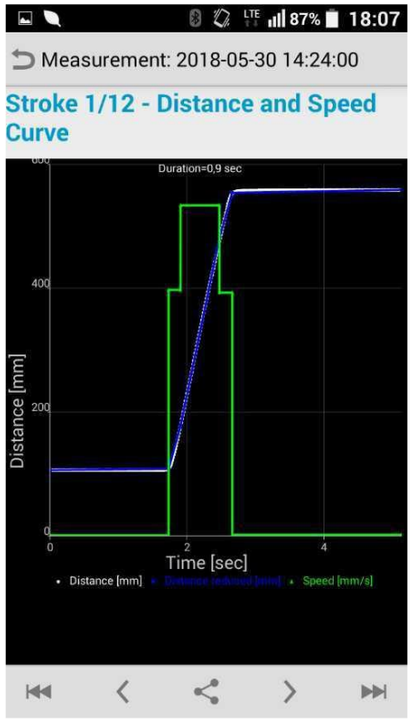
➢ During the testing, all measured data are transferred to the mobile.

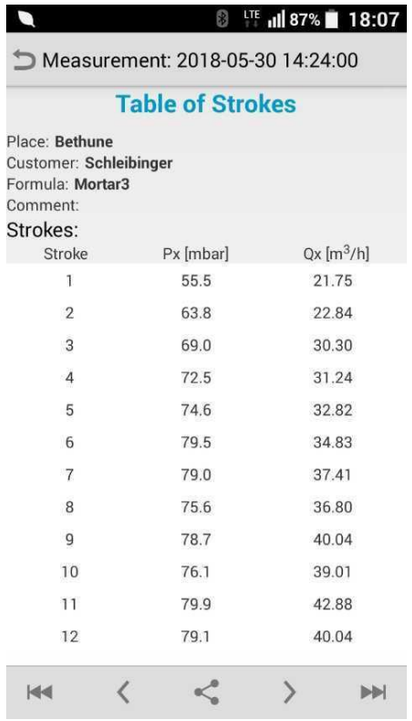
Measuring pumpability

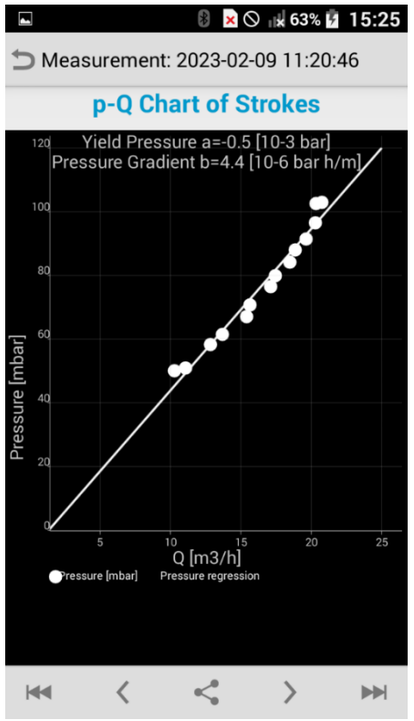
Mobile app:

- Measurement of pressure and speed for each stroke
- Calculation of relative parameters for yield stress (A) and for viscosity (B)





