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CONTRIBUTION OF THE COARSE AGGREGATE FRACTION TO RHEOLOGY –

EFFECTS OF FLOW COEFFICIENT, PARTICLE SIZE DISTRIBUTION, AND VOLUME FRACTION

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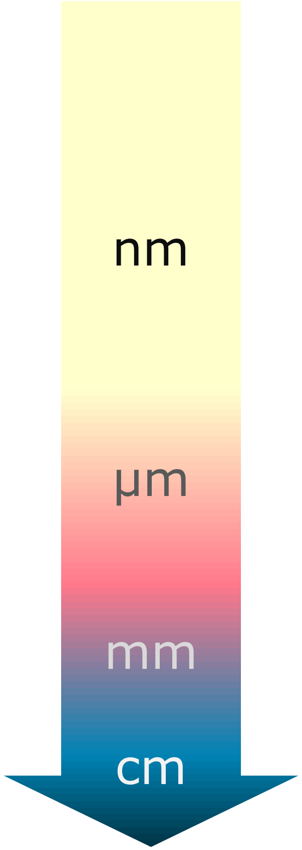
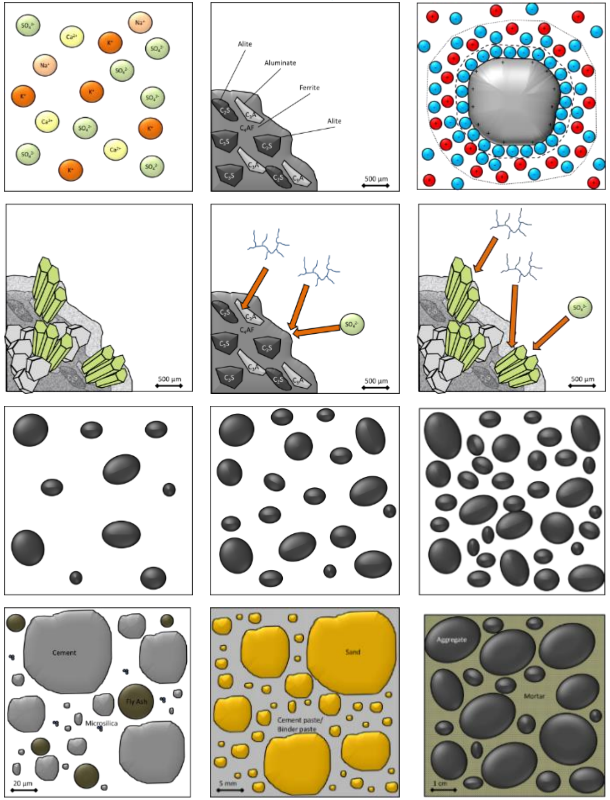
Introduction - Rheology influences in concrete

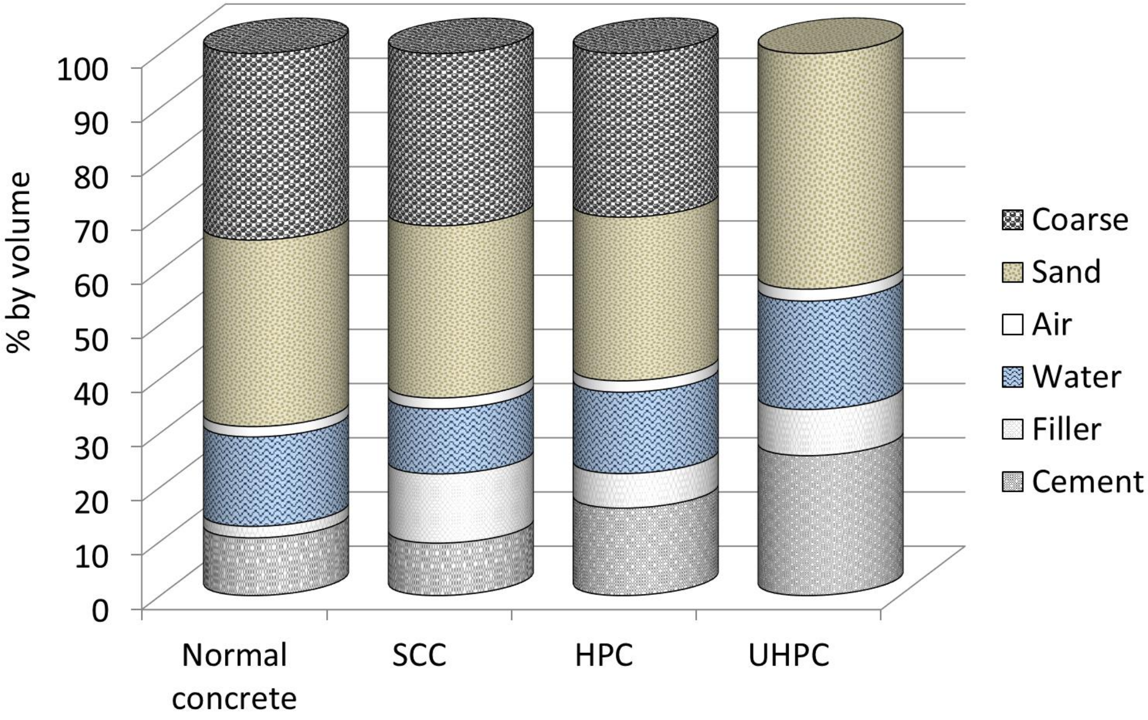


- Ion content and strength
- Surface chemistry and charges
- Polymer sizes and structure
- Selective adsorption
- Competitive adsorption
- Different particle charges
- Hydration phases
- Morphology
- Powder properties
- Different particle sizes
- Solid volume fraction
- Interaction of particle sizes
- PSD of finest particles
- PSD of coarser particles



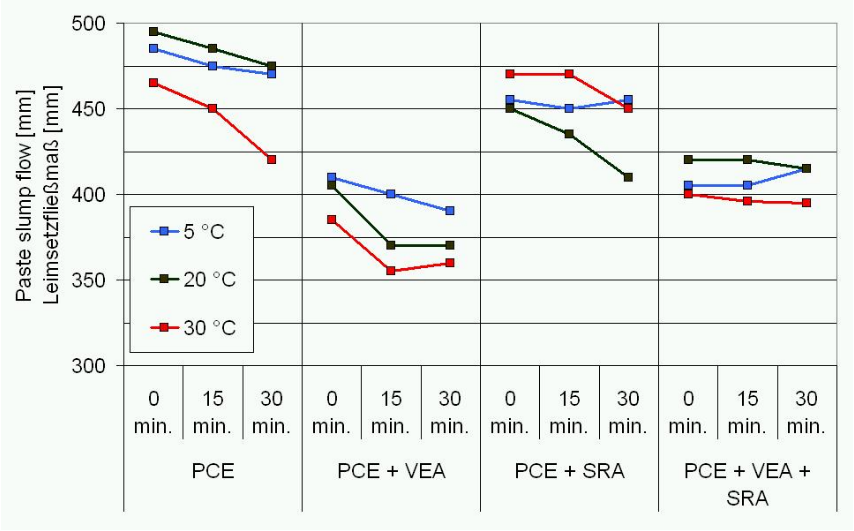
Introduction – Relevance of coarse aggregates

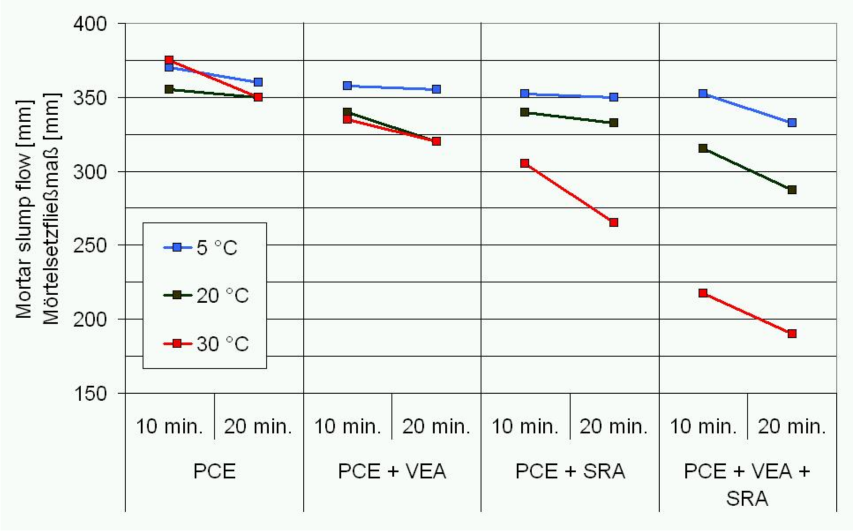
- With increasing flowability and increasing strength, the relevance of the finer fractions increases.
- However, 96% of all ready mixed concrete types are normal strength and normal consistency. (BTB 2016)



Introduction – Relevance of coarse aggregates

- We can effectively manipulate the rheology on nm to mm scale.
- We would not try to significantly control rheology based on mm scale.
- But effects on mm and cm scale overlap with paste effects.





