IFF WEIMAR E.V. - SCIENCE MEETS INDUSTRY

APPLICATION OF THE PARTICLE SIMULATION ON THE EVALUATION OF THE RHEOLOGICAL PROPERTIES OF FRESH CONCRETE

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Rheologische Messungen an mineralischen Baustoffen
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Overview

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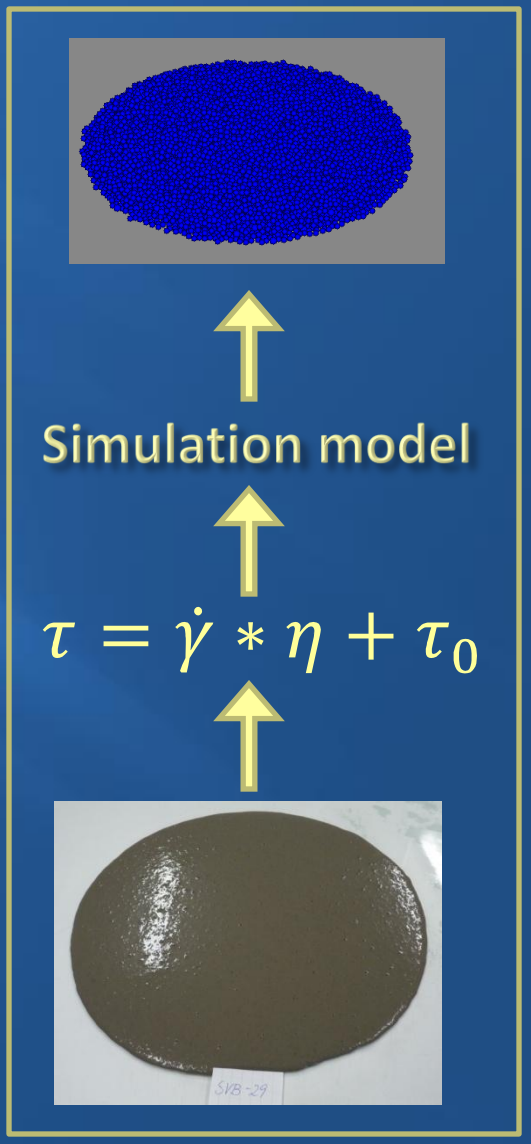
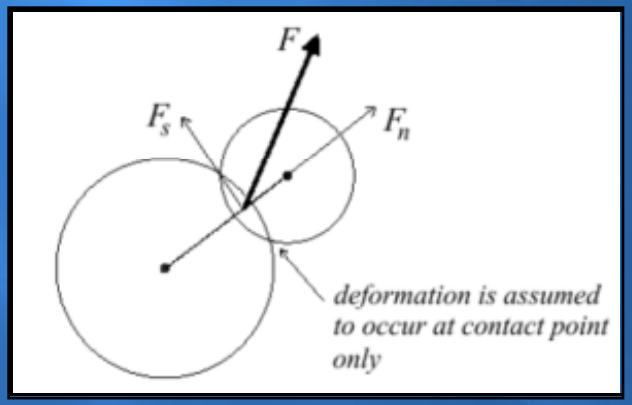
   1. Simulation technique
   2. Contact models
   3. Simulation vs. Experiments
   4. Conclusion
2. Parameter extraction
   1. Viskomat NT
   2. Piping test rig
   3. Results

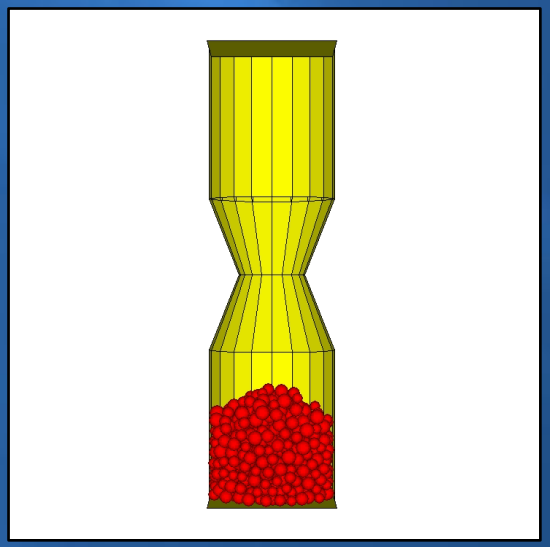


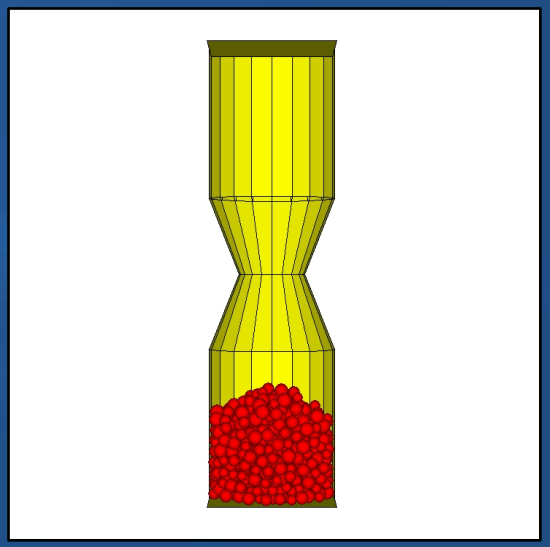
DEM Simulation

Basics of the Discrete Element Method

- Granular and flowable materials
- Large amount of independent elements(particles)
- Discrete timesteps
- Contact models



