MIX COMPOSITIONS AND THE RHEOLOGICAL PROPERTIES OF UHPC

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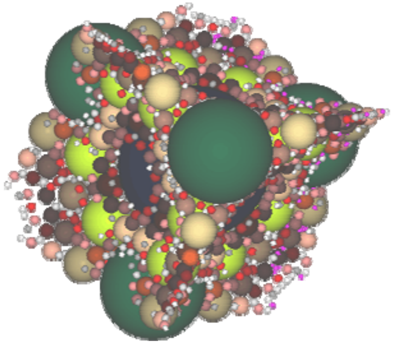

DFG priority programme No. 1182 „Sustainable Building with Ultra High Performance Concrete“

Binder Optimization

Motivation:

- High contents of energy and cost-intensive components

Cement Silica fume Quartz powder

Replacement by fly ash in parts or complete

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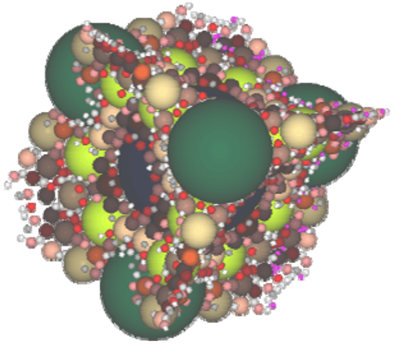

DFG priority programme No. 1182
„Sustainable Building with Ultra High Performance Concrete“

Binder Optimization

Motivation:

- High contents of energy and cost-intensive components
- It is not possible to predict workability only with the slump flow test

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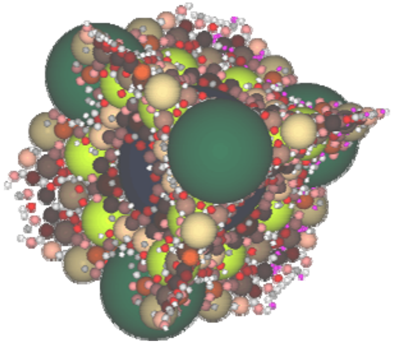

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Binder Optimization

Aim:

- Rheological measurements with Viskomat NT for characterization of workability
- Identify a range of workability from rheological parameters

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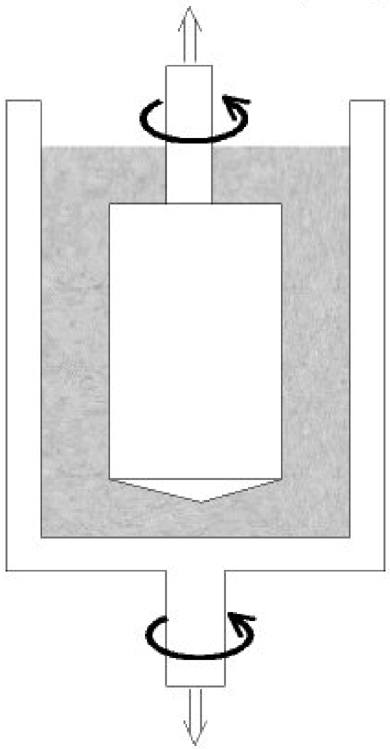
Methods for measurement

Inner cylinder

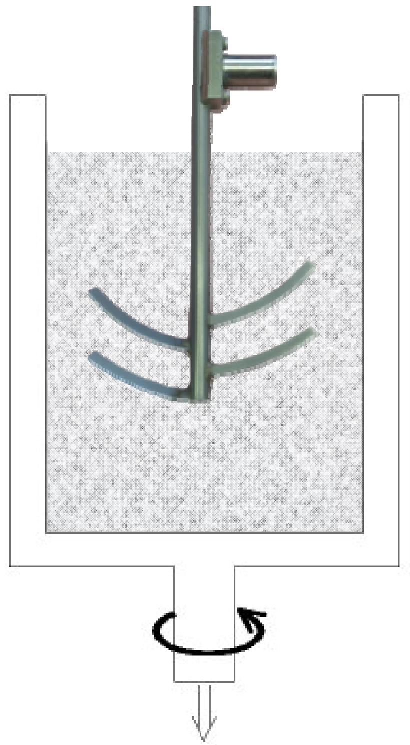


$$\tau = \tau_0 + \eta_{pl} \cdot \dot{\gamma}$$

Difference:

- Geometry of measurement system
- Surface of load transmission
- Measurement gap