Introduction – Challenges

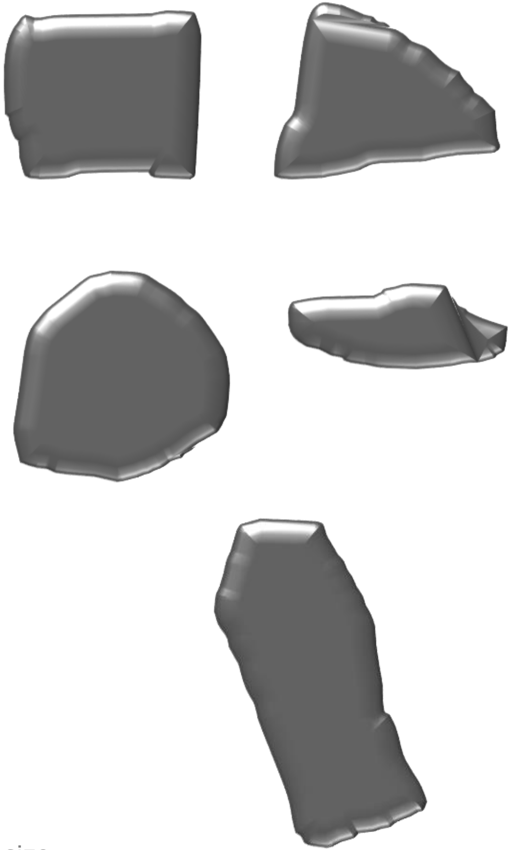
Different ideas have been developed,

– Grading curves (e.g. Andreasen, Funk & Dinger)

– Modelling (e.g. De Larrard, Stroeven)

But grading curves cannot represent the complex reality,

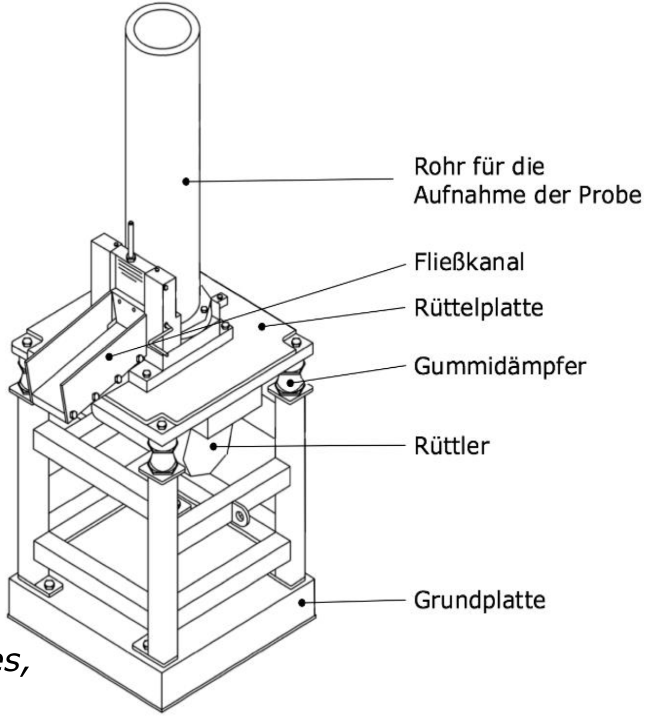
And real aggregates seldomly behave like modellised (and mostly uni-sized, often round) particles.



Introduction - Motivation

Is there a simple experimental parameter that can predict the „rheology" of aggregates?

Can the flow coefficient provide adequate information?



EN 933-6 Tests for geometrical properties of aggregates - Part 6: Assessment of surface characteristics - Flow coefficient of aggregates, Beuth Verlag GmbH, Berlin, Juli 2014

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EXPERIMENTAL SETUP

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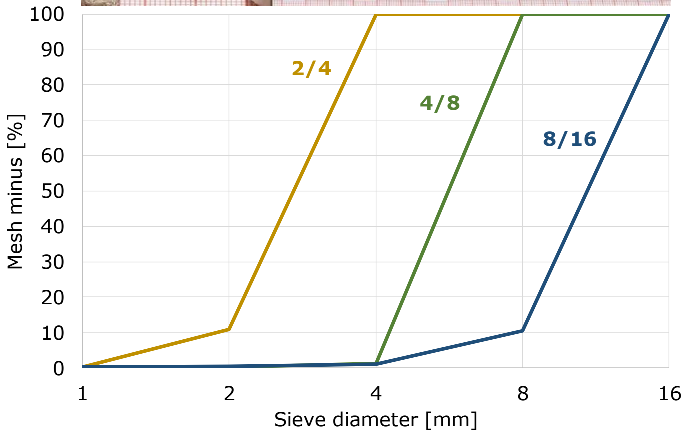
Experimental – aggregate properties