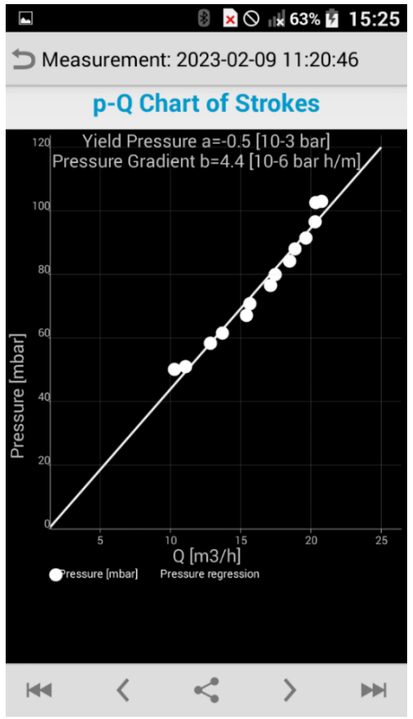


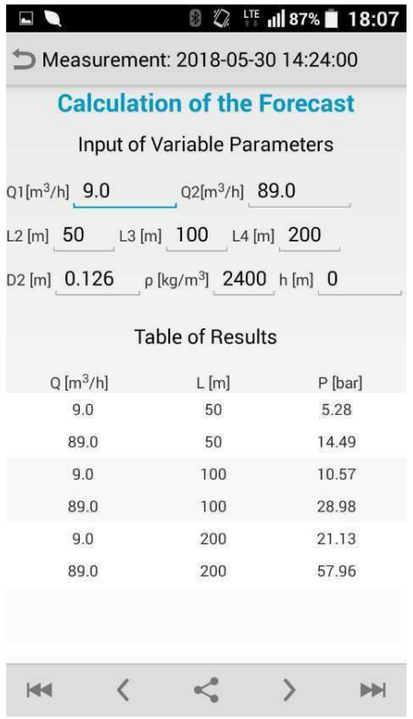


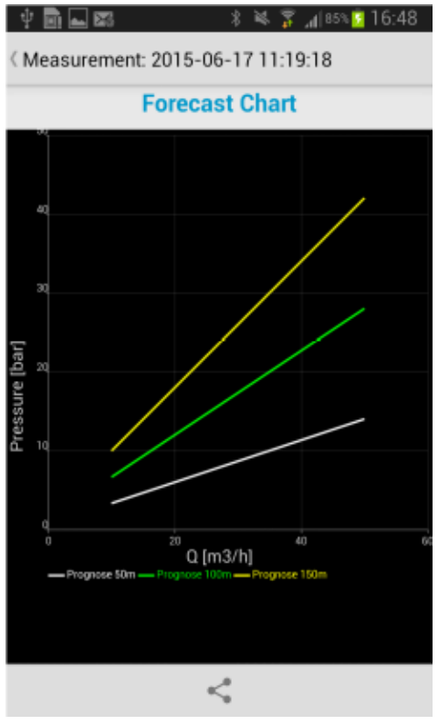
Measuring pumpability

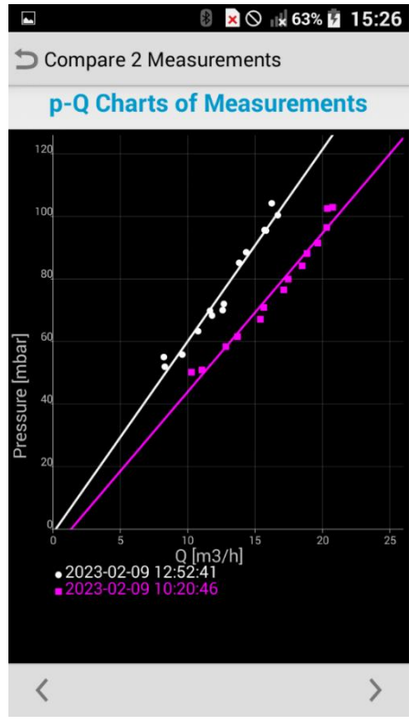
Mobile app:

- Input of the pipeline parameters (length, diameter, height)
- Forecast: calculation of pressure needed for the pumping of the mixture measured:









Measuring...

Measuring...

Measuring results

Flow cone test:

Mix	Flow cone flow time, sec.	Flow cone flow diameter, cm
Mix 1, reference	4	72
Mix 2 with 40% recycled material	4	73