Mortar paddle



$$T = g + h \cdot n$$

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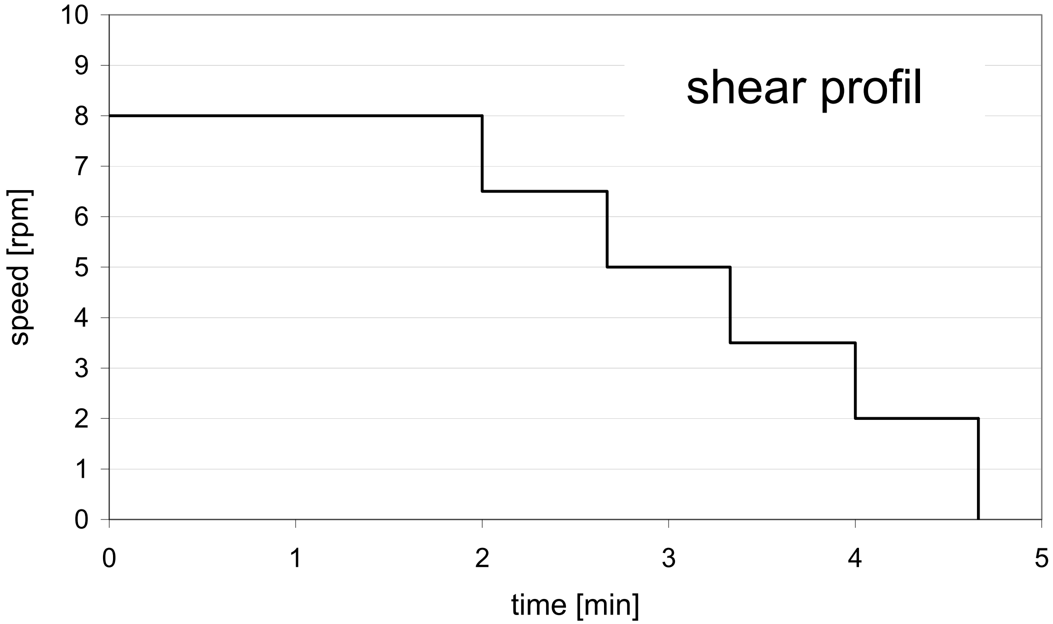
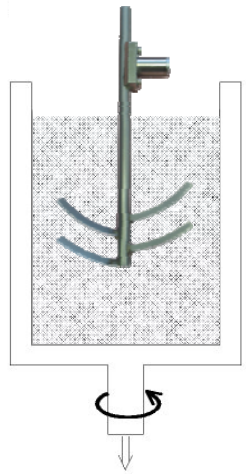
Approach and methodology





- Start measurement 15 minutes after addition of water
- 2 minutes constant pre-shear to cause structural breakdown
- Low rotational speed due to
  - high viscosity of concrete
  - speed similar to slump flow measurement