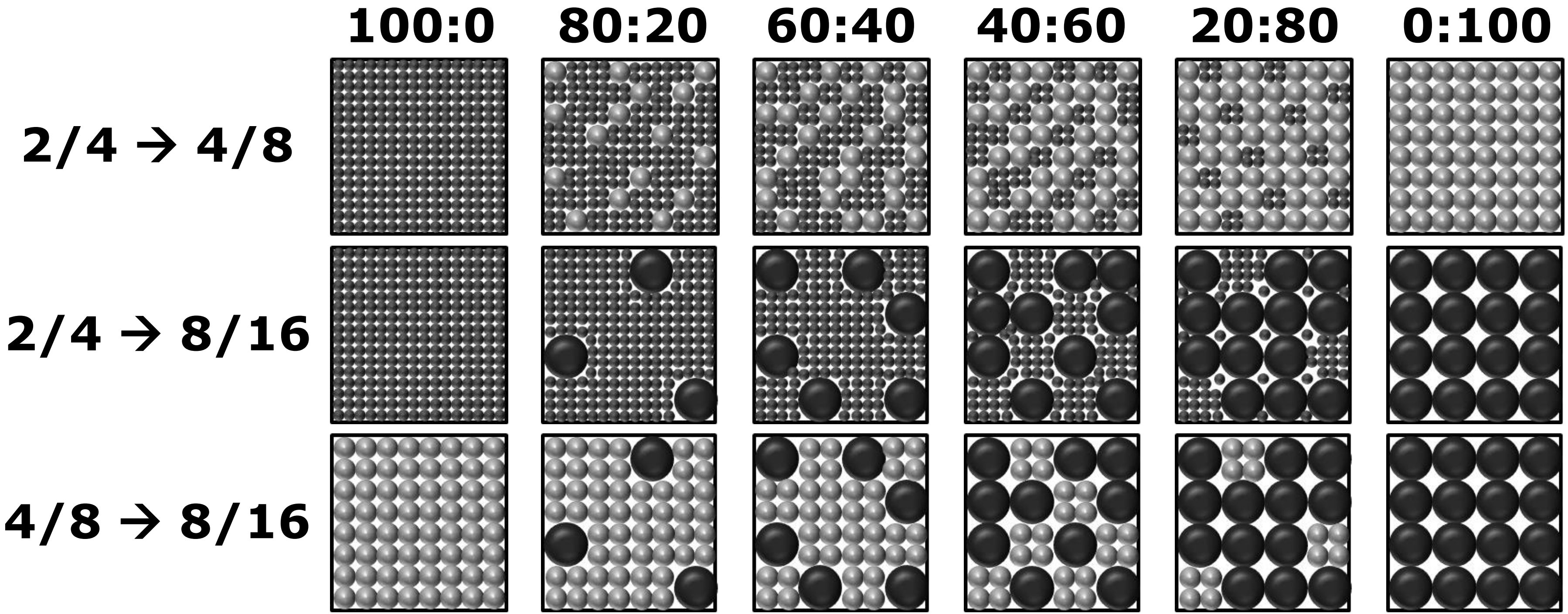
Quartzitic aggregates

Three fractions: 2/4; 4/8; 8/16

Density ~ 2650 kg/m³

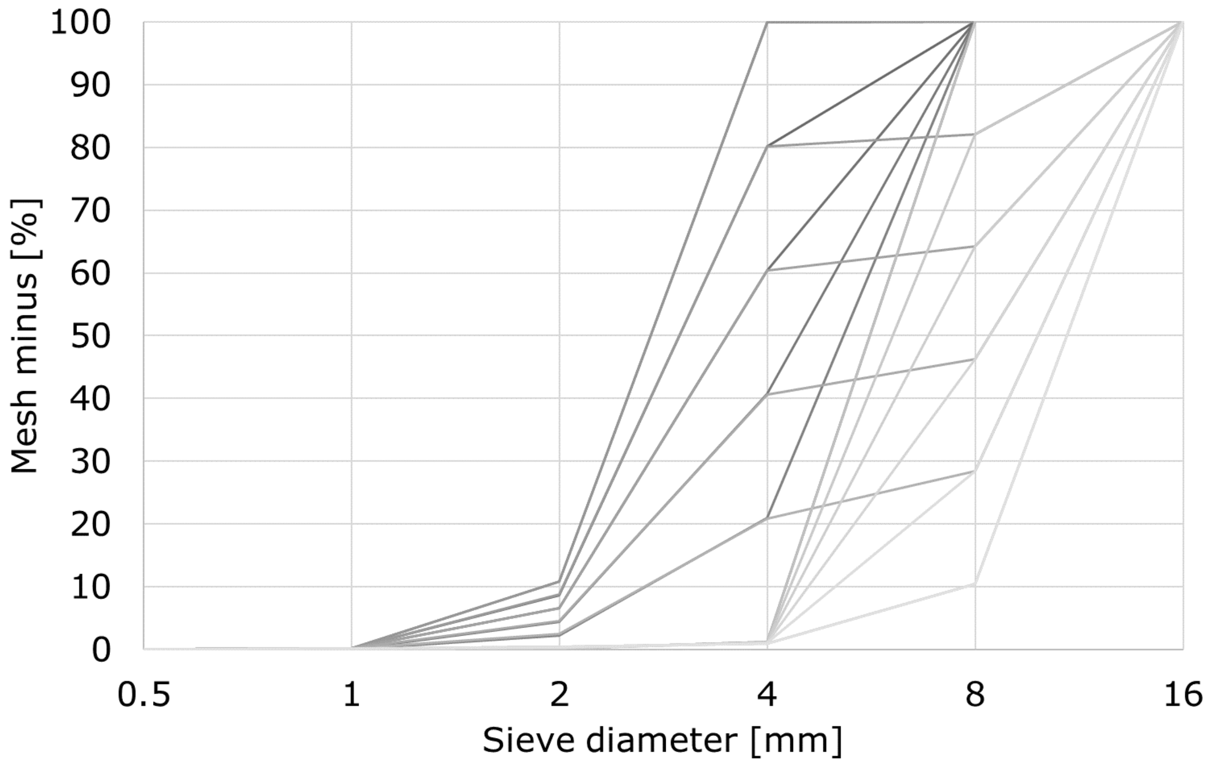


Experimental – investigated variations



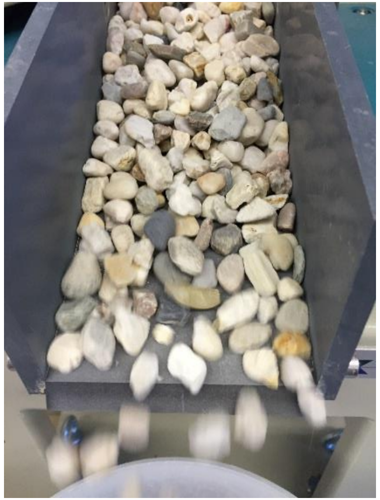
Experimental – investigated variations

Experimental – grading curves



Experimental – flow coefficient

1. Determine funnel opening
2. Place beaker and balance
3. Fill aggregates in plastic pipe
4. Start vibrating
5. Open funnel
6. At 1000 g, start stop watch
7. Take time, when balance shows
   $m = 1000 \cdot (1 + 7 \cdot \rho_p/2.70)$
8. For standard aggregates, the flow coefficient is the time that ~7 kg or ~2.6 l take to run out.



Experimental – flow coefficient

Each sample was tested three times from the same batch.

Each batch was repeated individually for three times.

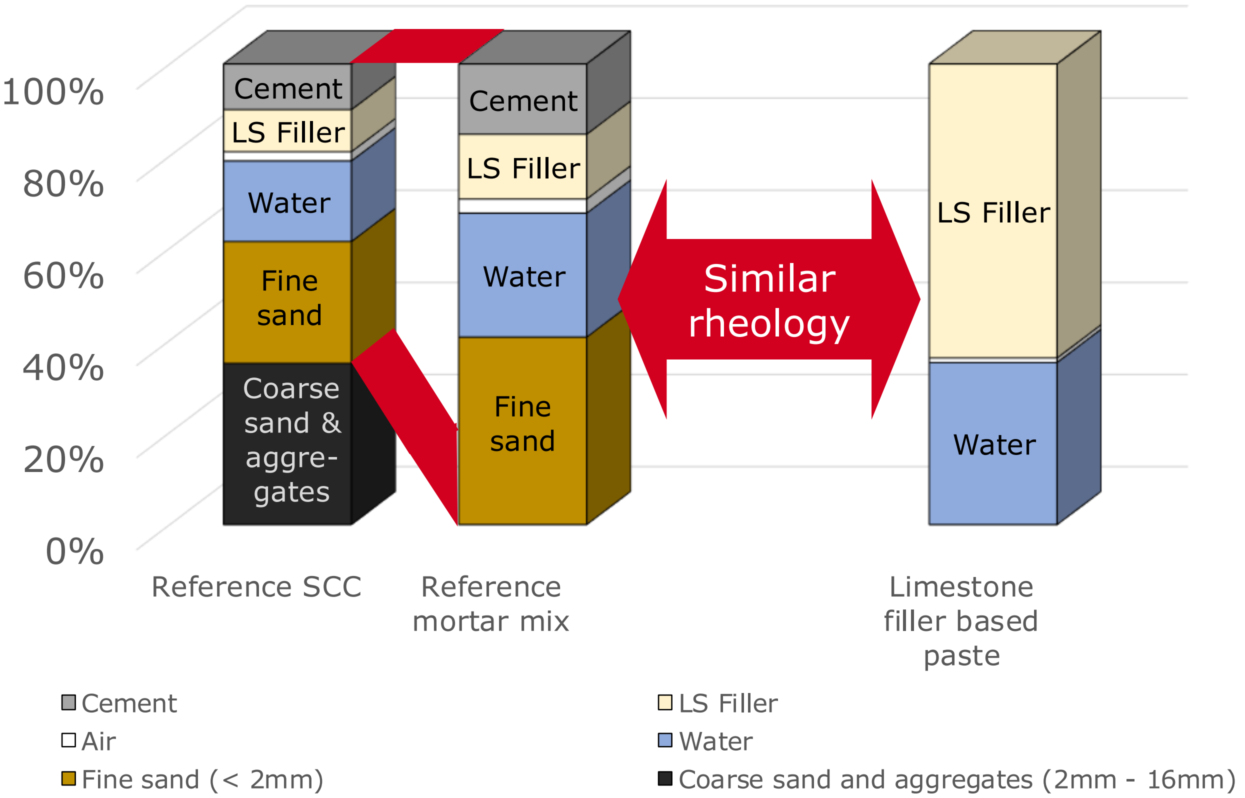
→ 3 x 3 x 15 = 135 repetitions

The flow coefficient was determined as the arithmetic mean of 9 measurements.

Experimental – loose bulk density

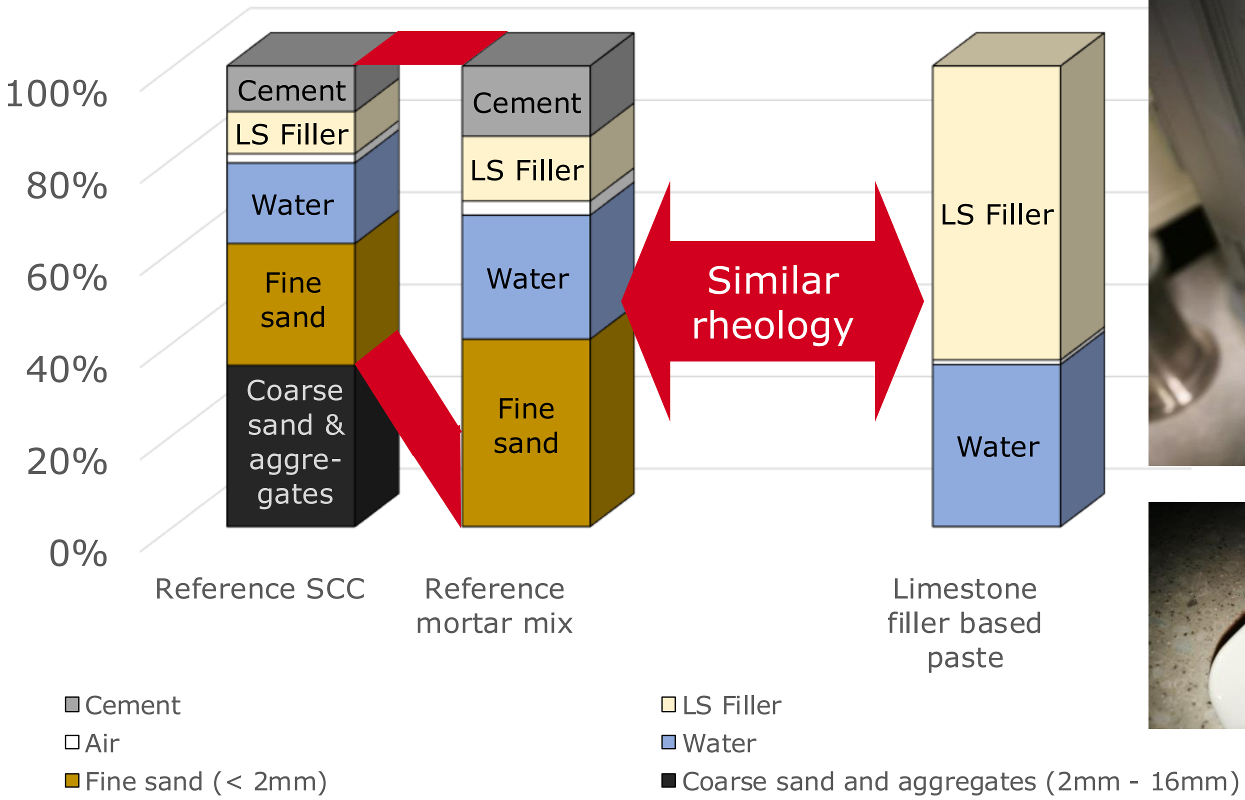
EN 1097-3:199 Tests for mechanical properties of aggregates. Part 3: Determination of loose bulk density and voids

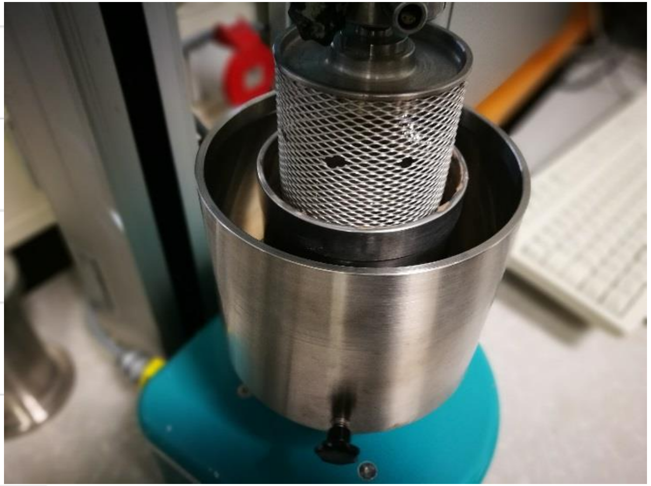
Experimental – limestone filler paste



No fine sand in the paste to avoid any interactions!