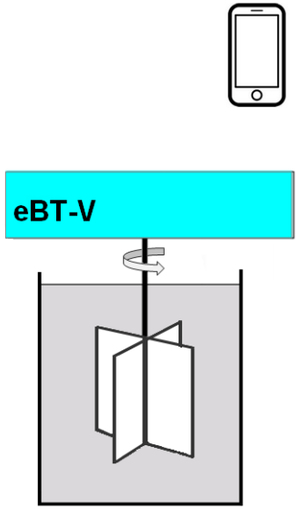
→ **Mixtures are comparable!**

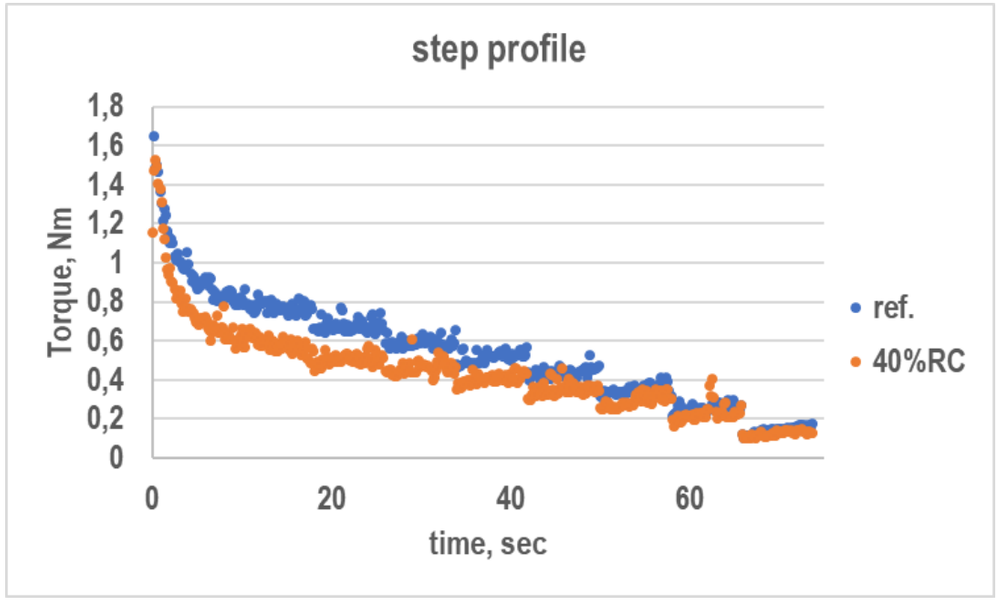
Measuring results

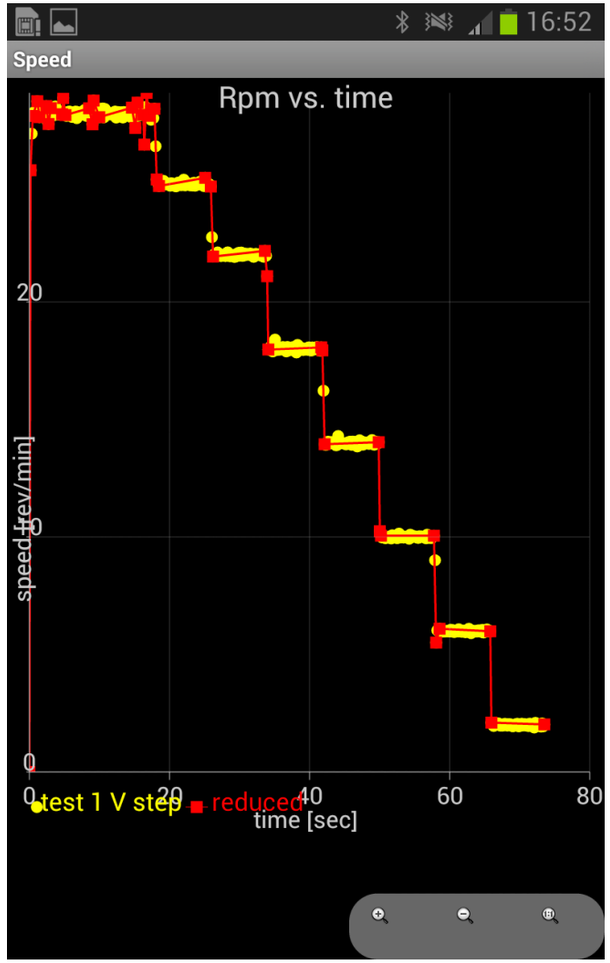
Rheological parameters with eBT-V

V mode, step profile:

- pre-shearing at 28 rpm for 18 sec.
- additional 7 steps down with 8 sec. duration each
- total measuring time 74 seconds







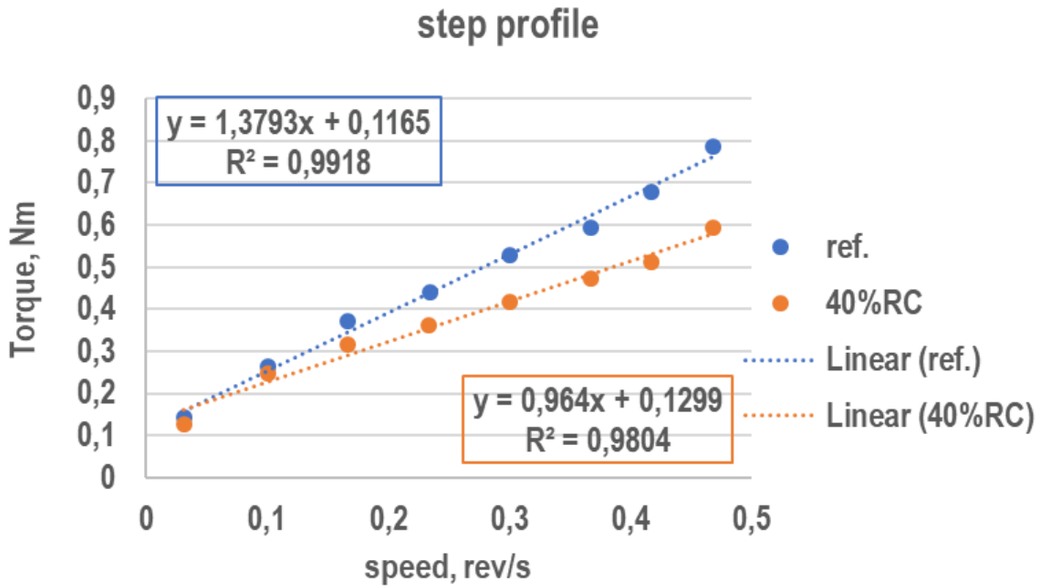
Measuring results

Rheological parameters with eBT-V

V mode, step profile

Reiner-Riwlin equation:

$$\tau_0 = \frac{\left(\frac{1}{R_i^2} - \frac{1}{R_o^2}\right)}{4\pi h \ln\left(\frac{R_o}{R_i}\right)} G \quad \text{and} \quad \mu = \frac{\left(\frac{1}{R_i^2} - \frac{1}{R_o^2}\right)}{8\pi^2 h} H$$



	rel. values		Calc. values accord. Reiner-Riwlin	
Mix	Rel. Viscosity, H [Nms]	Rel. Yield stress, G [Nm]	Calc. Viscosity [Pas]	Calc. Yield stress [Pa]
Mix 1, reference	1,38	0,12	53	33
Mix 2 with 40% recycled material	0,96	0,13	37	36