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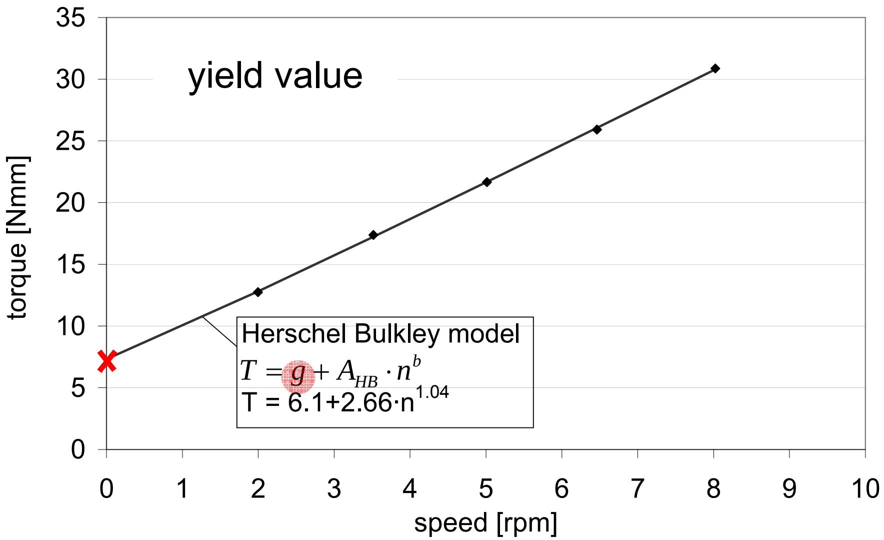
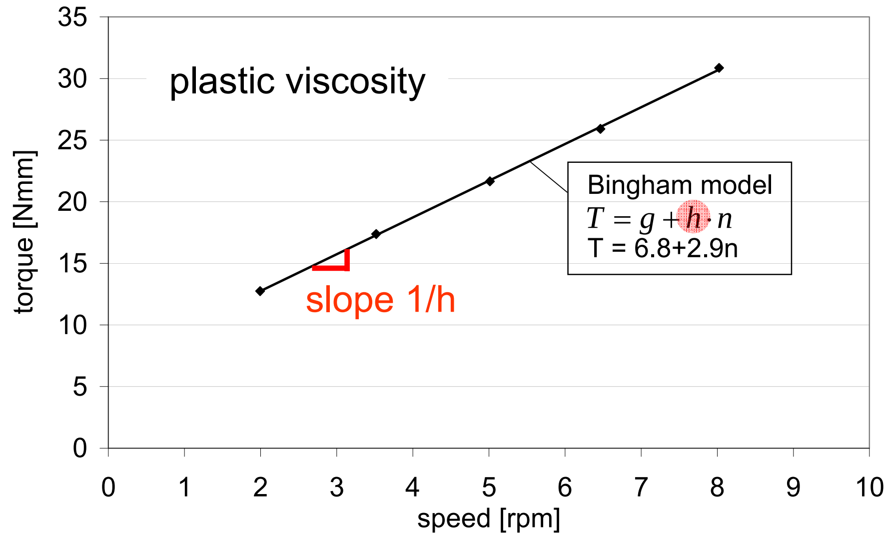
Analysis

Component		Reference
Cement	*kg/m³*	876
Silica fume	*kg/m³*	142
Quartz powder	*kg/m³*	218
Quartz sand	*kg/m³*	985
Superplasticizer	*kg/m³*	16.7
Water	*kg/m³*	187

- Yield value is determined by Herschel Bulkley model
- Plastic viscosity is determined by Bingham model





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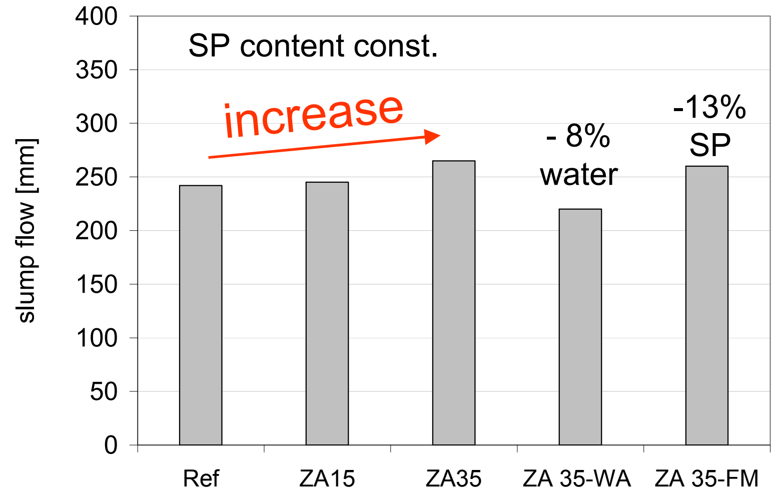
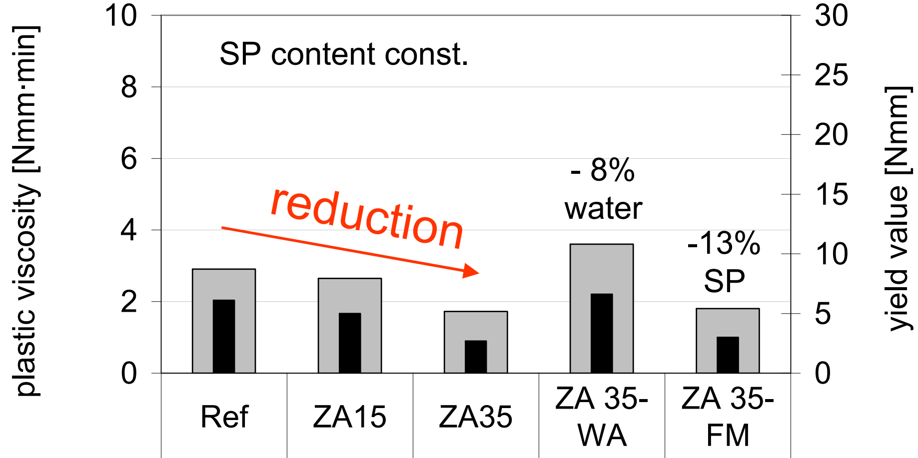
Replacement of cement by fly ash (FA)