Experimental – limestone filler paste

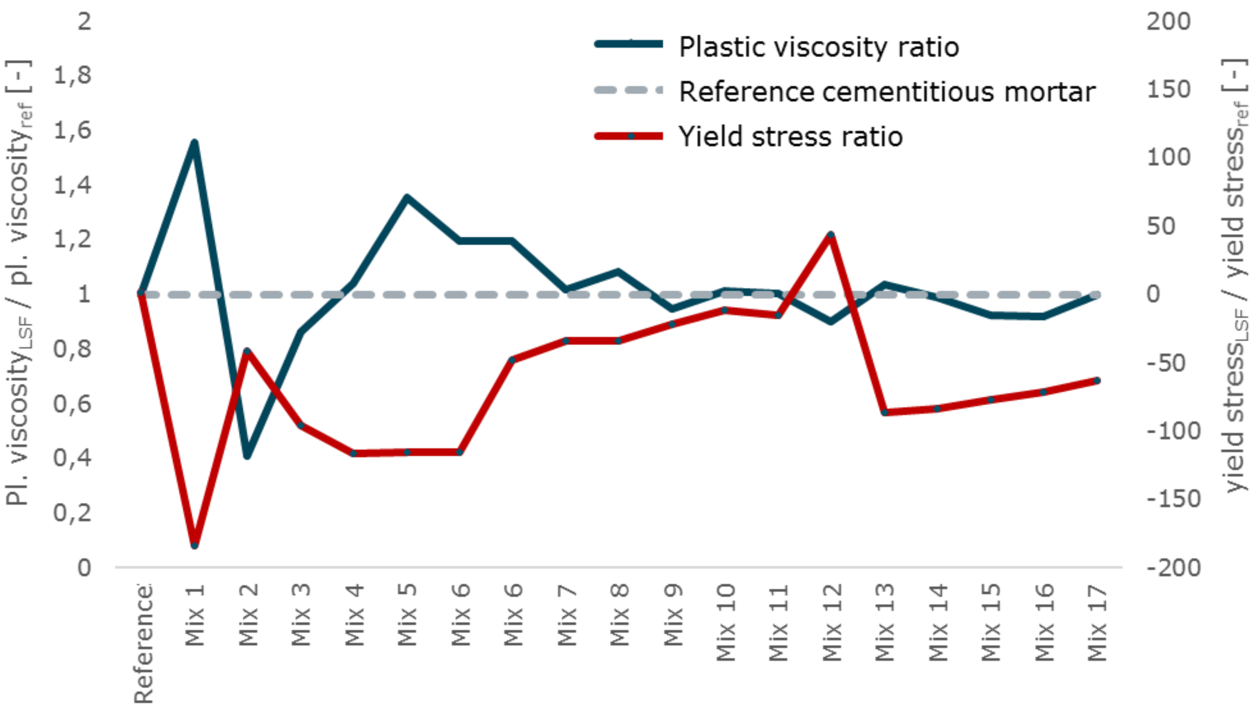




Experimental – limestone filler paste

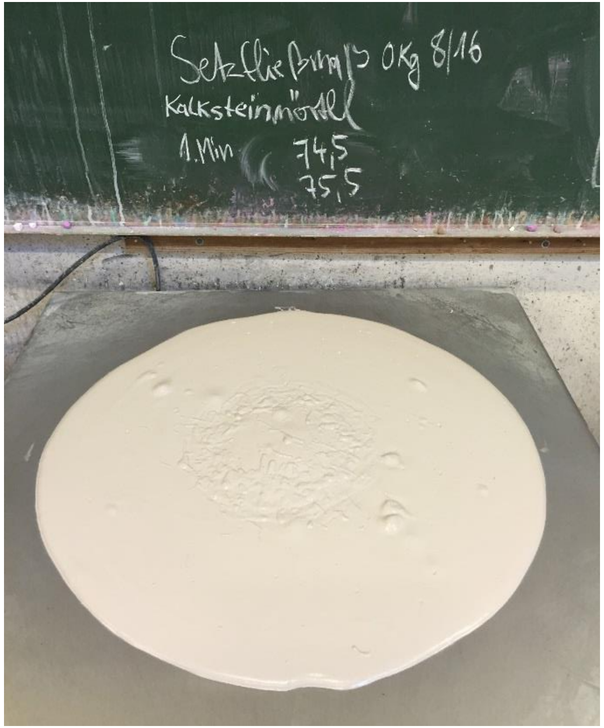
Influence of the admixture combination:

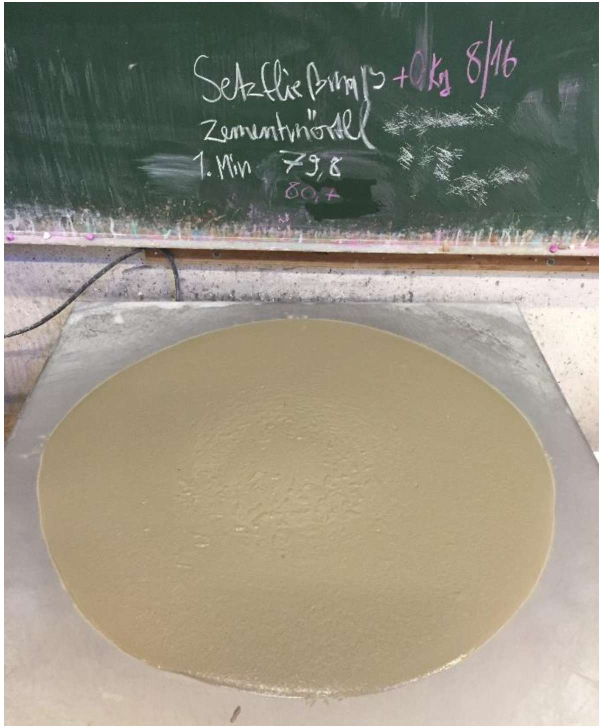
Experimental – limestone filler paste



Experimental – limestone filler paste

Influence of the admixture combination:





Experimental – limestone filler "concrete"

100% LS paste

88% LS paste

12% coarse

78% LS paste

22% coarse

70% LS paste

30% coarse

64% LS paste

36% coarse

59% LS paste

41% coarse

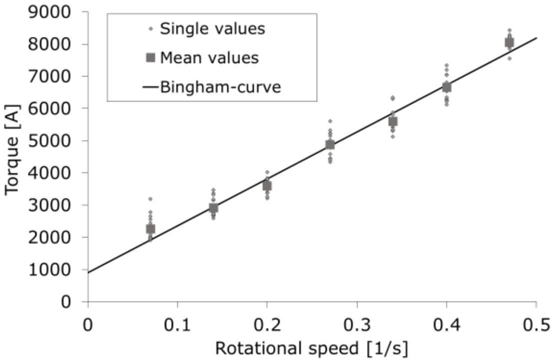
Experimental – rheometric investigations

Rheometer 4-SCC

Bingham evaluation of measurement data

Only qualitative results possible:

- Yield stress related value: [A]
- Plastic viscosity related value: [A·s]



