Tests der Wirkung von PCE-Fließmitteln auf Stoffe für Ressourcen-effizienten, nachhaltigen Beton

Effect of PCE-Superplasticizers on Powders for Eco-Concrete

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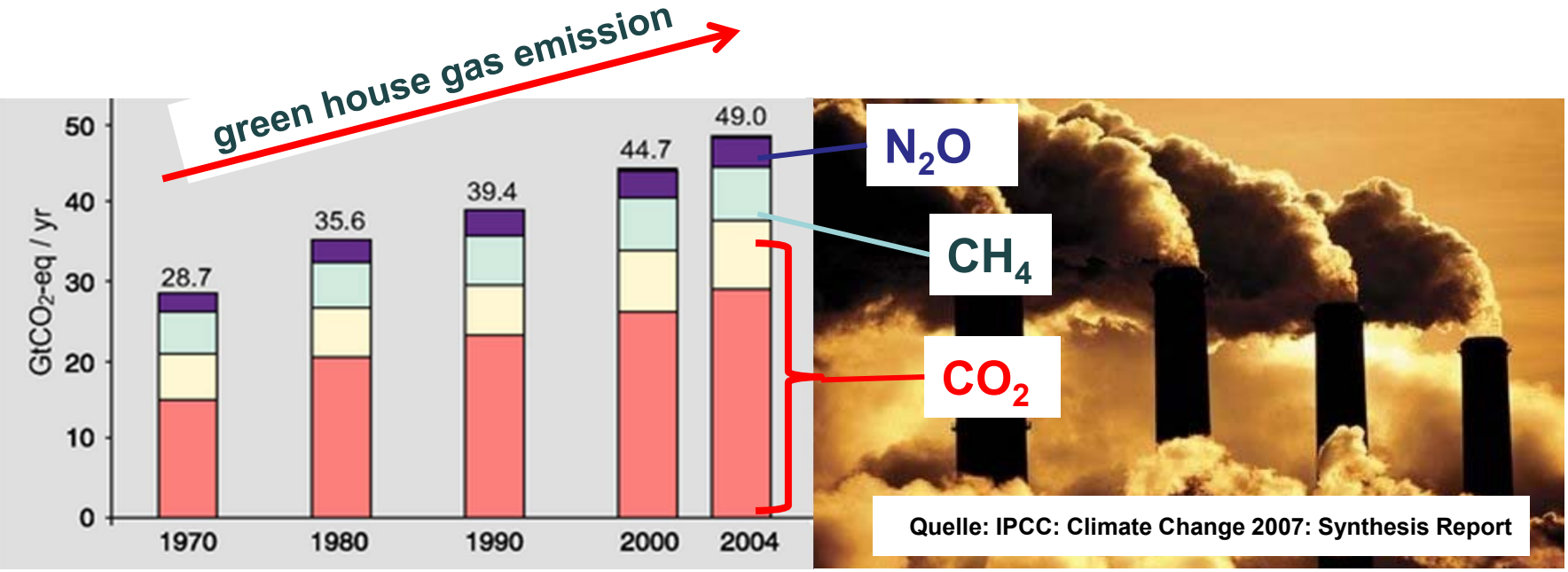
Institute of Technology and Testing of Building Materials

Institute of Applied Geosciences

Laboratory for Particle Analysis (RCPE)

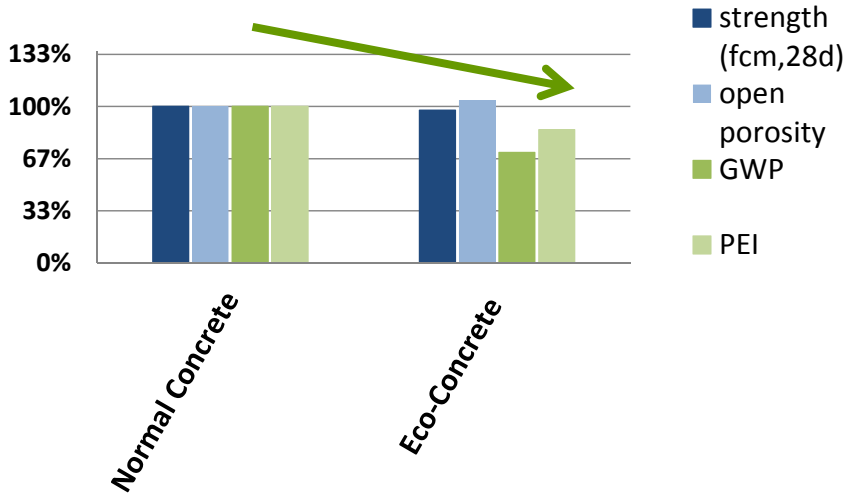
Motivation
Climate Protection and Sustainable Development



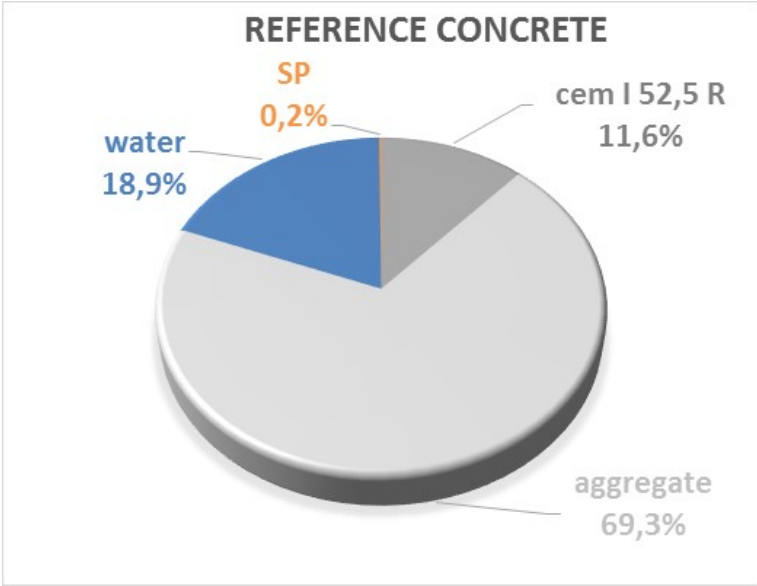
Cement production causes ~ 5% of world wide CO_2-emission [Quelle: VÖZ]

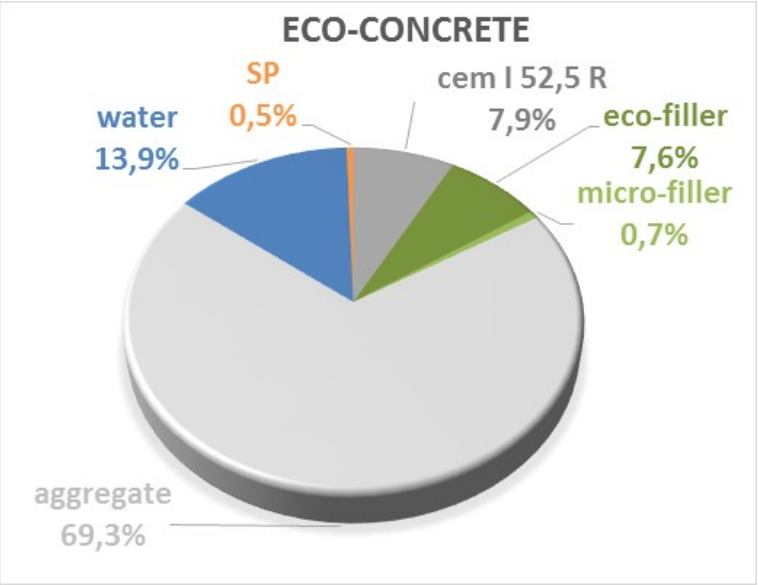
Concrete demand worldwide ~ 7 billion m³/year [KIT 2012]

Development of Eco-concrete

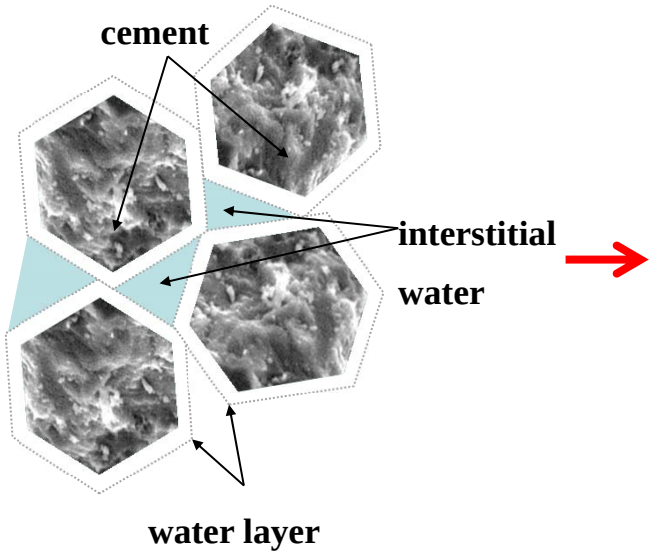


- **reduction of GWP and PEI by - 10-30% is possible**
- **equal concrete performance**