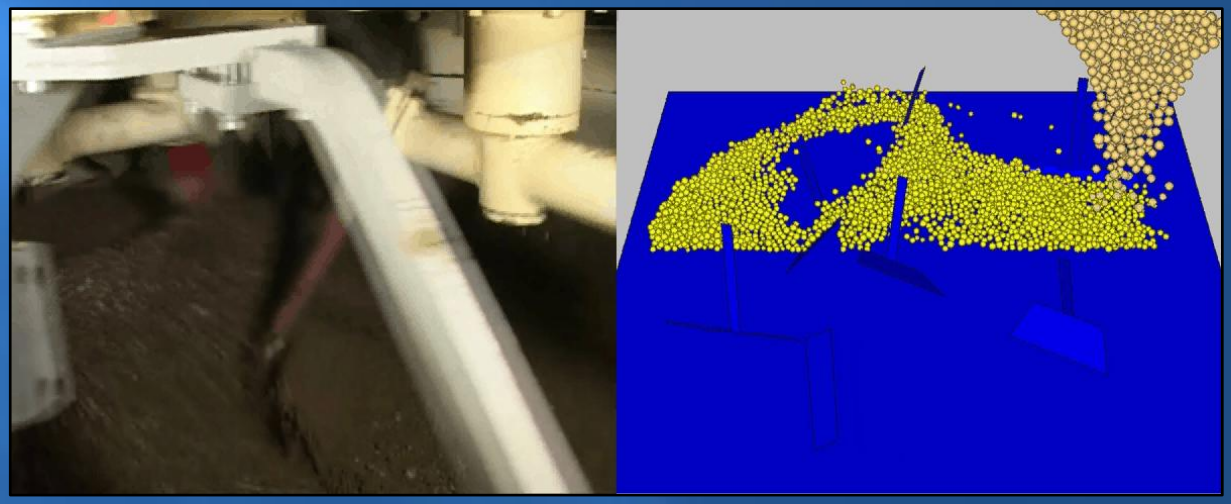


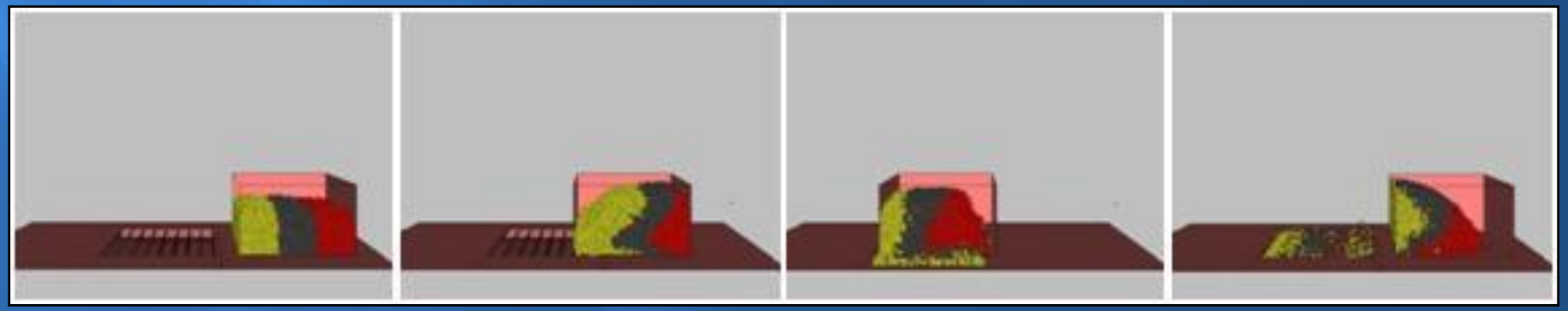


DEM Simulation

Applications

- Mixing
- Filling
- Transport
- Compaction





Contact models

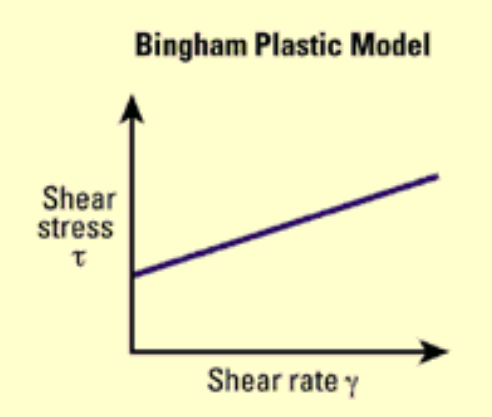
User defined contact models

- Goal:
  - Process/Material-specific simulation
  - More exact material behavior
- Precondition: complex models
- Modeling accuracy vs. Computation time
- Examples:
  - Wet Mixing
  - Model for flowable concrete