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RESULTS

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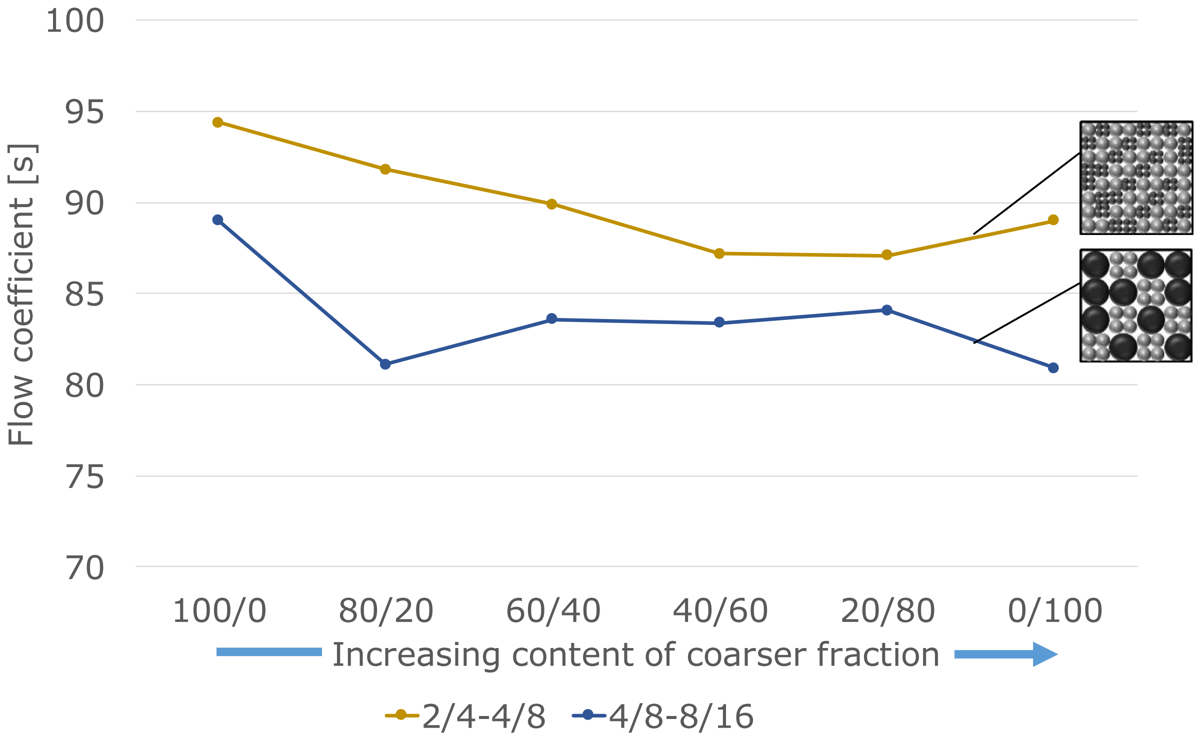
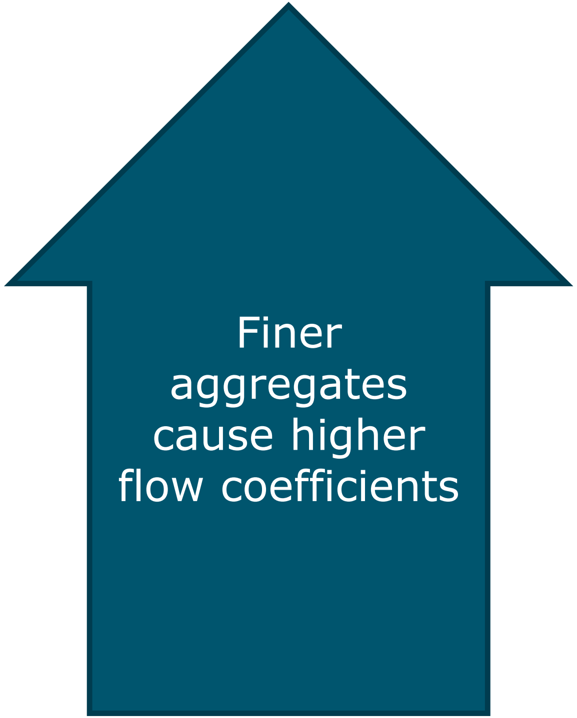
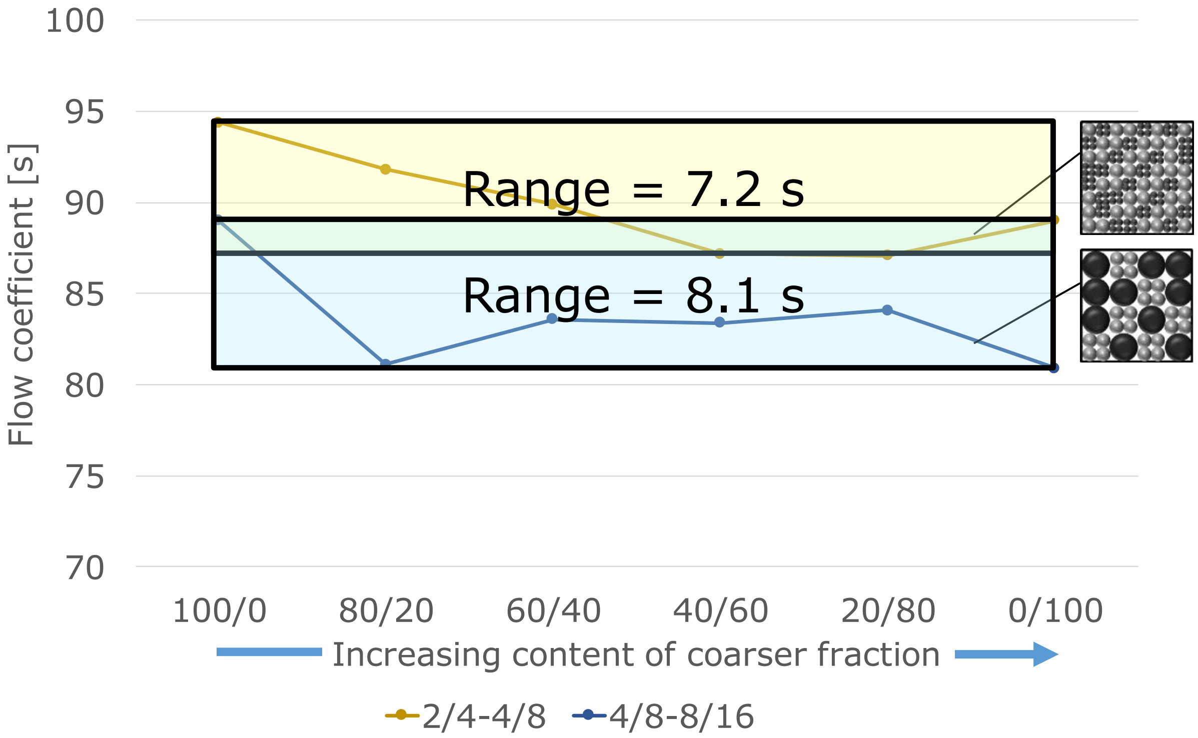
Results – flow coefficient





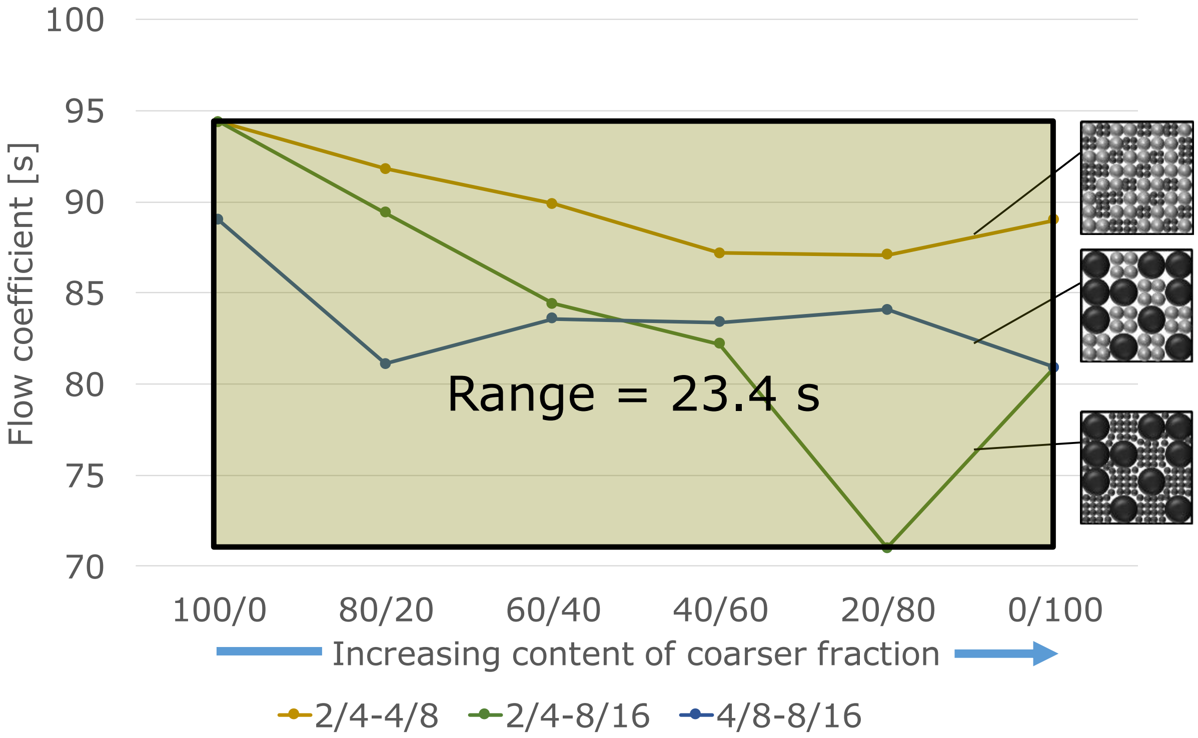
Results – flow coefficient



The variation ranges are similar for:

fine → medium
and
medium → coarse

Results – flow coefficient

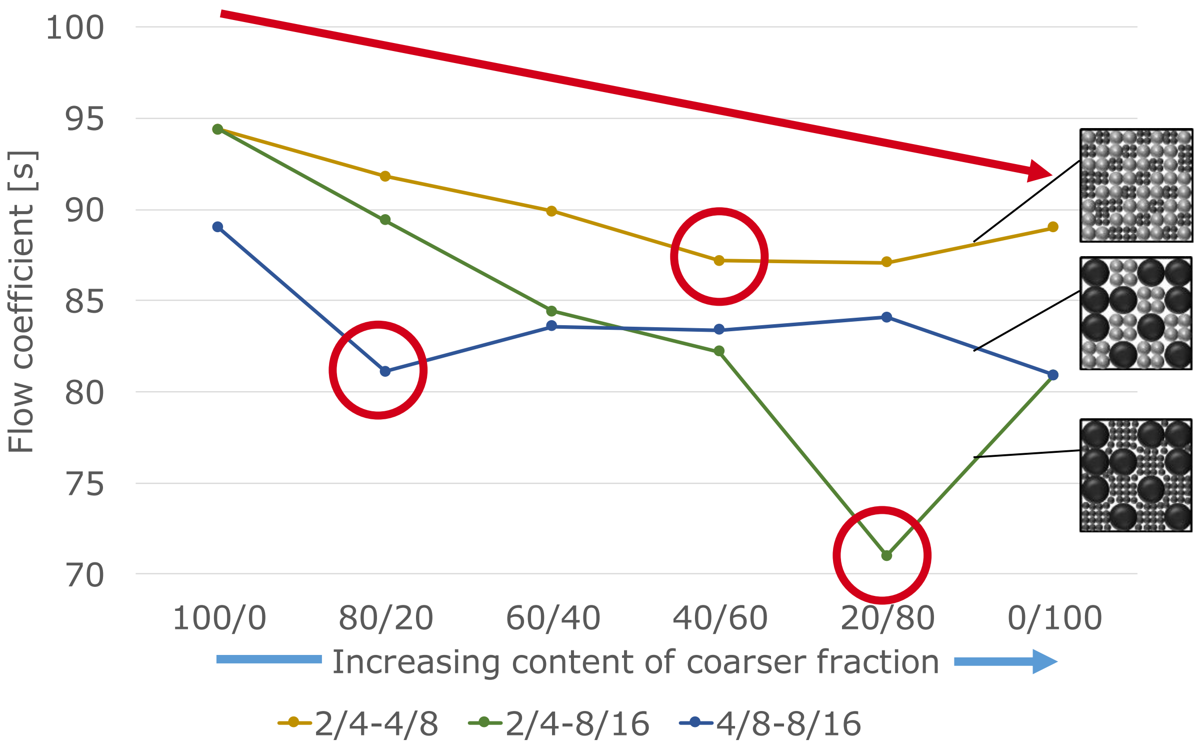


The variation ranges are similar for:

fine → medium
and
medium → coarse

but
significantly wider for:
fine → coarse

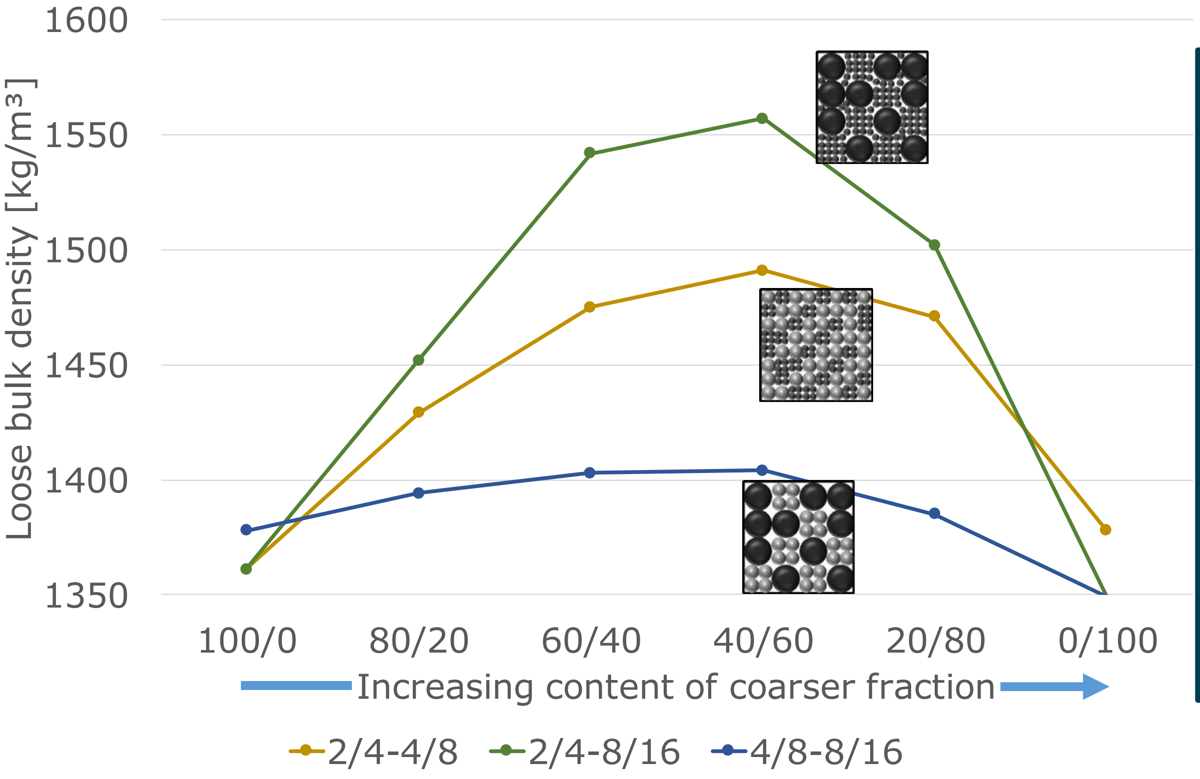
Results – flow coefficient



Increasing coarse aggregate contents decrease the flow coefficient.

A minimum can be found between the two fractions.

Results – loose bulk density

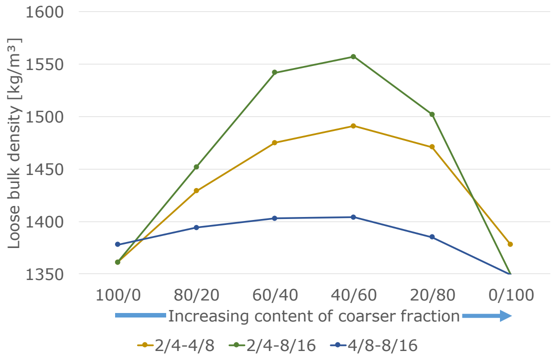


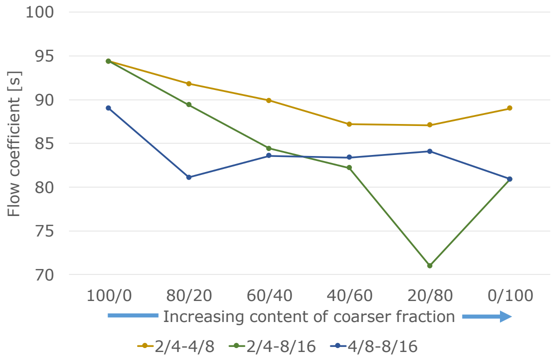
Ideal packing was achieved for 40:60 and 60:40 of two fractions.

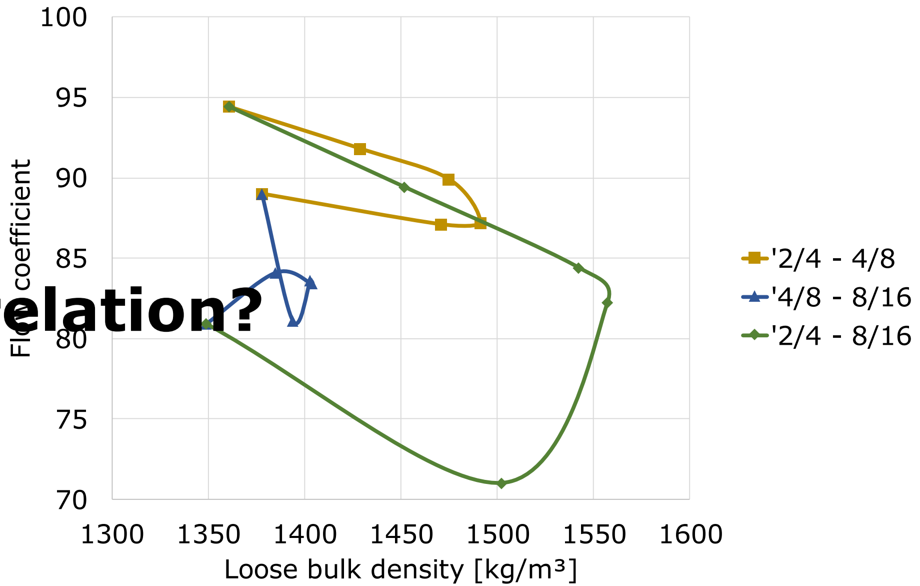
Better packing density when the smaller fraction is finer sand.

Best packing possible with largest gap between coarse and fine aggregate.

Results – loose bulk density



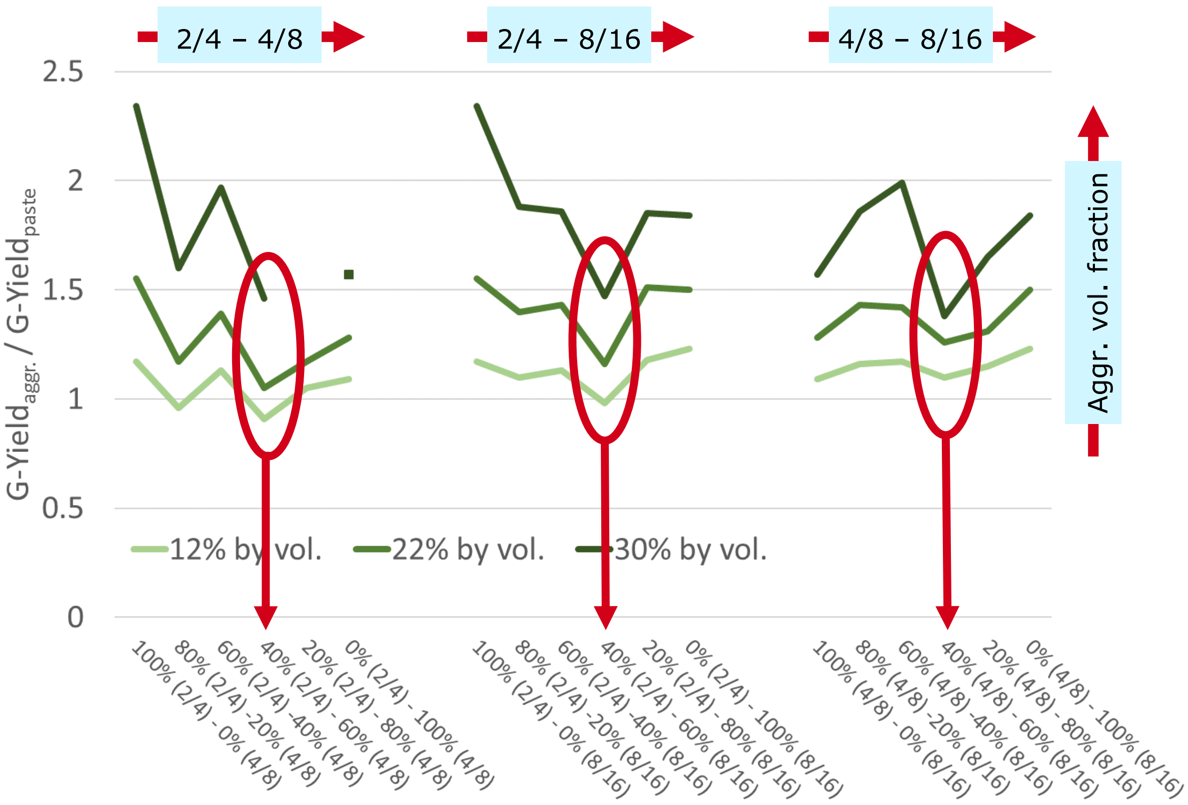




Correlation?