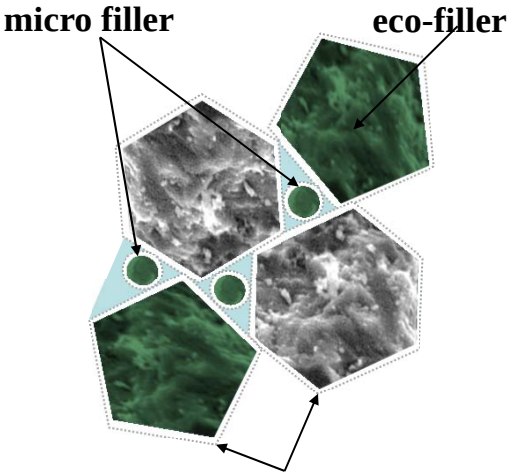




Packing Optimization & Effect of Fillers



normal paste



+ superplasticizer
water layer thickness ↓

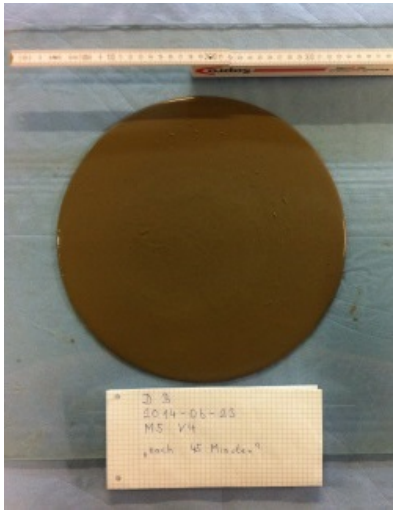
+ "eco-filler"
CEM-clinker↓ (w/c ↗) → „eco"-concrete

→ Same workability/strength/ durability of eco-concrete and normal concrete

Flowability of Different Powders

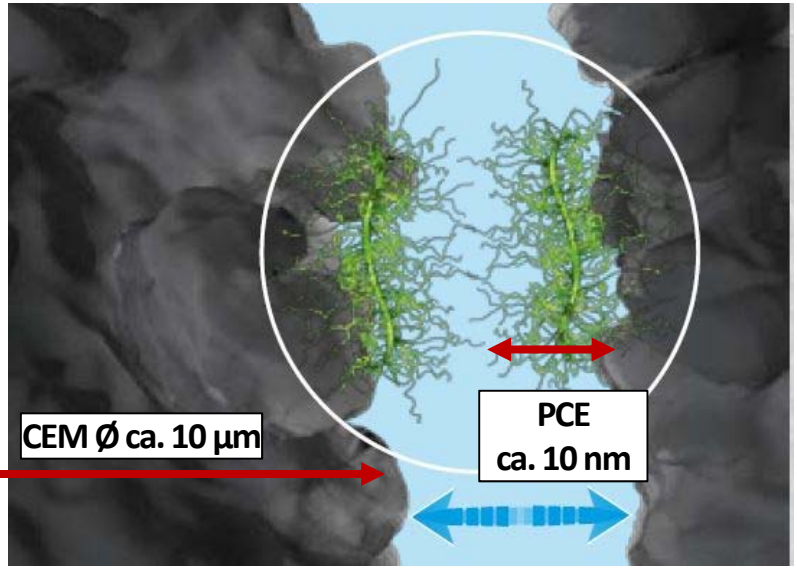
Which SP do you recommend for eco-concrete and what performance will we reach with different fine powders ?

Spread flow test



Superplasticizers PCE

superplasticizer [PCE]	application	bulk density	PCE content (solid)
	-	g/cm³	M.%
SP 55	ready-mixed concrete	1,07	30
SP 108	ready-mixed concrete	1,08	29
SP 109	precast concrete	1,09	40
SP 110	precast concrete	1,06	30
SP 144	precast concrete	1,06	28
SP 147	precast concrete	1,06	30
SP 170	precast concrete	1,06	25
SP 182	precast concrete	1,07	30



Quelle: SIKA Produktbroschüre

Powders

Portland Cement d_{50} = 7,5 µm
Micro-fillers d_{50} < 4 µm
Eco-fillers 5 µm < d_{50} < 15µm

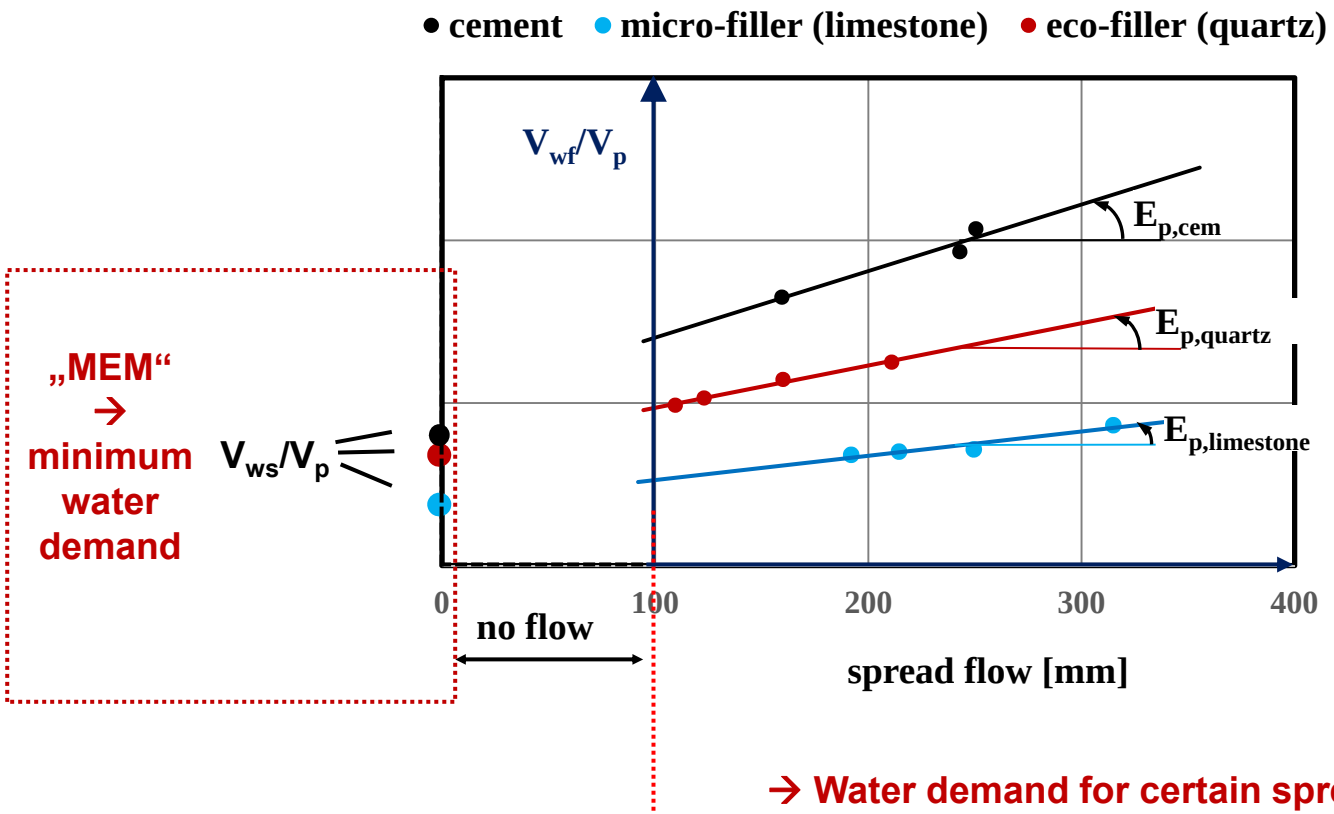
} inert stone powders

type	true density ρ_0	grain size d_{50}	location parameter x'	slope n	Blaine-value	water demand (MEM) V_{ws}/V_p	sensitivity to addition of water Ep	GWP	PEI
	g/cm³	µm	µm	-	cm²/g	-	-	$kgCO_2/t$	MJ/t
cem I 52,5 R	3,14	7,50	8,50	0,90	5110	0,92	0,0041	831	
quartz eco	2,65	13,80	18,60	1,00	4640	0,85	0,0026	41	133
quartz micro	2,65	3,26	4,60	1,10	(12680)	0,83	0,0005	57	178
microsilica	2,20	0,20			(34908)	1,28	0,0033	(0)	
limestone micro	2,73	2,20	3,50	1,20	9314	0,61	0,0015	36	100
limestone eco 1	2,70	9,00	15,80	1,20	5630	0,59	0,0028	25	
limestone eco 2	2,70	12,00	20,40	1,00	3689	0,69	0,0026	25	717
dolomite micro	2,90	3,30	4,30	1,30	8300	0,85	0,0030	36	1006
dolomite eco	2,86	15,00	33,50	0,80	2962	0,61	0,0021	25	717

factor 1/20

Water Demand and Flowability of Powders
New combination-method “MEM-ST”

- **Mixing energy method (MEM) → water demand at saturation (Vws/Vp) ≙ void content**
- **Spread flow test ST (Okamura) → water demand for certain spread flows (Vwf,i/Vp)**