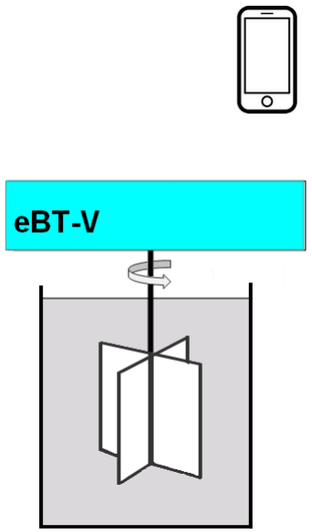
→ different viscosities

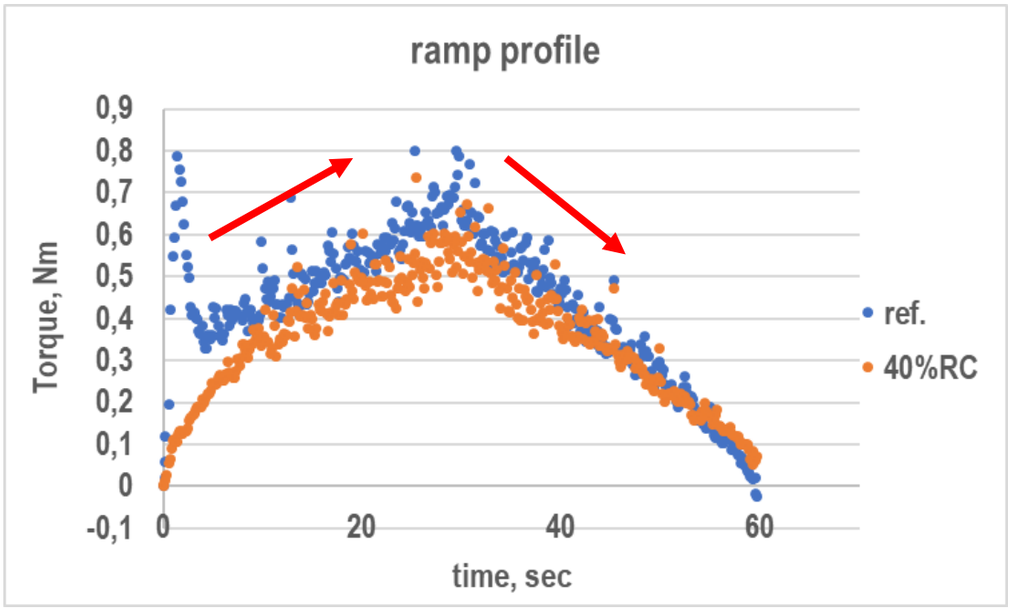
Measuring results

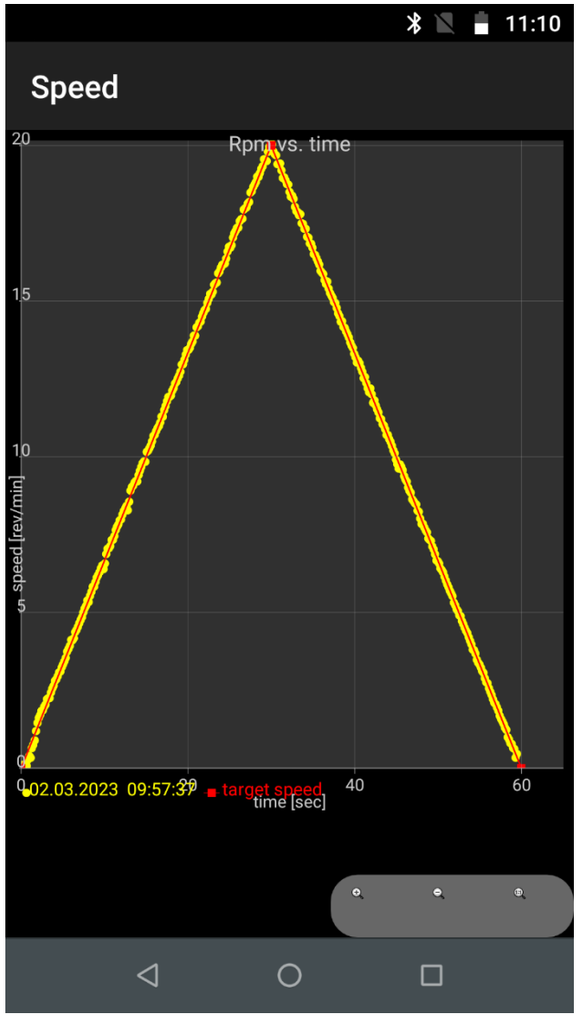
Rheological parameters with eBT-V

V mode, ramp profile:

- no pre-shearing
- continuous speed increase from 0rpm to 20rpm for 30 sec.
- continuous speed decrease from 20rpm to 0rpm for add. 30 sec.