Contact models

Flowable concrete

- Based on Bingham-Model
- Double layer particles
- Independent from particle size
- Direct parameter implementation



$$\tau = \dot{\gamma} * \eta + \tau_0$$

Contact models

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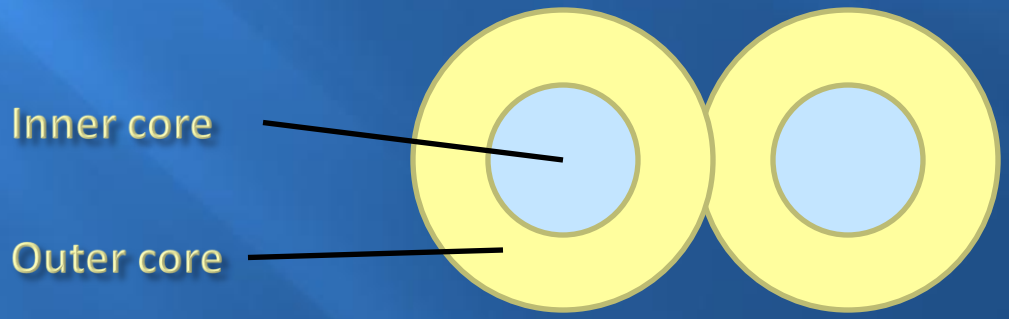

Contact models

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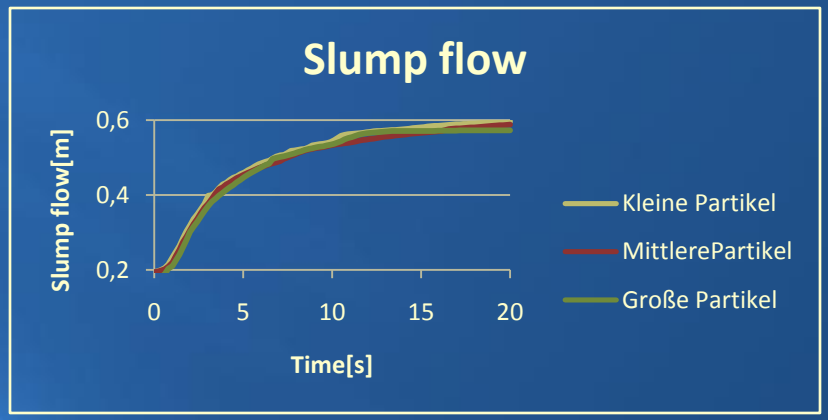
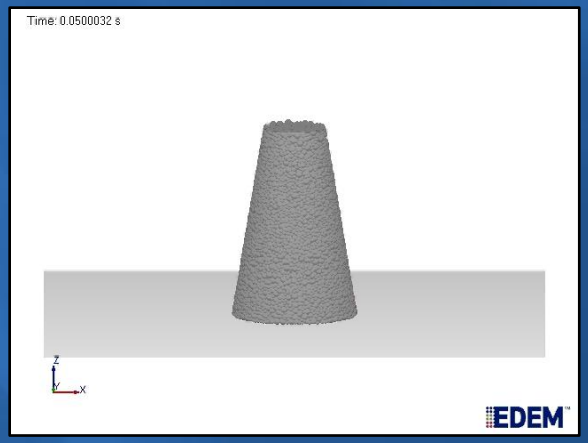


Fine Material



Medium Material

Coarse Material

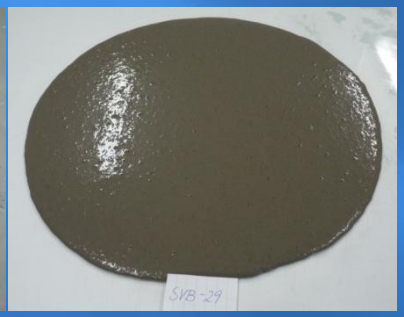
Contact models

Flowable concrete

- Based on Bingham-Model
- Double layer particles
- Independent from particle size
- Direct parameter implementation