No correlation!

Results – yield stress

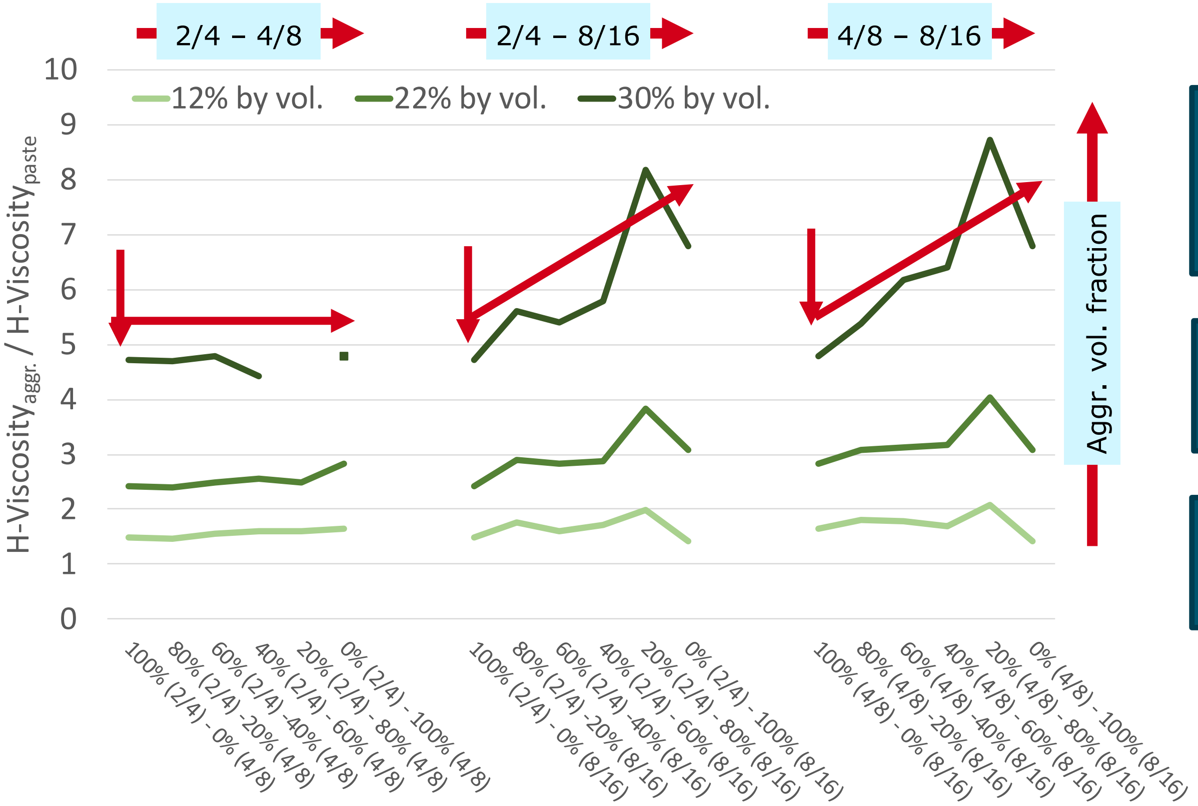


No similarity between the blends.

Minimum always between the single fractions.

Minimum always with higher coarse volume.

Results – viscosity

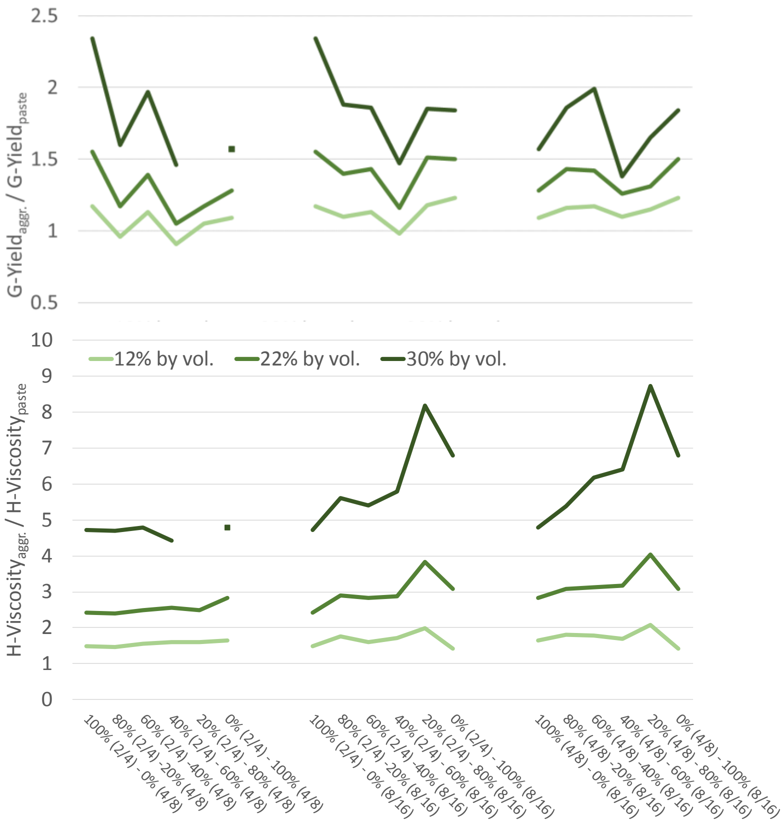


Lowest viscosity always with smallest aggregate fraction.

No big effect from small to medium

Significant effect with coarsest fraction.

Results – rheology



Regardless of the volume fraction, the influence of the aggregates was always particular.

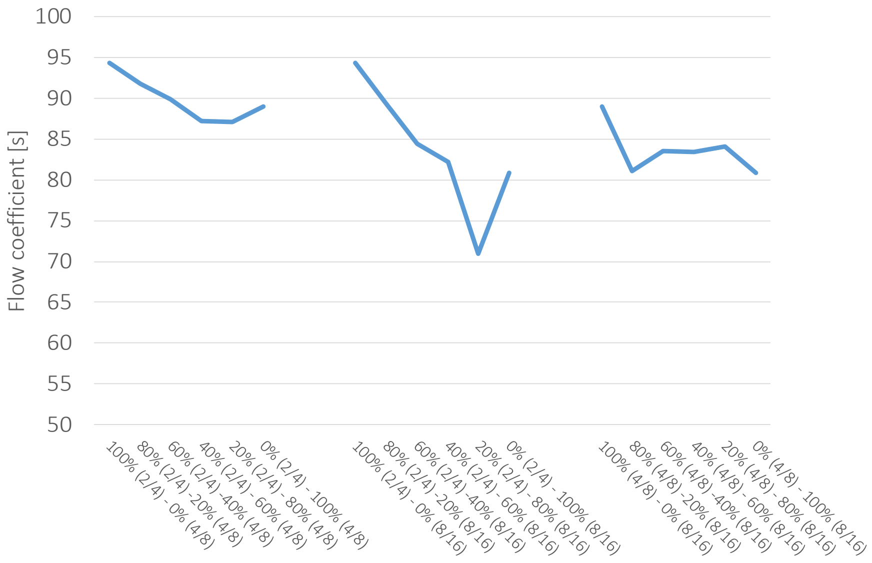
This means:
Already at smallest volume fractions, the aggregates affect the rheology.

And:
The aggregate volume fraction is a multiplier of the particular effect.