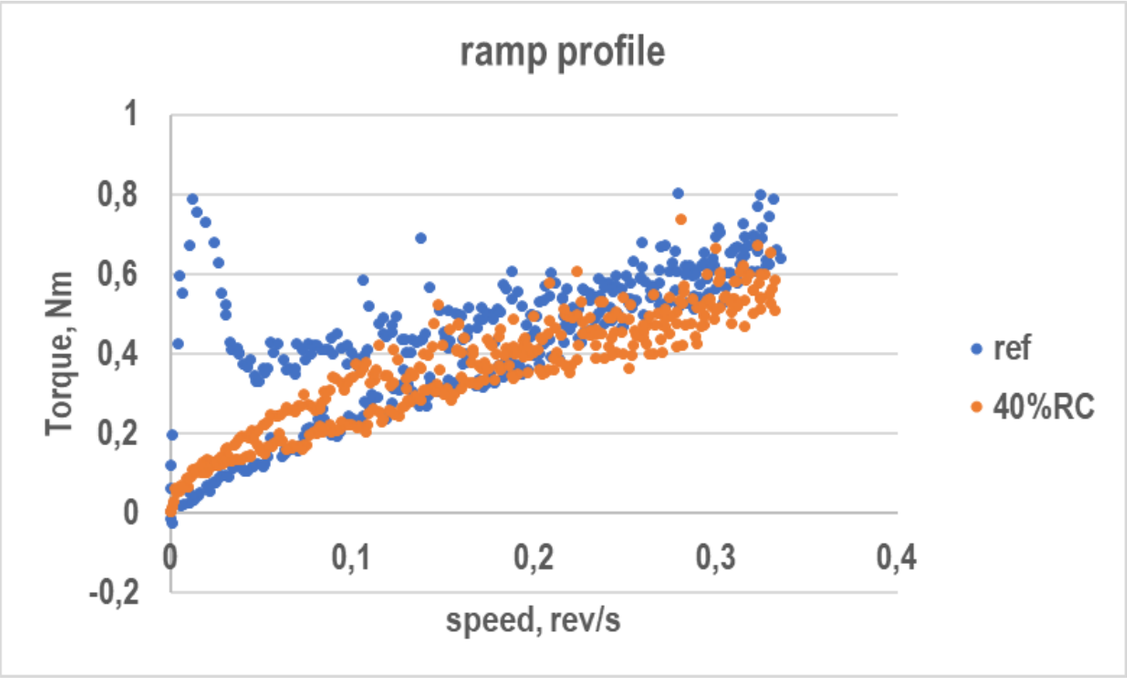


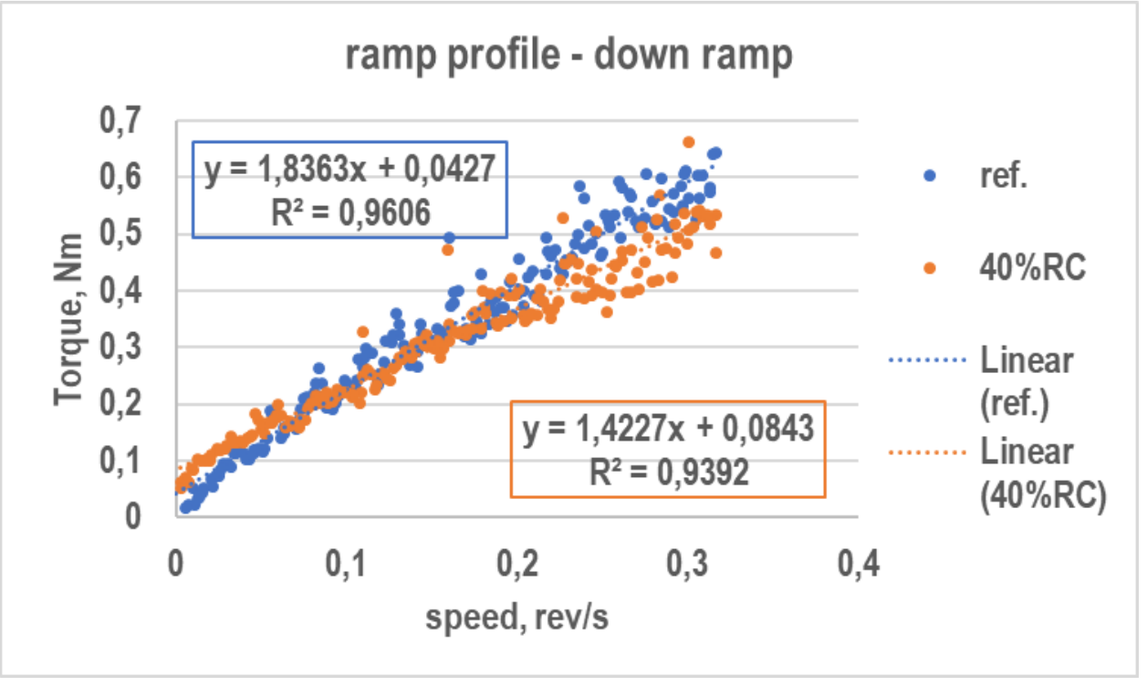


Measuring results

Rheological parameters with eBT-V

V mode, ramp profile





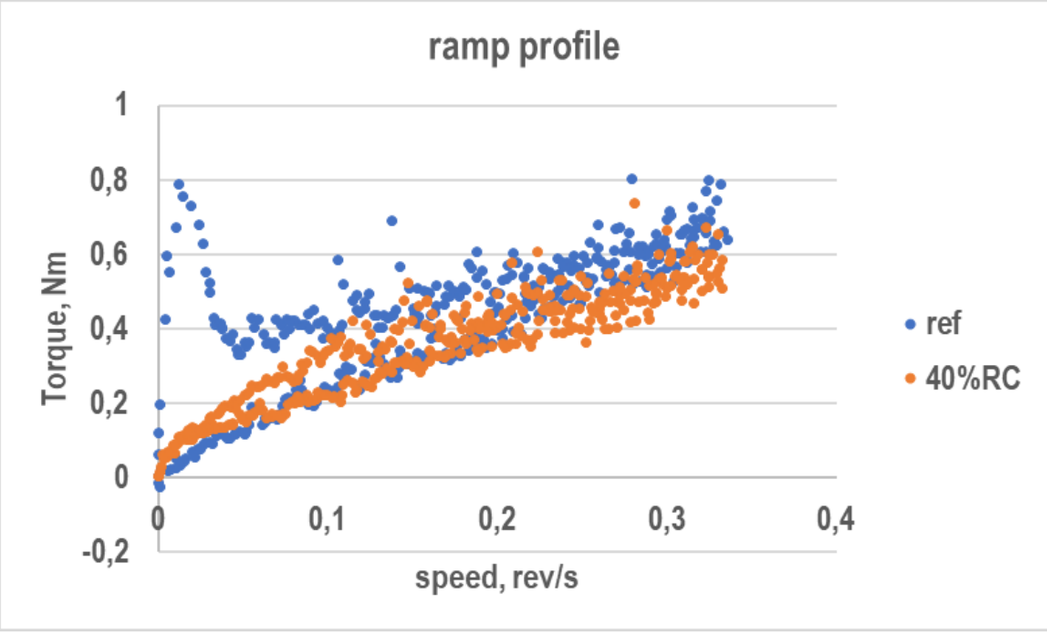
Measuring results

Rheological parameters with eBT-V

V mode, ramp profile:

→ No equilibrium reached

→ Different results compared to step profile but same tendency!



Mix	A_{thix}	rel. values		Calc. values accord. Reiner-Riwlin	
		Rel. Viscosity, H [Nms]	Rel. Yield stress, G [Nm]	Calc. Viscosity [Pas]	Calc. Yield stress [Pa]
Mix 1, reference	0,8	1,84	0,04	**70**	12
Mix 2 with 40% recycled material	-	1,42	0,08	**54**	23

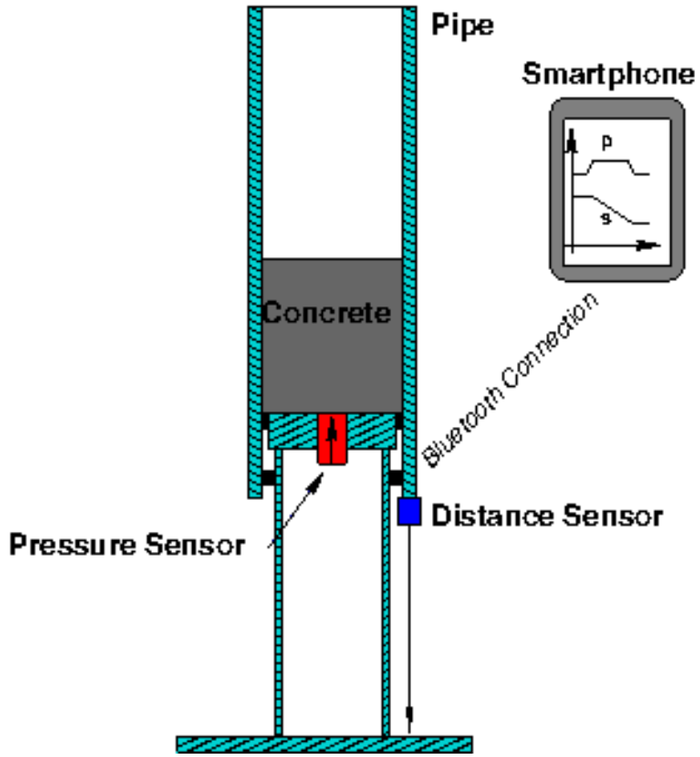
→ **Additional information: reference material shows thixotropy**

→ **viscosity (and yield stress) not comparable**

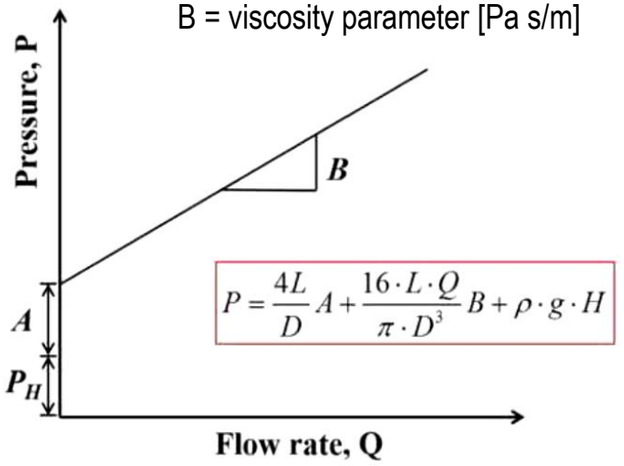
→Different rheological behaviors!

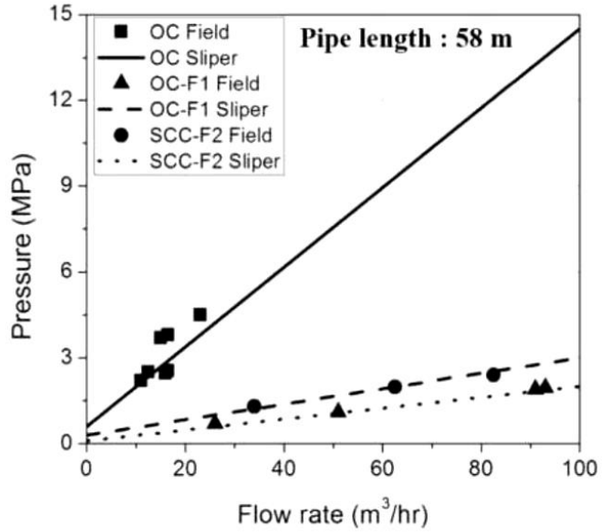
Measuring pumpability

Pumpability with SLIPER – calculation basis



P = pump pressure [bar]
Q = flow rate [m^3/h]
L = length of the pipeline [m]
D = diameter of the pipeline[m]
A = yield stress parameter [Pa]
B = viscosity parameter [Pa s/m]