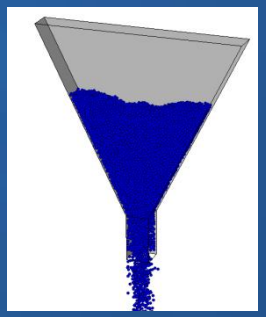
Simulation vs. Experiments

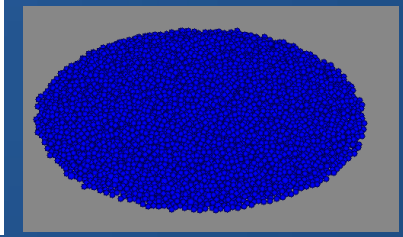
Real calibration experiments

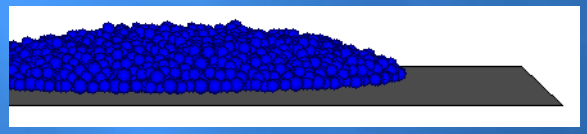


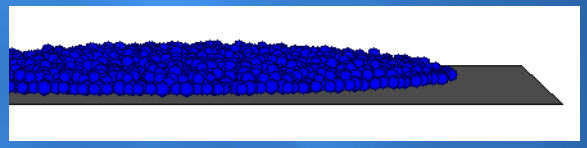
Verification

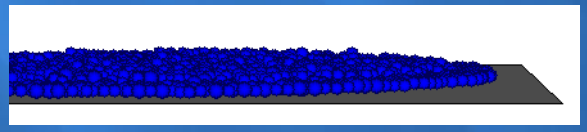
Simulated Experiments

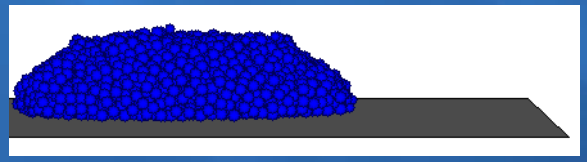










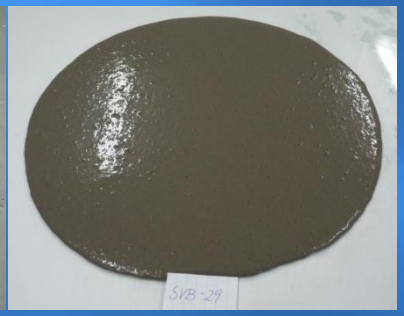


Parameter adaption

Simulation model

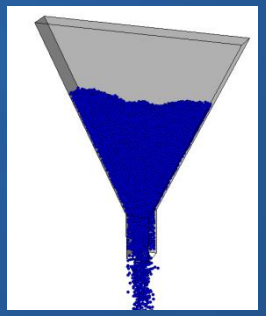
Simulation vs. Experiments

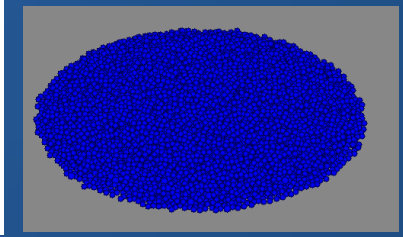
Real calibration experiments



Verification

Simulated Experiments





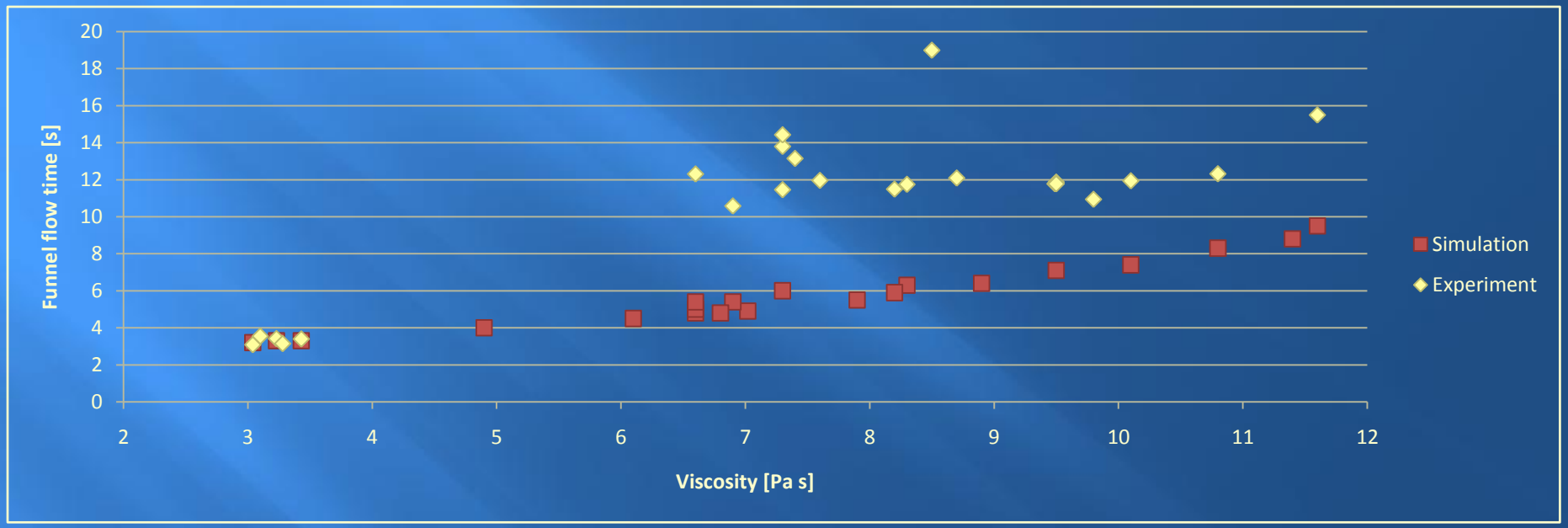
Parameter extraction

Yield Stress & Viscosity

Simulation model

Simulation vs. Experiments

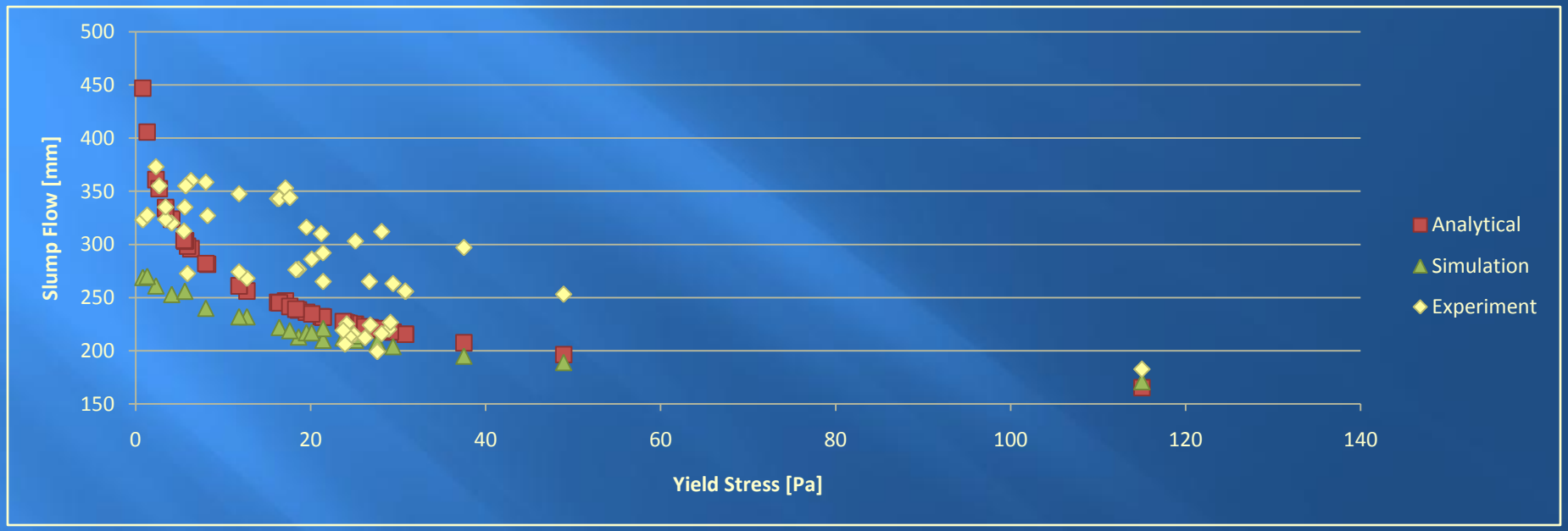
V-Funnel Test