→ Water demand for certain spread flow

Sequence of Testing of Water-Powder mixes with SP

- **water/powder mixes at minimum water demand (MEM)**

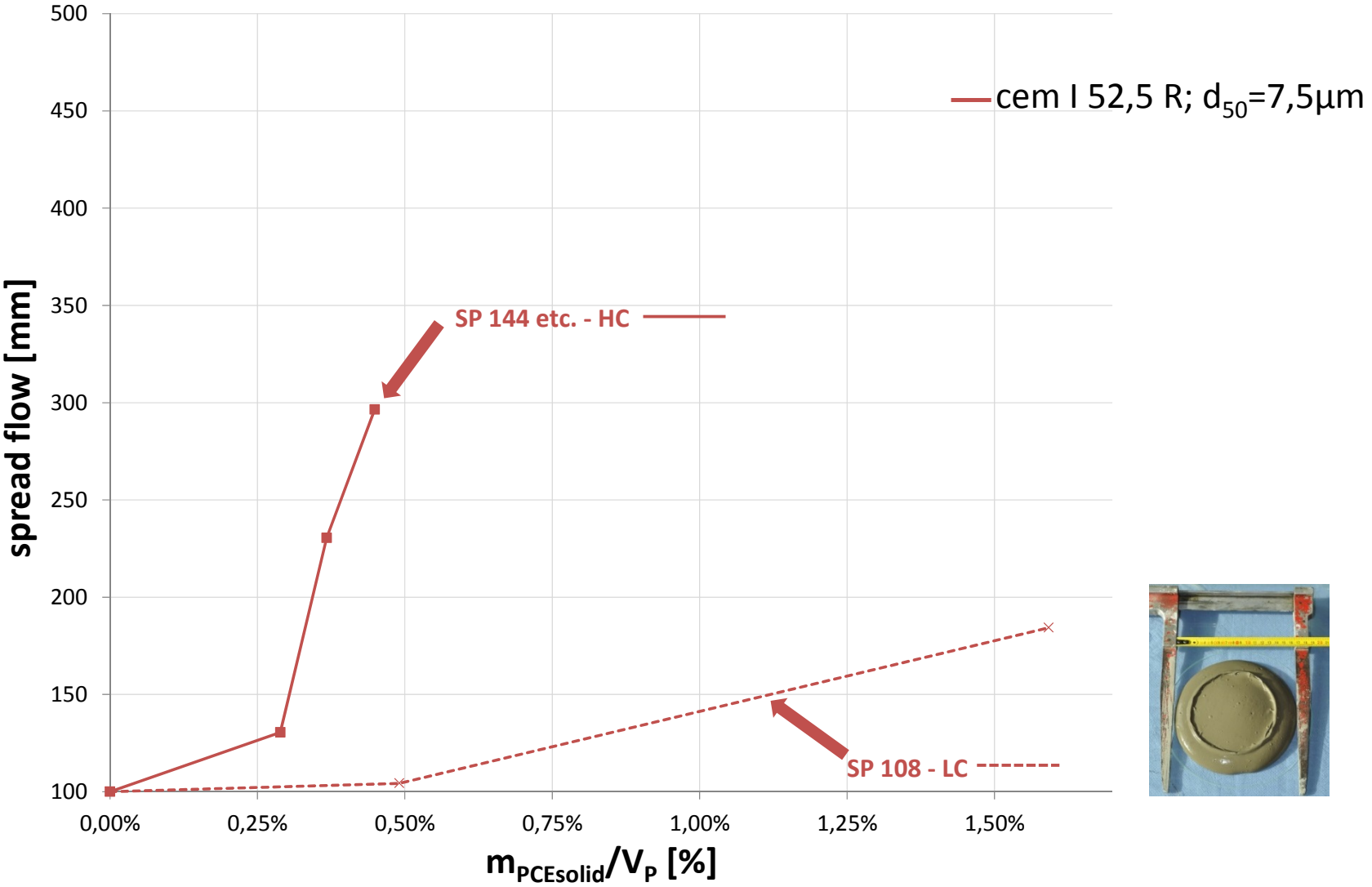
  → constant starting consistency
- **addition of superplasticizers / mixing**