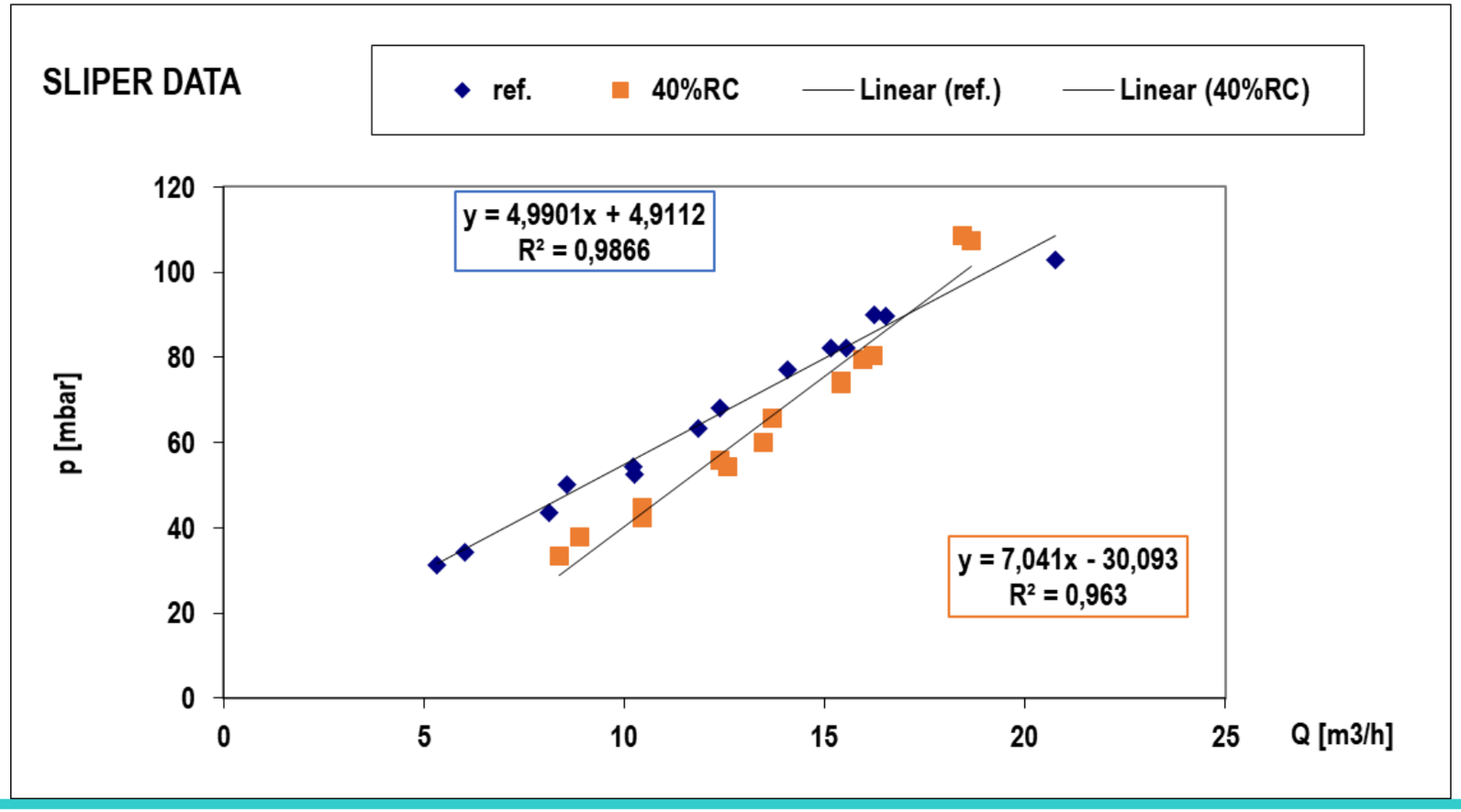




- K.J. Kasten, Gleitrohr-Rheometer: Ein Verfahren zur Bestimmung der Fließeigenschaften von Dickstoffen in Rohrleitungen, Dissertation, Dresden, 2010
- V. Mechtcherine et al., Testing pumpability of concrete using Sliding Pipe Rheometer, Constr. Build. Mater. 53, 2014