- Simulation has same tendency
- Simulation underestimates increase of time

Simulation vs. Experiments

Slump flow



- Simulation has same tendency
- Simulation underestimates slump flow

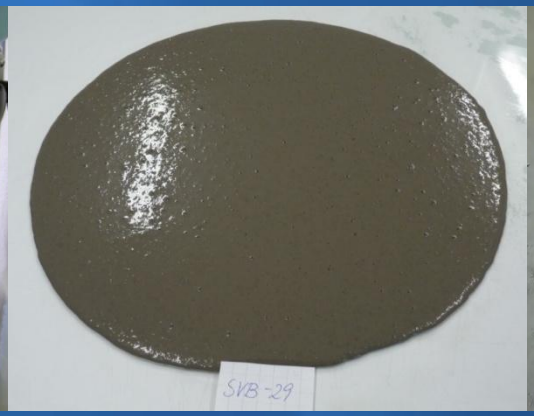
Conclusion

- User defined Contact models
  => process specific material behavior
- Behavior of fresh concrete by Bingham model parameters
- Simulation shows adequate approximation for free flow

Parameter Extraction

Goal: rheological parameters of scc-mortar like viscosity and yield stress

- slump flow test
- v-funnel test
- Viscometer tests with viskomat NT
- pipe test




Parameter Extraction

Viskomat NT

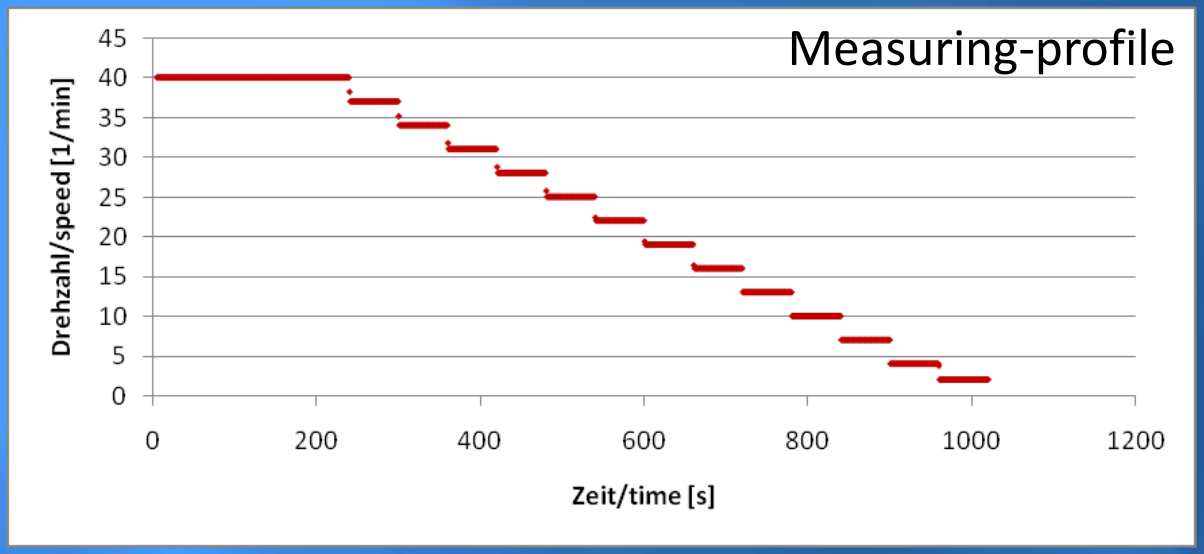
- Flow behavior of scc-mortars and fly ash mortar
- Using of Vogel - measuring cell
- Vogel-approximation