spread flow tests

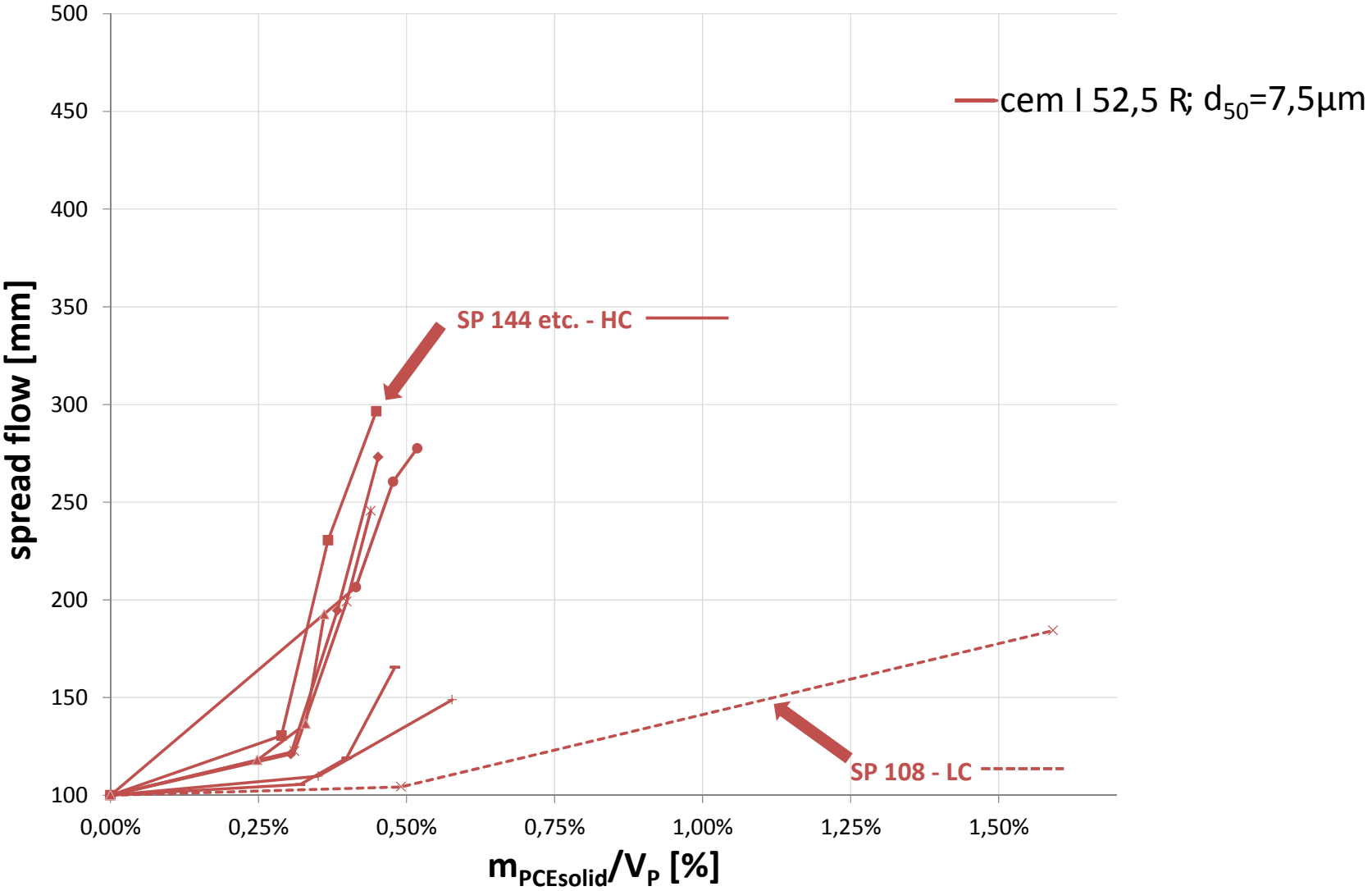
rheometer test

$$SP - dosage = \frac{m_{PCE\_solid}}{V_{powder}} = \frac{m_{PCE\_s}}{V_p}$$

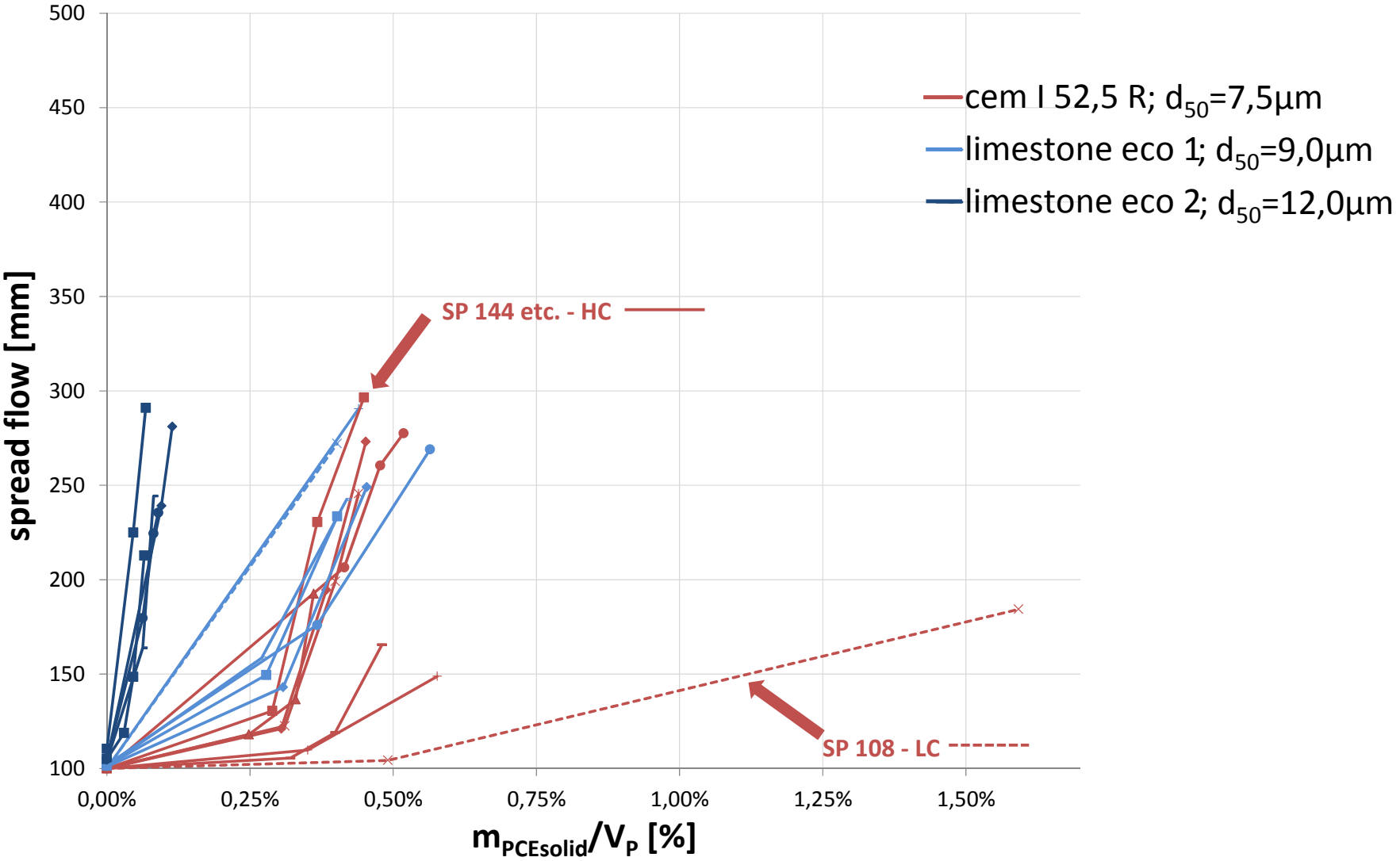
Results


500
450
400
350
300
250
200
150
100
spread flow [mm]
0,00%
0,25%
0,50%
0,75%
1,00%
1,25%
1,50%
$m_{PCEsolid}/V_P$ [%]
cem I 52,5 R; d_{50}=7,5µm
SP 144 etc. - HC
SP 108 - LC

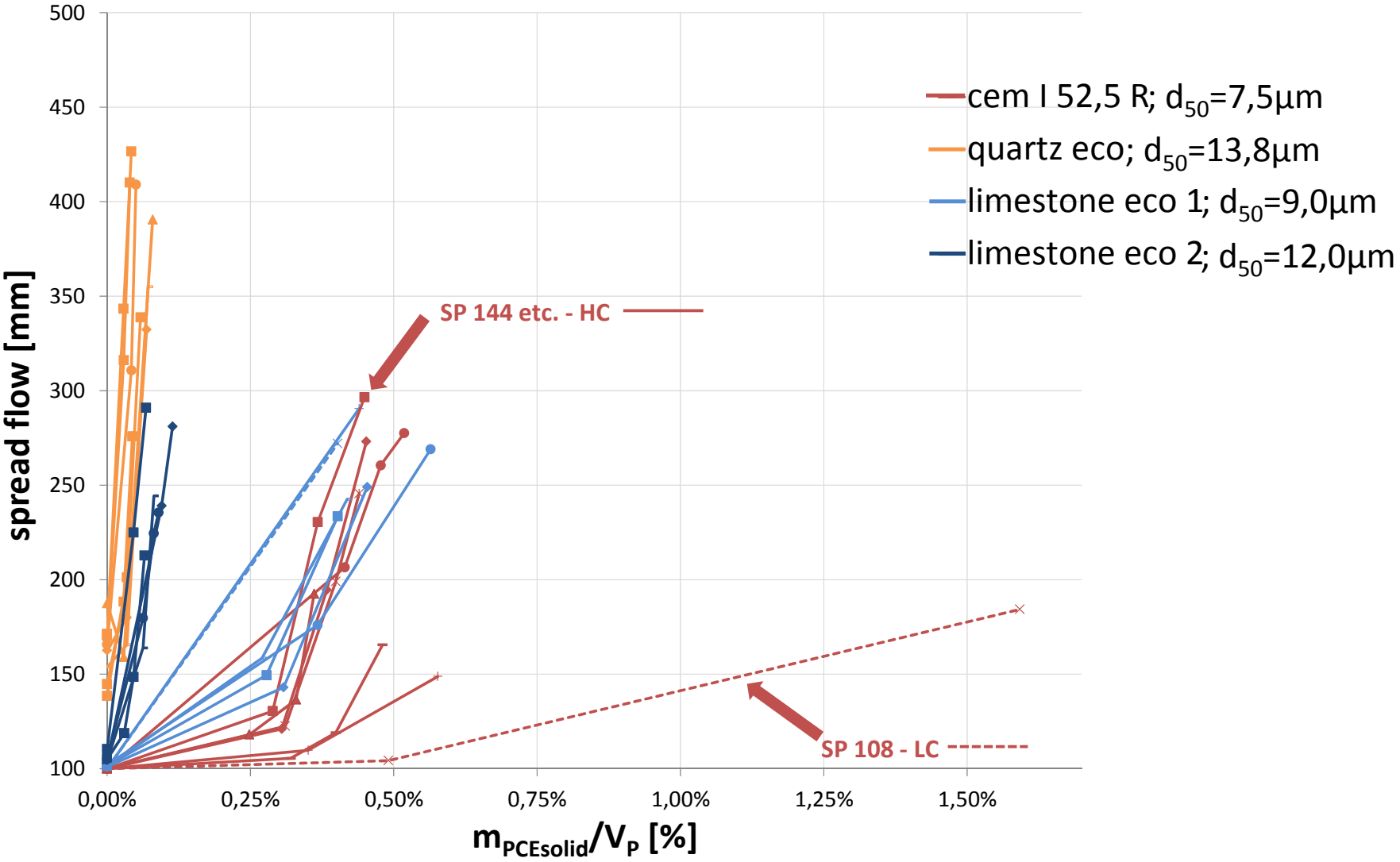
Results


cem I 52,5 R; d_{50}=7,5µm
SP 144 etc. - HC
SP 108 - LC
spread flow [mm]
500
450
400
350
300
250
200
150
100
0,00%
0,25%
0,50%
0,75%
1,00%
1,25%
1,50%
$m_{PCEsolid}/V_P$ [%]