Measuring results

Pumpability with SLIPER - results

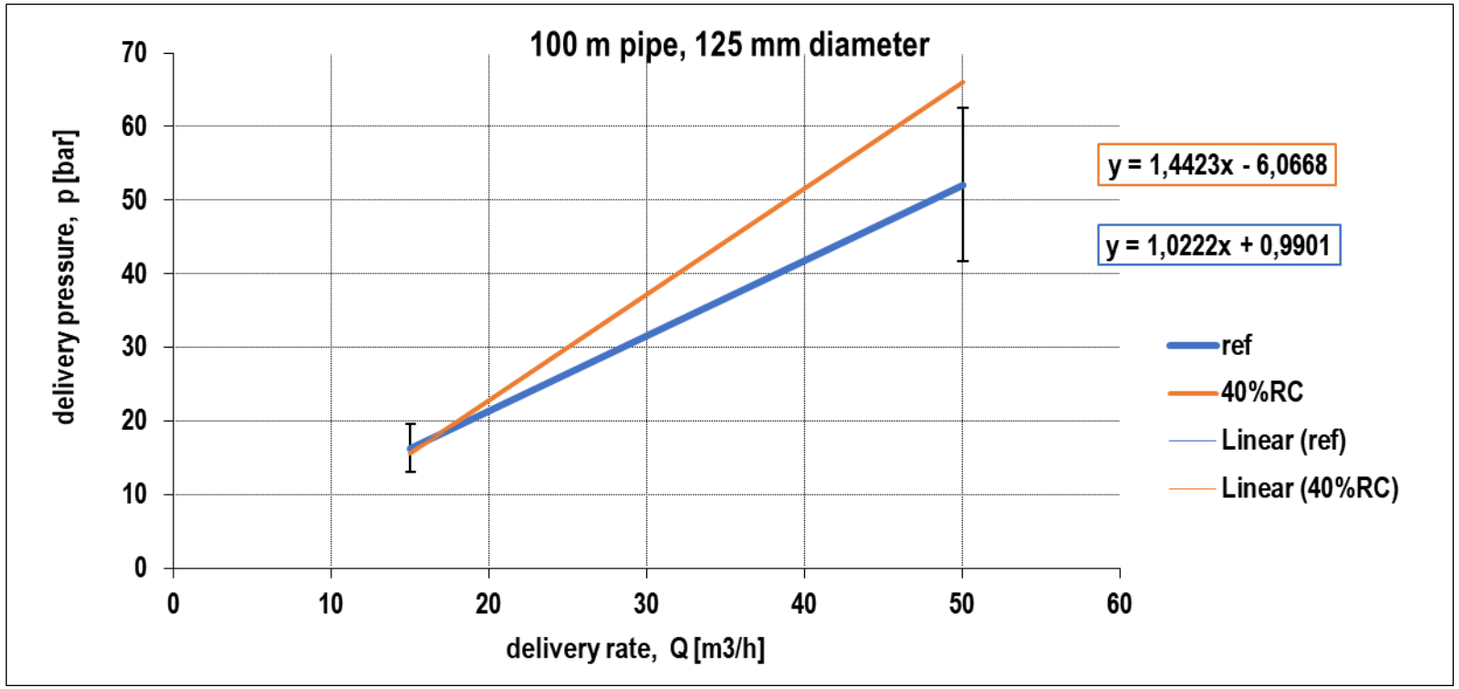


→ Different behaviors of the mixtures in regards to the pumping procedure!

Measuring results

Pumpability with SLIPER

Calculated delivery pressure for 100 m pipe with 125 mm diameter:



	Pump requirement / delivery pressure in bar for 100m pipe with 125 mm diameter	
	desired flow rate	
Mix design	15 m3/h	50 m3/h
Mix 1, reference	16,3	**52**
Mix 2 with 40% recycled material	15,6	**66**

Measuring results - conclusion

- Investigation of the rheological parameters of the reference mixture 1 and the mixture 2 where 40 % of the aggragates were replaced by recycled mineral material
- Water amount of the mixture 2 was adoped to the adsorption behavior of the recycled material
- Measuring result of flow cone: both mixtures are comparable
- Measuring results from eBT-V rheometer:
  - different rheological behaviours of mixture 1 and mixture 2: mixtures are not comparable
  - Measuring results are dependent on measuring setup
    - Pre-shearing
    - Equilibrium
    - Measurement duration
- Measuring results from SLIPER:
  - Different behaviours of the mixtures in regards to the pumping procedure
  - Mixtures are not comparable!

- Investigation of rheological parameters using Abrams cone or flow cone or similar is not always sufficient!

Our products:

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Building Materials Testing Systems

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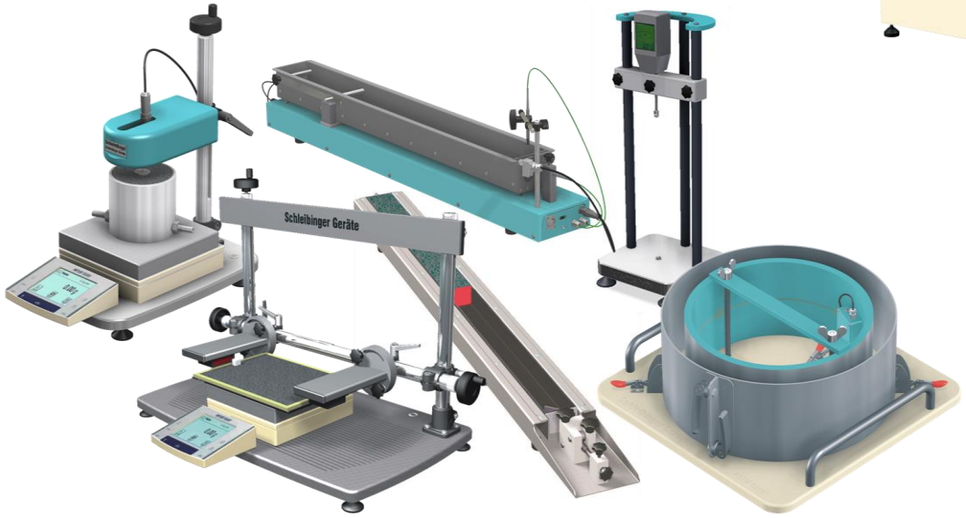
- Durability



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Thank you for your attention!

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