Results – yield stress vs. flow coefficient

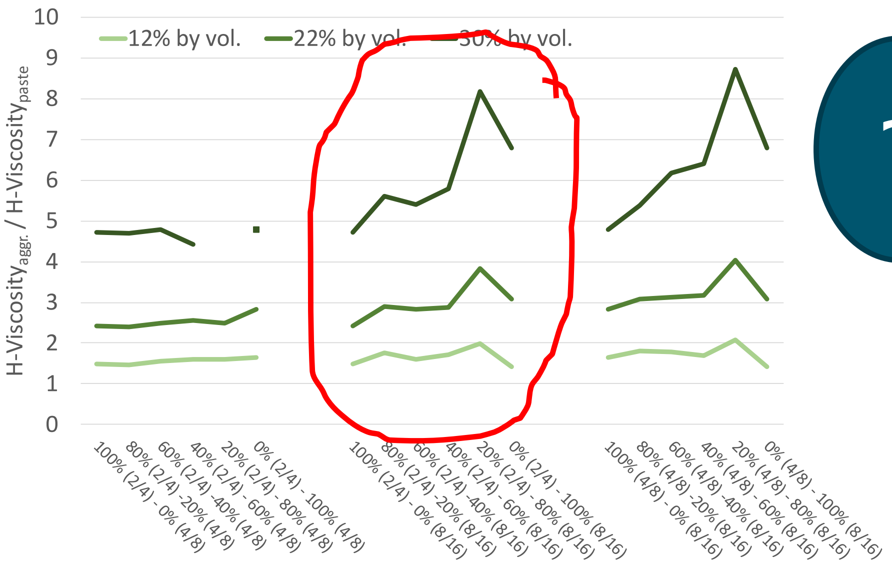
Yield stress

Flow coefficient



Results – viscosity vs. flow coefficient

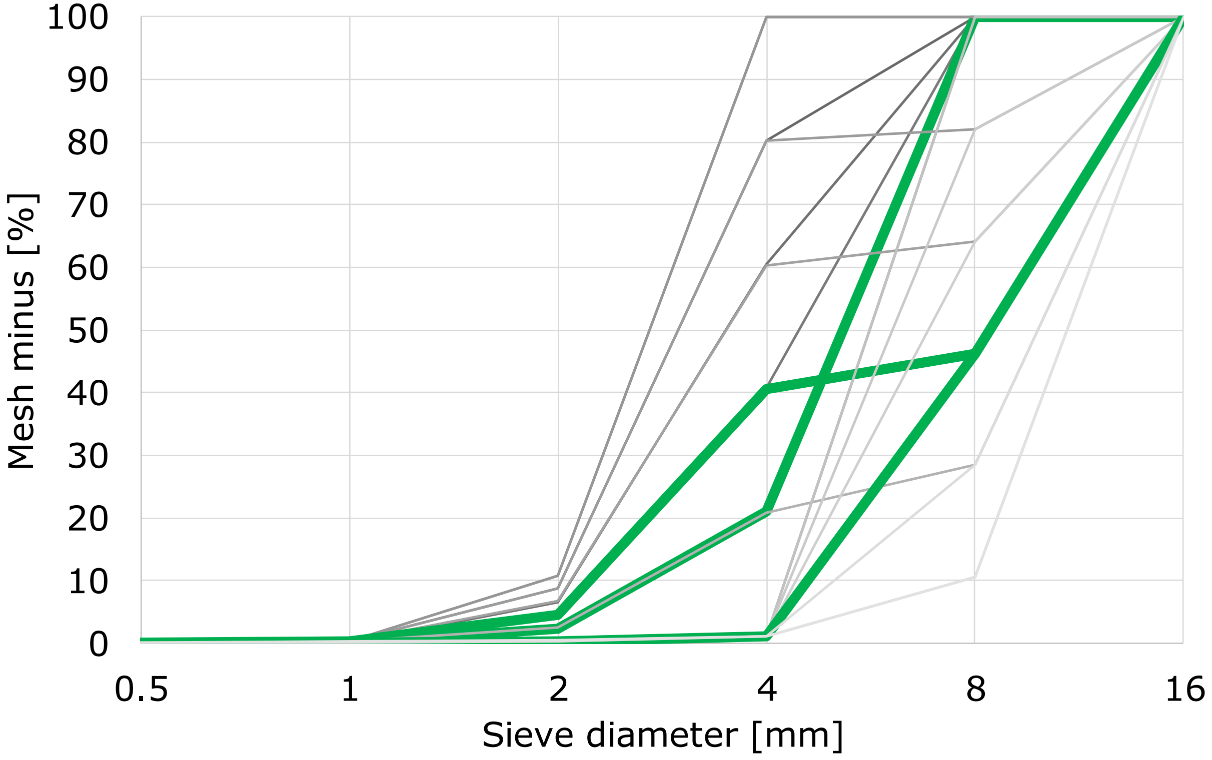
Plastic viscosity



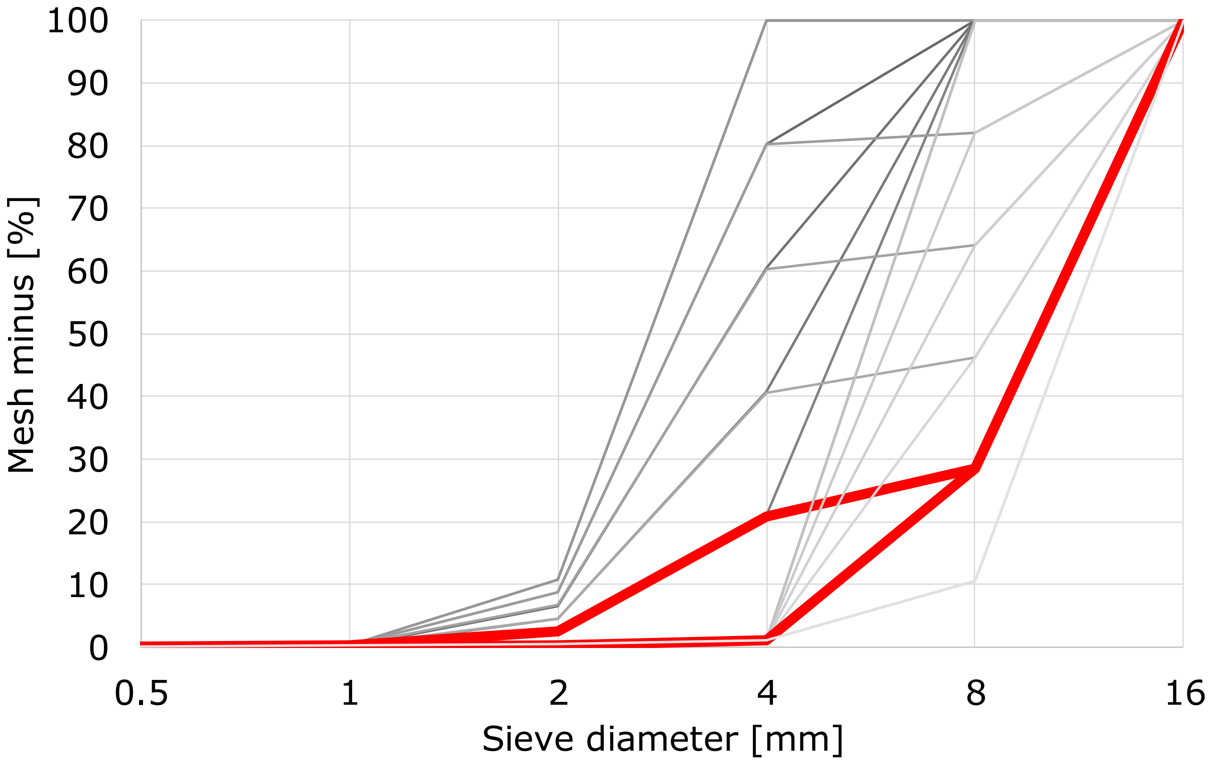
?

Flow coefficient

Results – lowest yield stress PSD



Results – highest viscosity PSD



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CONCLUSIONS

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Conclusions

Flow coefficient assessment:

- The flow coefficient does not correlate with loose bulk density.
- The flow coefficient is also not an adequate tool to predict the rheology influence of the coarse particle.

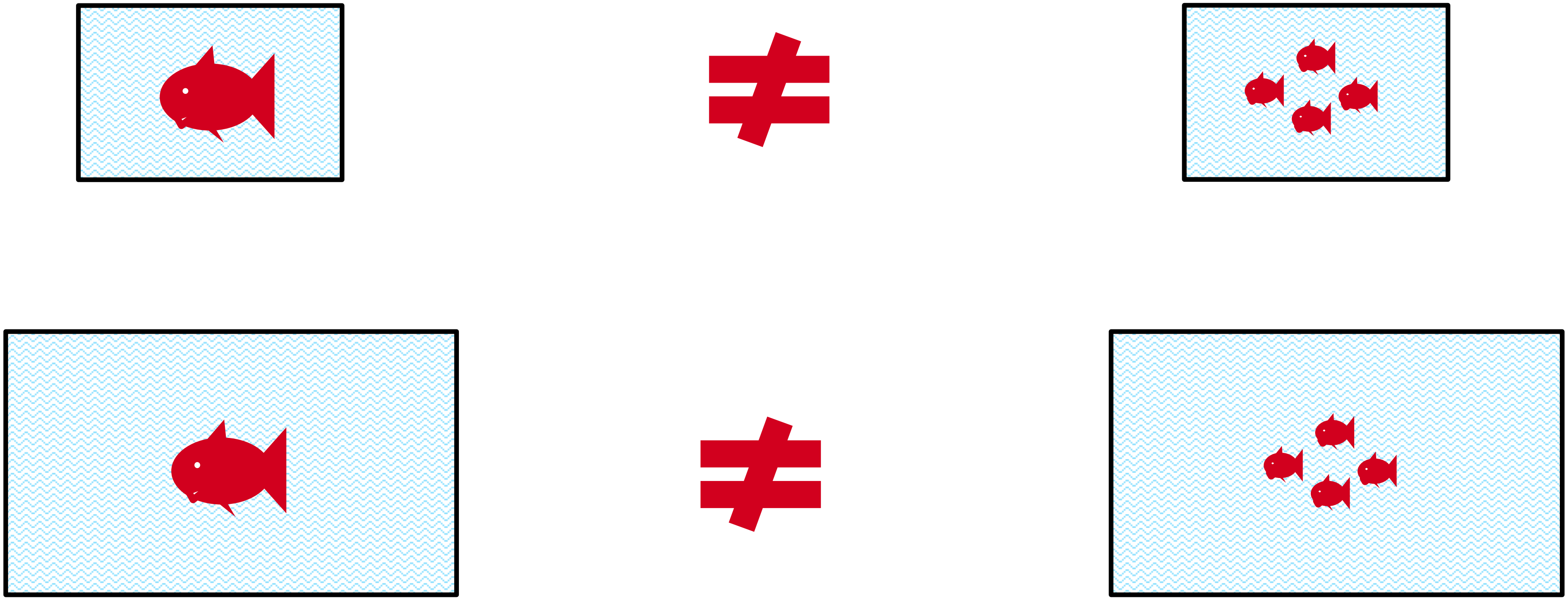
Grading:

- Best yield stress reduction with coarse fractions > 50%
- Hardly effects of sand fractions on viscosity. Strong effect of coarse fraction.

Volume fraction:

- Blends of different aggregate fractions have particular influence of rheology.
- Volume fraction does not change particular effects, only the order of magnitude.

Conclusions



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THANK YOU VERY MUCH FOR YOUR KIND ATTENTION

<u>ACKNOWLEDGEMENT:</u>
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