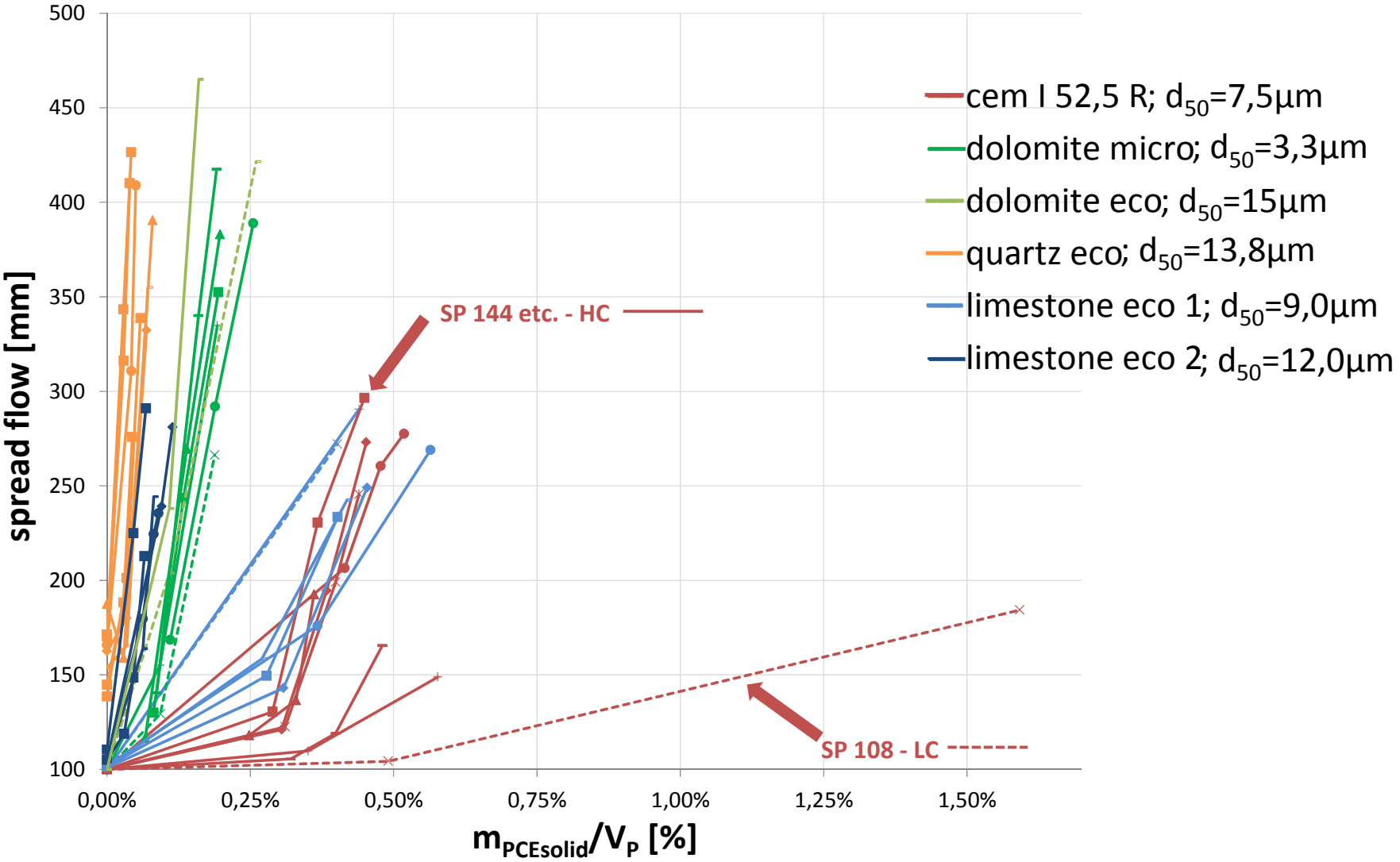
Results


500
450
400
350
300
250
200
150
100
spread flow [mm]
0,00%
0,25%
0,50%
0,75%
1,00%
1,25%
1,50%
$m_{PCEsolid}/V_P$ [%]
SP 144 etc. - HC
SP 108 - LC
cem I 52,5 R; d_{50}=7,5µm
limestone eco 1; d_{50}=9,0µm
limestone eco 2; d_{50}=12,0µm

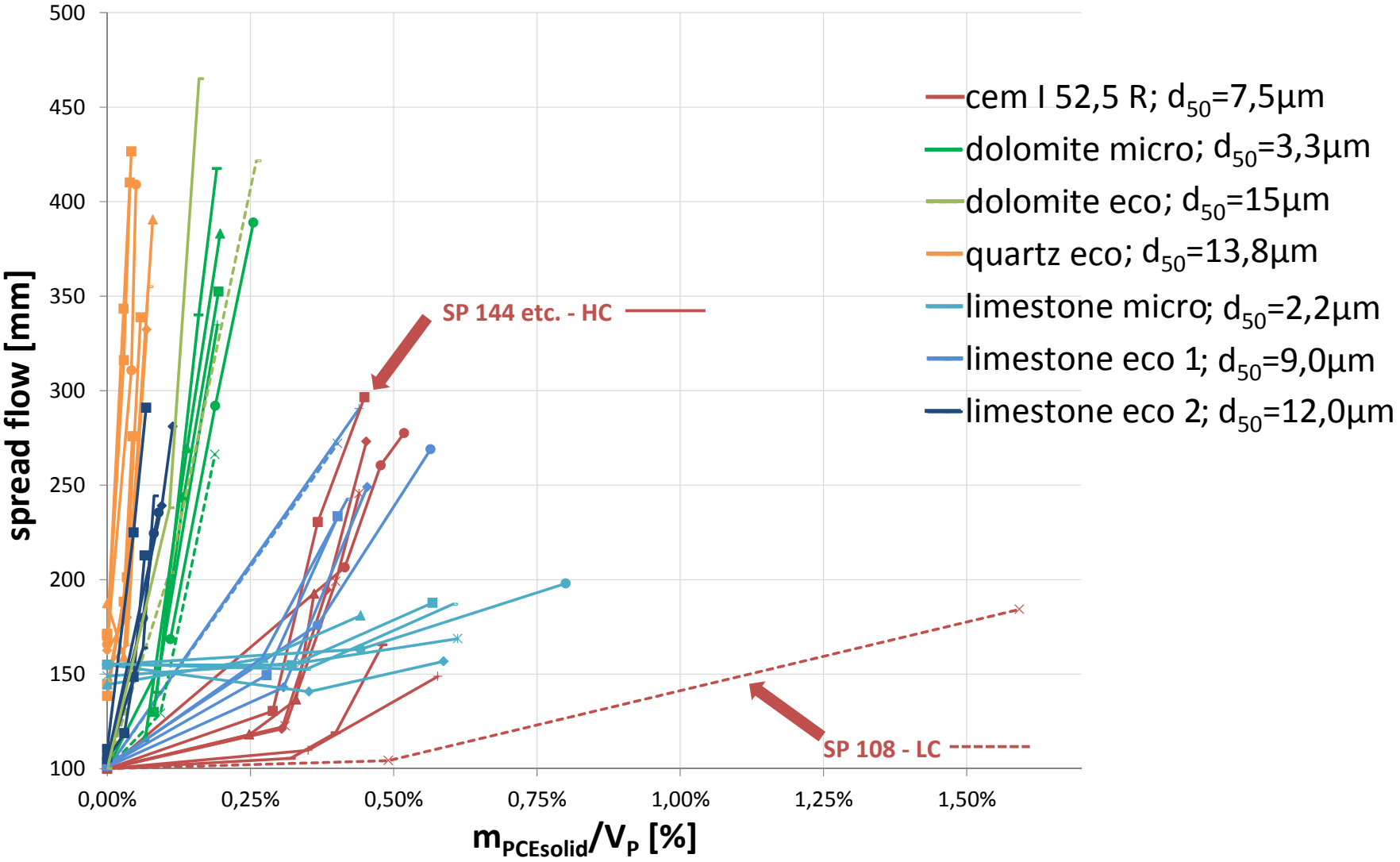
Results


spread flow [mm]
500
450
400
350
300
250
200
150
100
0,00%
0,25%
0,50%
0,75%
1,00%
1,25%
1,50%
$m_{PCEsolid}/V_P$ [%]
SP 144 etc. - HC
SP 108 - LC
cem I 52,5 R; d_{50}=7,5µm
quartz eco; d_{50}=13,8µm
limestone eco 1; d_{50}=9,0µm
limestone eco 2; d_{50}=12,0µm