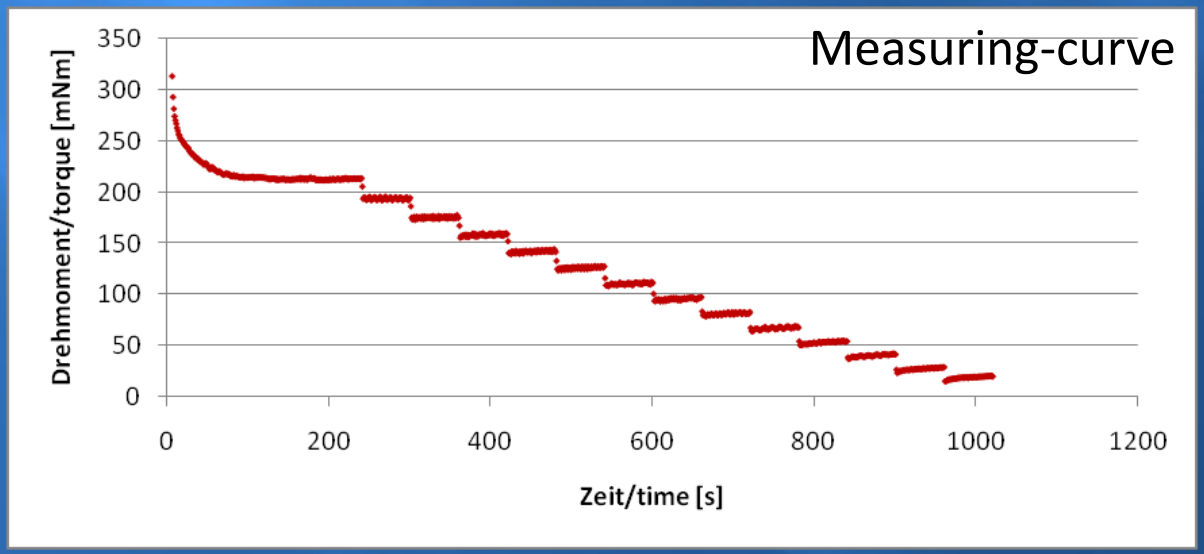
$$\tau = \tau_0 + \eta_0 \dot{\gamma} \frac{1}{\left\{1 \pm \frac{\eta_0}{2\sigma} \dot{\gamma}\right\}}$$

- Bingham-approximation

$$\tau = \tau_0 + \eta_{pl} \dot{\gamma}$$

Parameter Extraction





Composition

Bestandteil / component	Menge / amount [g]
Zement / cement	506
Flugasche / fly ash	270
Sand 0/2 / sand 0/2	930
Wasser / water	228
w/z-Wert	0,45

Bestandteil / component	Menge / amount [g]
Flugasche / fly ash	600
Sand 0/2 / sand 0/2	1200
Wasser / water	270
w/b-Wert	0,45

Parameter Extraction

Superplasticizers:

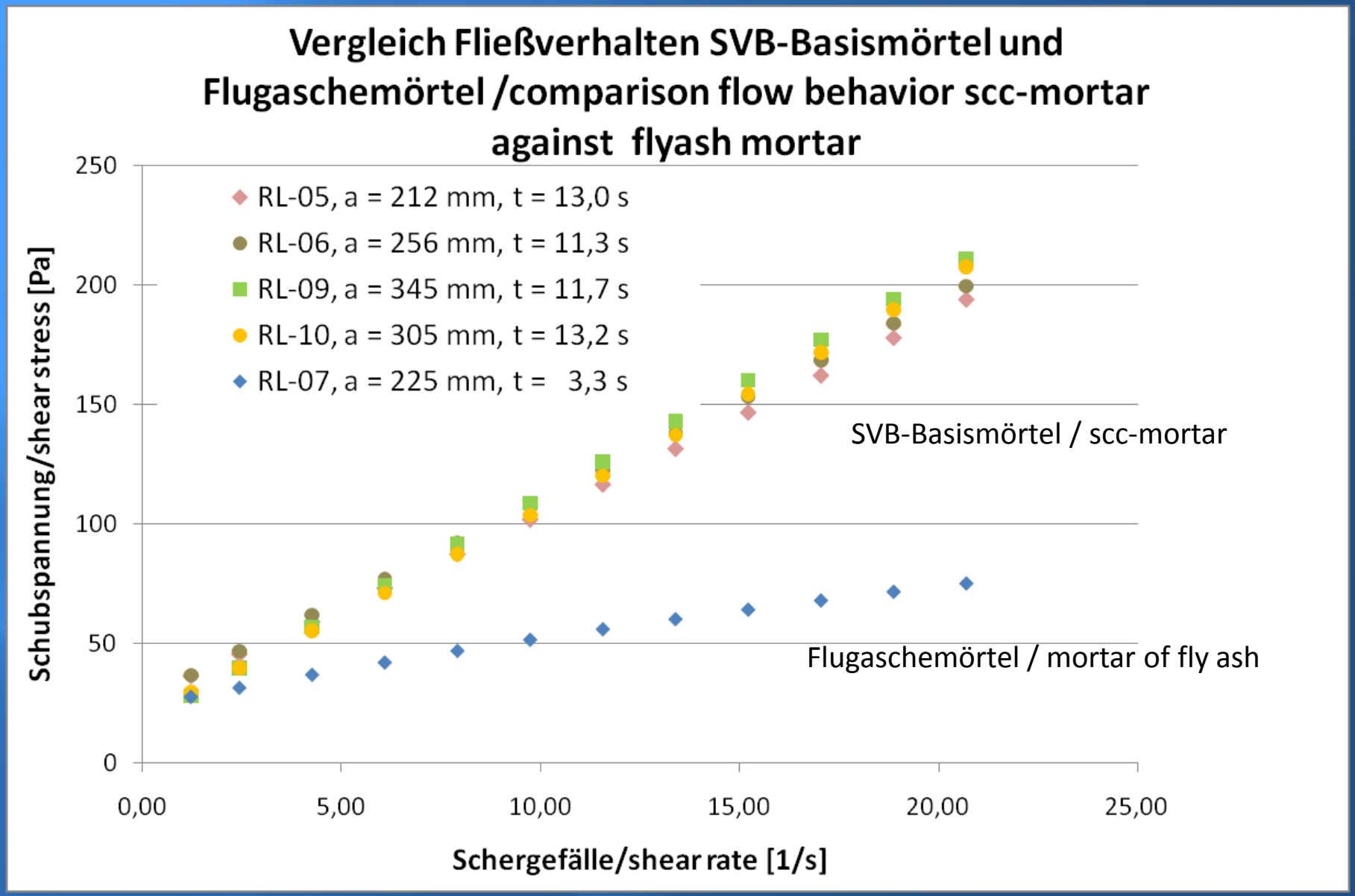
6 several Polycarboxylatether (PCE)