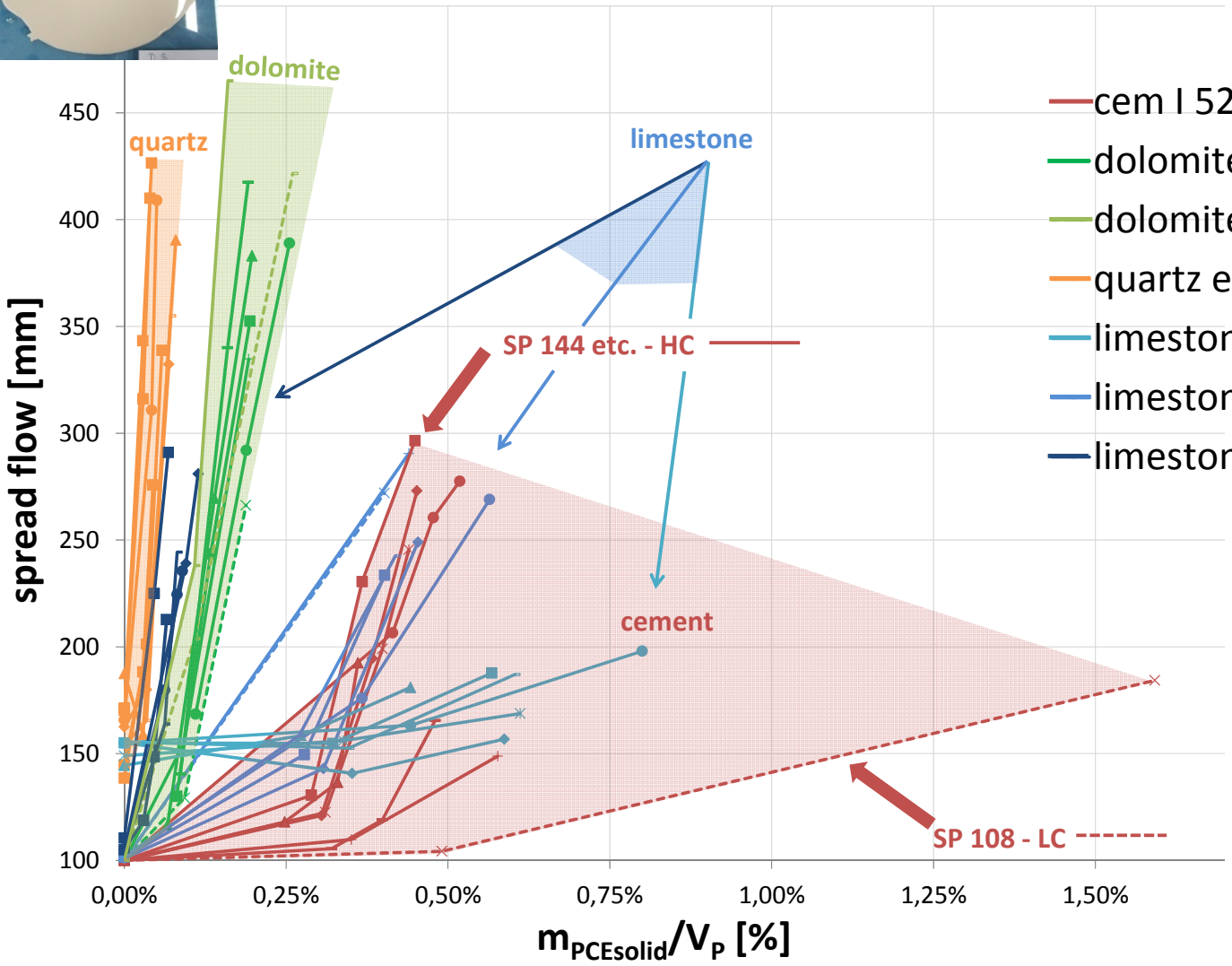
Results


spread flow [mm]
500
450
400
350
300
250
200
150
100
0,00%
0,25%
0,50%
0,75%
1,00%
1,25%
1,50%
$m_{PCEsolid}/V_P$ [%]
SP 144 etc. - HC
SP 108 - LC
cem I 52,5 R; d_{50}=7,5µm
dolomite micro; d_{50}=3,3µm
dolomite eco; d_{50}=15µm
quartz eco; d_{50}=13,8µm
limestone eco 1; d_{50}=9,0µm
limestone eco 2; d_{50}=12,0µm

Results


spread flow [mm]
500
450
400
350
300
250
200
150
100
0,00%
0,25%
0,50%
0,75%
1,00%
1,25%
1,50%
$m_{PCEsolid}/V_P$ [%]
SP 144 etc. - HC
SP 108 - LC
cem I 52,5 R; d_{50}=7,5µm
dolomite micro; d_{50}=3,3µm
dolomite eco; d_{50}=15µm
quartz eco; d_{50}=13,8µm
limestone micro; d_{50}=2,2µm
limestone eco 1; d_{50}=9,0µm
limestone eco 2; d_{50}=12,0µm

Results



- cem I 52,5 R; d_{50}=7,5µm
- dolomite micro; d_{50}=3,3µm
- dolomite eco; d_{50}=15µm
- quartz eco; d_{50}=13,8µm
- limestone micro; d_{50}=2,2µm
- limestone eco 1; d_{50}=9,0µm
- limestone eco 2; d_{50}=12,0µm

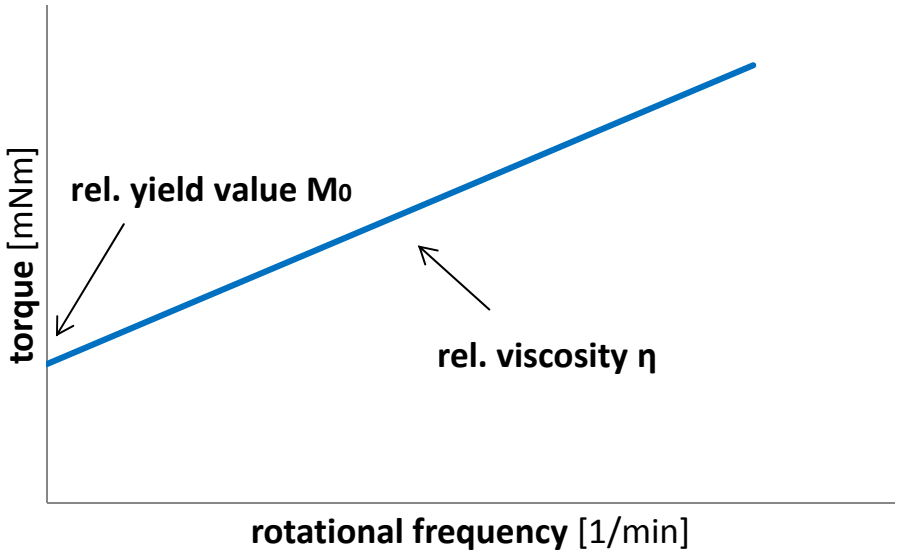
Rheometer –Tests

water/powder mixes with constant starting consistency
(near minimum water demand, spread flow= 130 mm)

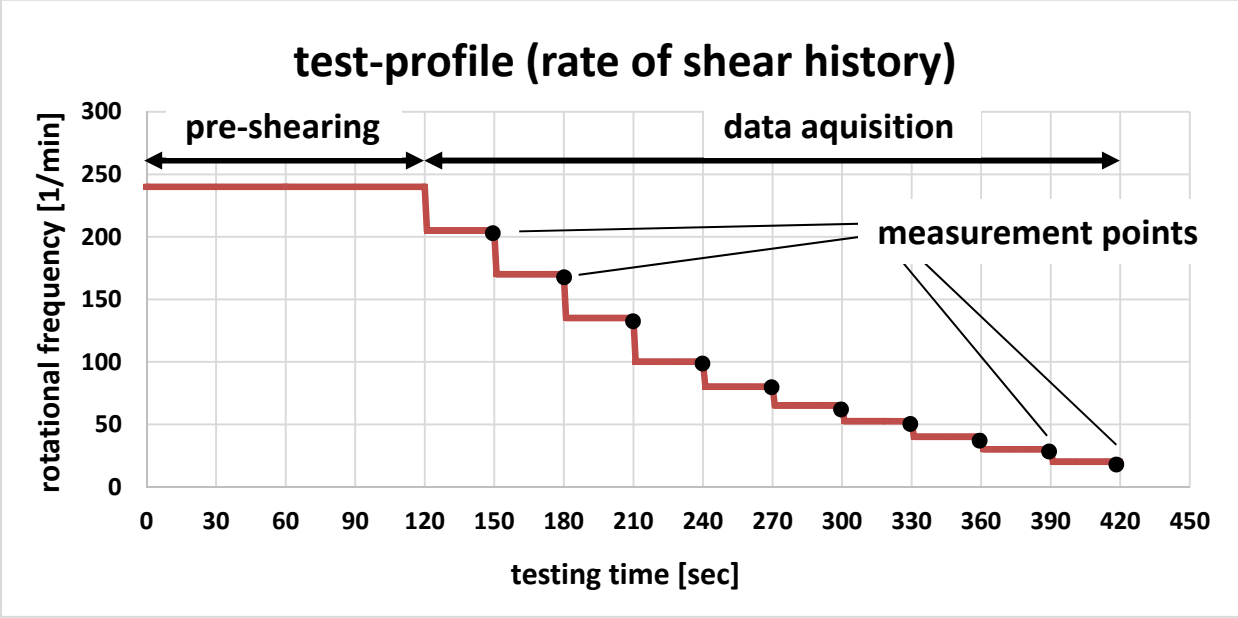
addition of superplasticizers + external pre-mixing

$V_{measuring}$ ~ 15 ml

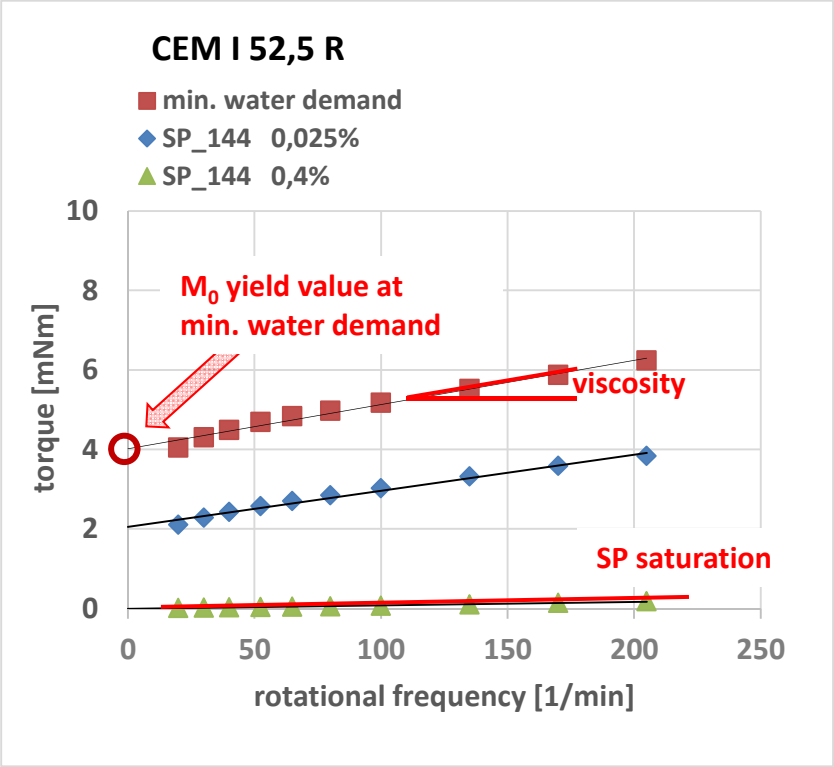
assumption: **linear Bingham flow-curve**