Cements:

Composite cement C1
Composite cement C2
Portland cement C3

Determination of kind and amount of superplasticizer and kind of cement on flow behavior

Parameter Extraction



Parameter Extraction

Nr.	Be-zeich-nung / name	Binde-mittel / binder	Fließ-mittel / super-plasti-cizer	Setz-fließ-maß / slump flow	Trichter-auslauf-zeit / v-funnel	Approximation - Vogel			Approximation - Bingham	
						$\tau = \tau_0 + \eta_0 \dot{\gamma} \cdot 1/(1 \pm (\eta_0/2\,\sigma)\,\dot{\gamma}\cdot)$			$\tau = \tau_0 + \eta_{pl}\,\dot{\gamma}\cdot$	
				a	t	η_0	σ	τ_0	η_{pl}	τ_0
				[mm]	[s]	[Pas]	[Pa]	[Pa]	[Pas]	[Pa]
1	RL-V05	C1	PCE 1	212	13,0	7,2	732	26,4	8,3	21,5
2	RL-V06	C2	PCE 1	256	11,3	8,0	2339	24,0	8,4	21,7
3	RL-V10	C3	PCE 6	305	13,2	10,2	2173	27,4	10,1	27,3
4	RL-V09	C2	PCE 6	345	11,7	9,5	4940	16,8	9,9	13,3
5	RL-V07	fly ash	PCE 1	225	3,3	3,2	97	23,8	2,3	26,5

Parameter Extraction

pipe test

- Flow behavior of scc-mortars and fly ash mortar
- Using pipe test rig

→ Measuring of loss of pressure and volumetric flow rate

→ Determination of pipe characteristic curve of bingham fluids on the basis on Hagen-relation

- Bingham-approximation

$$\tau = \tau_0 + \eta_{pl}\,\dot{\gamma}$$

- Using of Buckingham-Reiner-relation

$$\dot{V} = \frac{\pi \cdot \Delta p \cdot R^4}{8 \cdot \eta_{pl} \cdot L}\left[1 - \frac{4}{3}\frac{r_0}{R} + \frac{1}{3}\left(\frac{r_0}{R}\right)^4\right]$$

Parameter Extraction

- pipe chracteristic curve

$$\frac{\Delta p}{L} = \frac{128 \cdot \eta_{pl}}{\pi \cdot D^4} \dot{V} + \frac{16 \cdot \tau_0}{3 \cdot D}$$

$$\tau_0 = \frac{3 \cdot n \cdot D}{16}$$

→ yield stress:

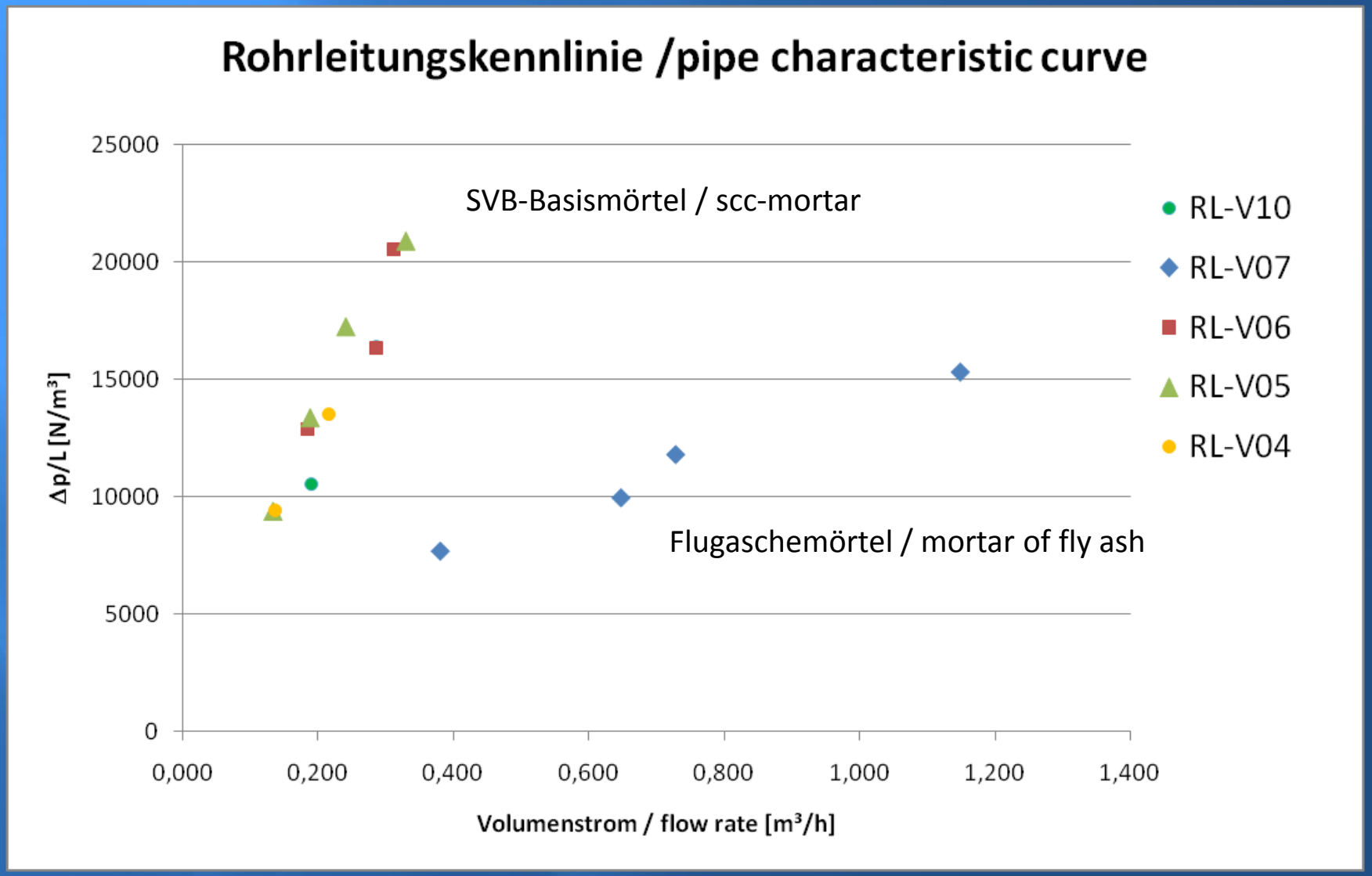
$$\eta_{pl} = \frac{m \cdot \pi \cdot D^4}{128}$$

→ plastic viscosity:

- intersection with x-axis is n and slope of the line is m

$$\Delta p / L = f(\dot{V})$$

Parameter Extraction



Parameter Extraction

Nr.	Bezeichnung / name	Bindemittel / binder	Fließmittel / superplasticizer	Setzfließmaß / slump flow	Trichterauslaufzeit / v-funnel	Approximation - Bingham		Ergebnisse des Rohrleitungsversuches /pipe results	
						$\tau = \tau_0 + \eta_{pl}\,\dot{\gamma}$		$\tau = \tau_0 + \eta_{pl}\,\dot{\gamma}$	
				a	t	η_{pl}	τ_0	η_{pl}	τ_0
				[mm]	[s]	[Pas]	[Pa]	[Pas]	[Pa]
1	RL-V05	C1	PCE 1	212	13,0	8,3	21,5	8,7	15,0
2	RL-V06	C2	PCE 1	256	11,3	8,4	21,7	7,9	19,3
5	RL-V07	fly ash	PCE 1	225	3,3	2,3	26,5	1,5	26,2

Parameter Extraction

Results:

Good correlation between results of the pipe test and the results of the viscometer Viskomat NT

Using following parameters for the DEM-simulation:

τ_0 = 20 Pa

η_{pl} = 8 Pas

Parameter Extraction

Results

- scc-mortar and fly ash-mortar were tested
- tests with viscomat NT, pipe test, slump flow and v-funnel test were made
- Approximation – Vogel and Approximation Bingham were made
- pipe characteristic curve was determined
- loss of pressure of scc-mortar in pipe is higher than the one of fly ash-mortar
- flow of the several scc-mortars is nearly comparable (one composition, several superplasticizers and cements) in pipe
- results of pipe test are comparable to results of viscomat NT
- rheological parameters could be determined, which are parameters for the simulation (plastic viscosity, yield stress)

Project

Research project:

Adaption numerischer Simulationsmodelle für die Optimierung von Verarbeitungsprozessen mineralischer Stoffsysteme

Research promotion:

Bundesministerium für Wirtschaft und Technologie

(Projekt-Reg. Nr.: VF080006)

Thanks for the attention

Your research partner and service provider for DEM and beyond:

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