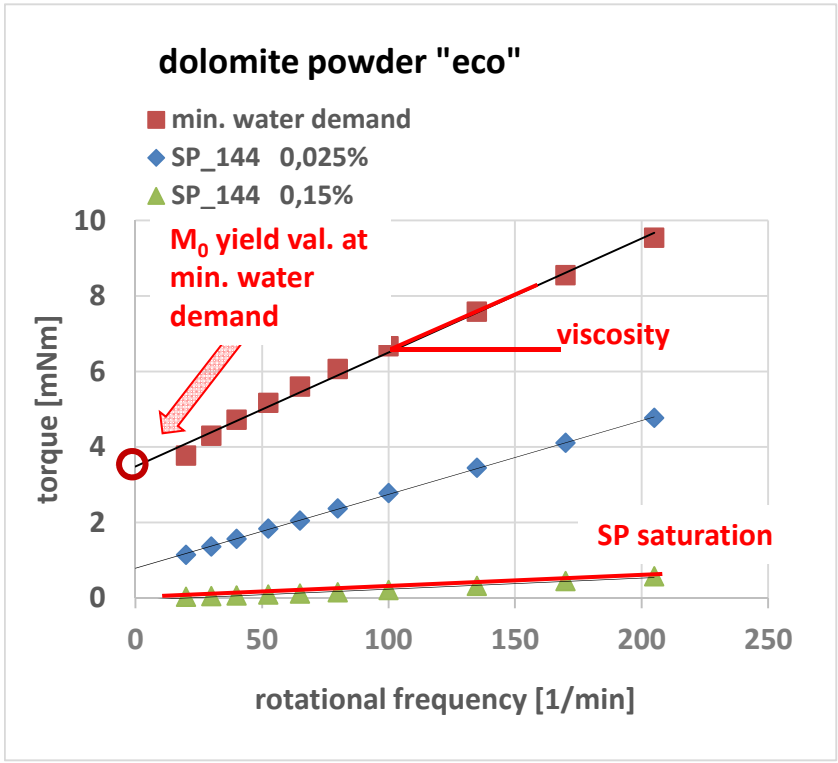


Specifications Rheometer Measurements



Results Rheometer – flow curves

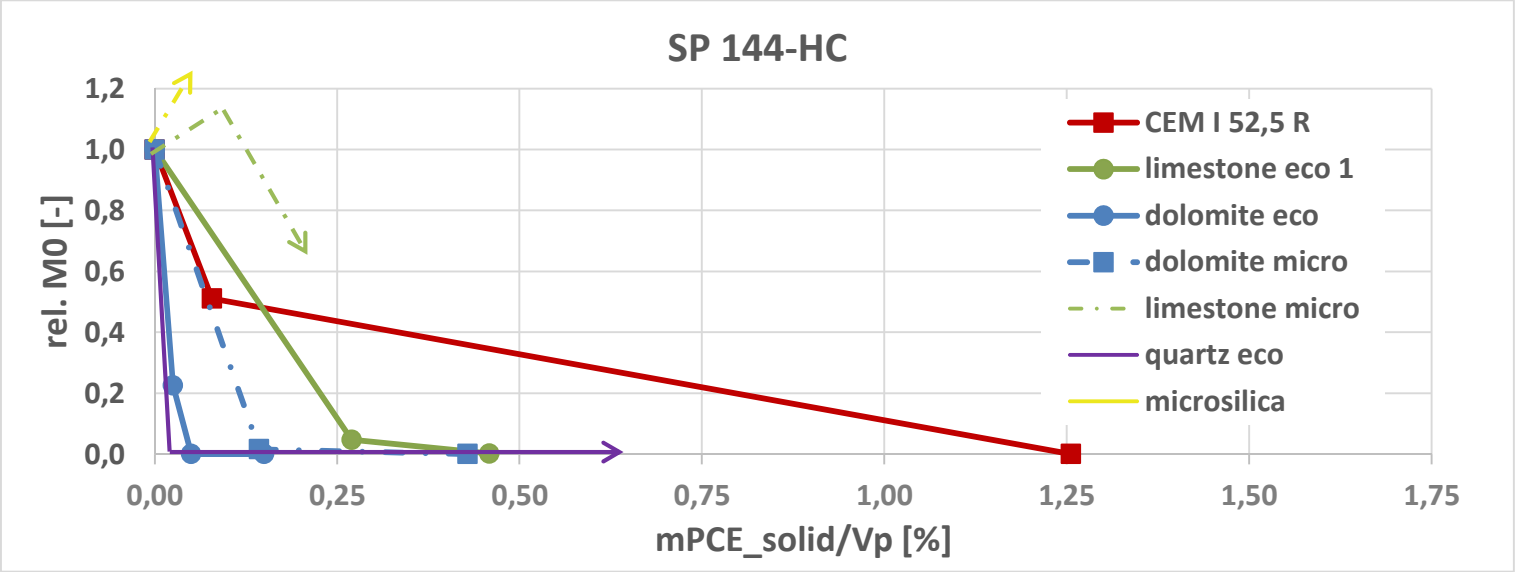


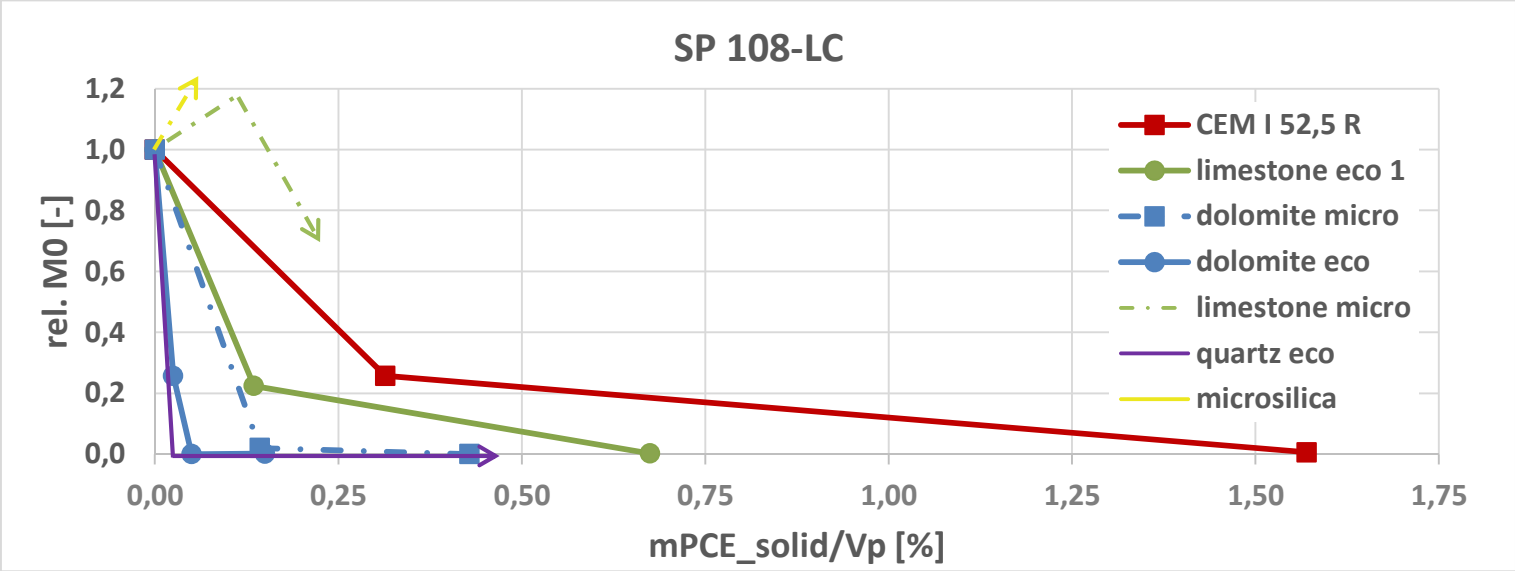


Yield value min. water demand $M_{0,mwd}$~ const.
for all water/powder mixes

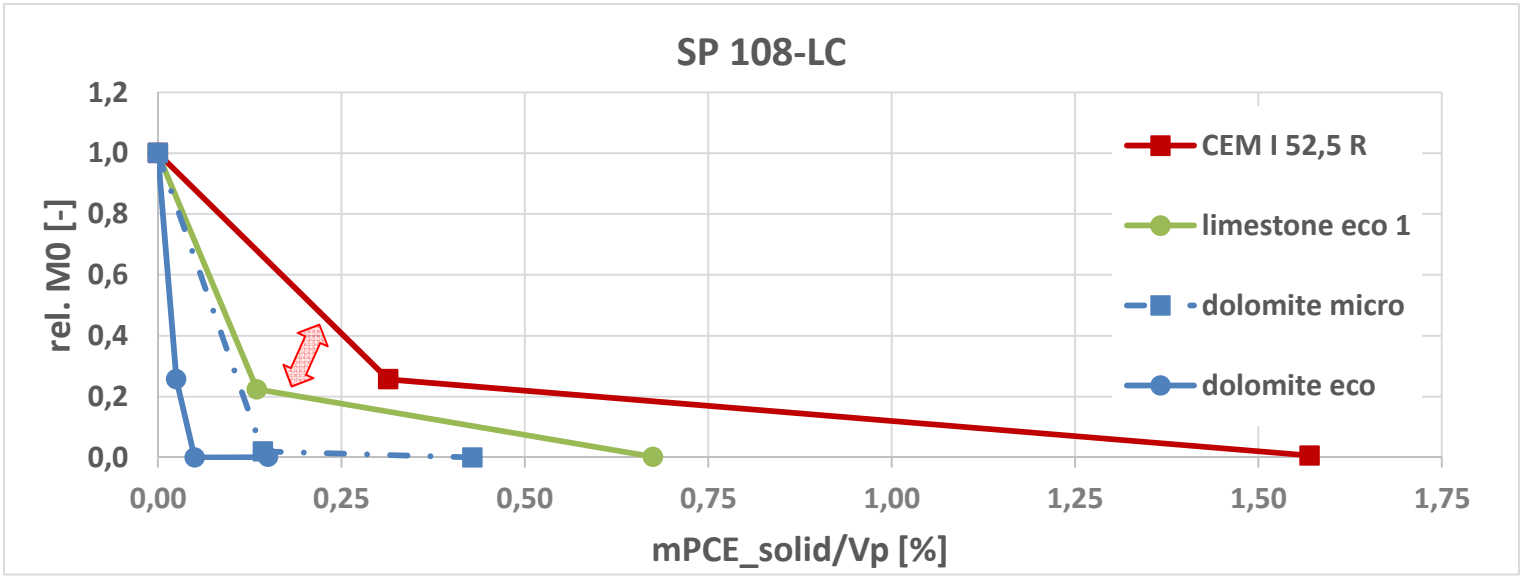
→ $$rel.M_0 = \frac{M_0}{M_{0,mwd}}$$

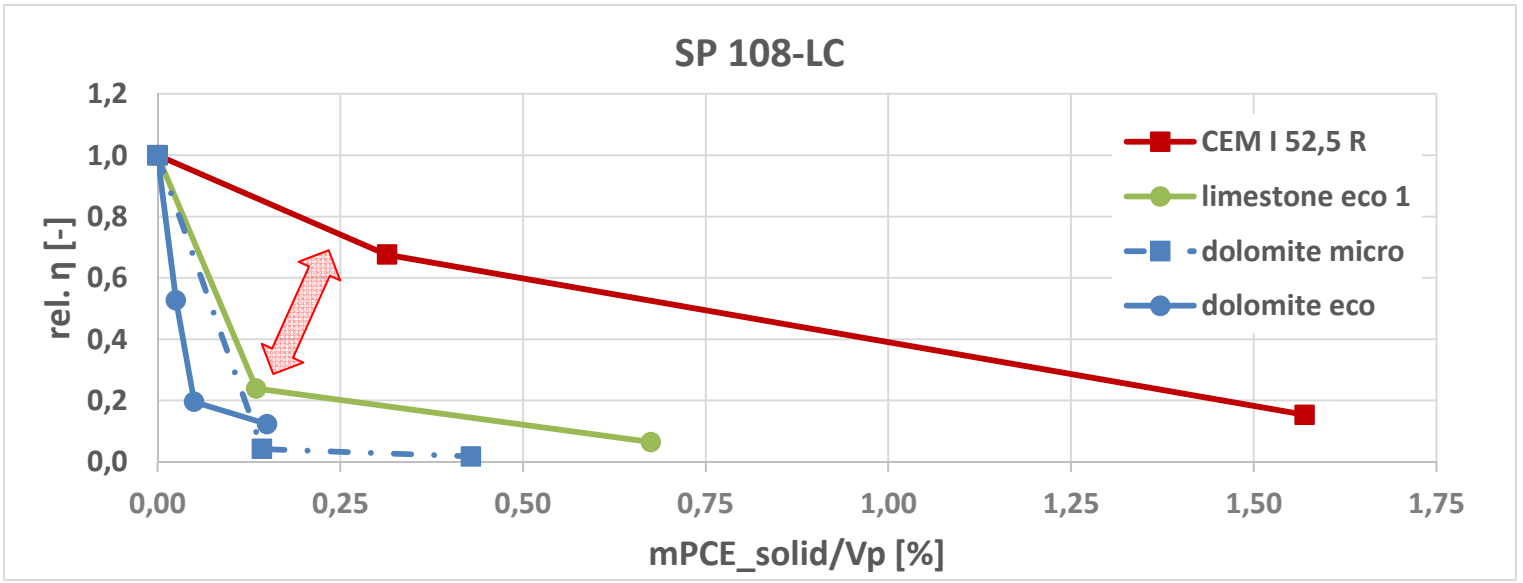
Results Rheometer –yield stress (rel. M_0) vs. SP-dosage



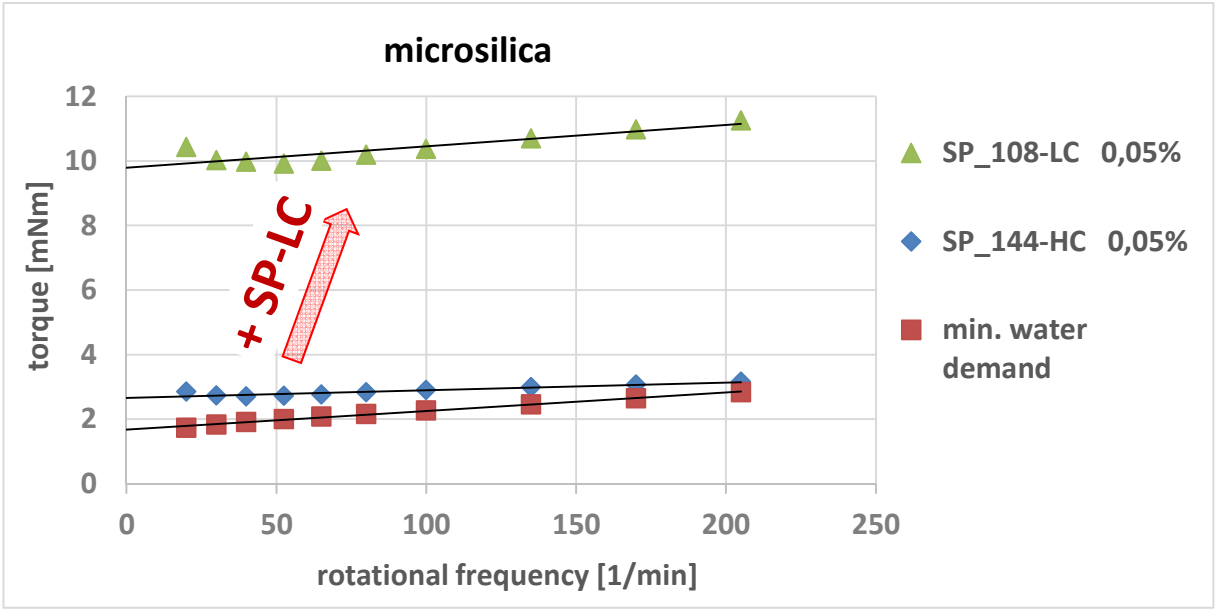


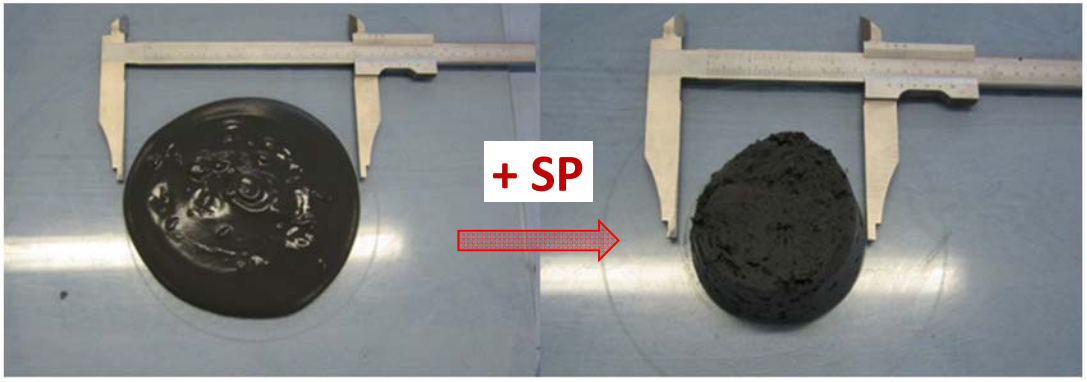
Results Rheometer – rel. M_0 vs. η





Influence of PCE-SP on Microsilica (d_{50}~0,2µm)





Summary and Conclusion

- investigations by spread flow test and Rheometer
- **SP-demand of CEM I > SP-demand of most stone powders**
  with similar fineness to CEM I
  (differs for quartz-dolomite-limestone)
- **viscosity of CEM I mixes > viscosity of most stone powder mixes** of similar fineness
- **„SP-demand“ ↗ with increasing fineness of powders**
  increase of yield stress & agglomeration of PCE with very fine powders observed
- **for stone-powders: only small differences between SP-HC and SP-LC**
- **spread flow over time:**
  decrease for cement (SP-HC) > decrease for stone powders
  (almost no decrease over time for stone powders with all SP)
- **estimation of spread flow of powder-mixes is possible when knowing the SP-demand of single ingredients** (by summing up the weighted spread flows)
- **Outlook:** testing of the effect of SP on powders in pore solution of cement-limes is recommended (pre-tests show a big influence of pH-value and ions in pore solution on the interaction of powders and pore solution)

Thank you for your attention!

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Data based on student works of D. Borovina, A. Schönauer, C. Maier, TU Graz 2014/2015