- Replacement of 15 and 35 vol.% cement by FA
- unchanged packing density with 88.4% (calculated)
- Improved workability due to reduced reactivity and ball-bearing effect of FA
- A reduction in water content increases plastic viscosity and yield value
- Similar workability when content of superplasticizer (SP) is reduced





	Ref	ZA15	ZA35	ZA 35-WA	ZA 35-FM
plastic viscosity	2.9	2.6	1.7	3.6	1.8
yield value	6.1	5.0	2.7	6.6	3.0

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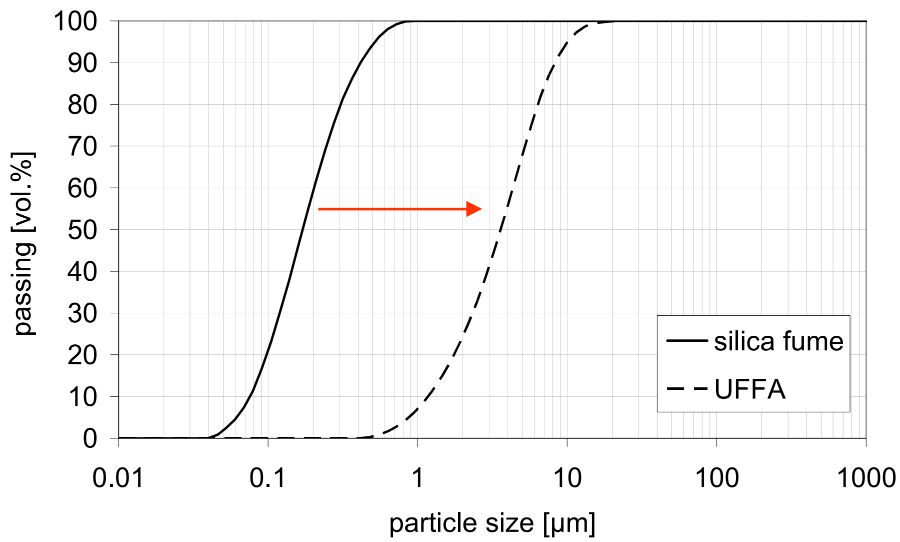
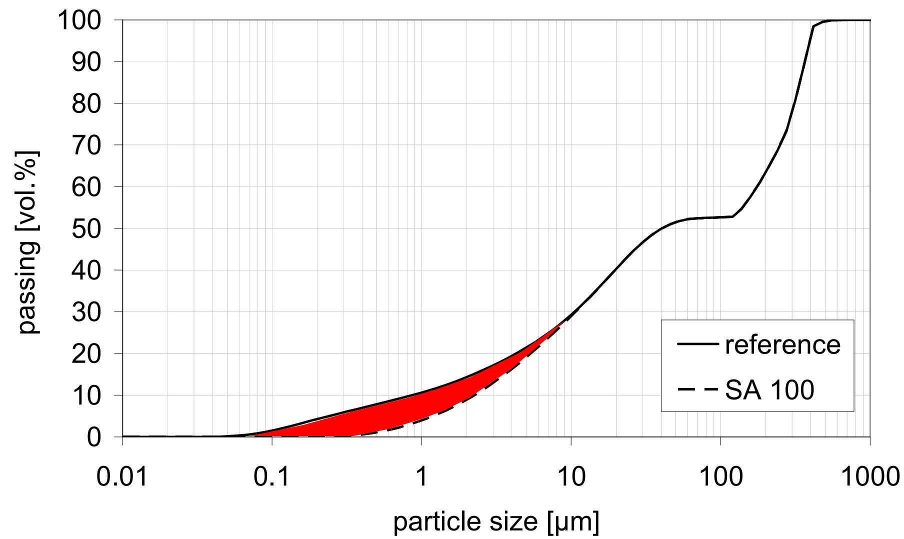
Replacement of silica fume by ultra-fine fly ash (UFFA)

- Replacement of 50 und 100 vol.% silica fume by UFFA
- Particle size of silica fume: 0.2 µm
  particle size of UFFA: 3.6 µm
- Particle size distribution of mixture becomes coarser





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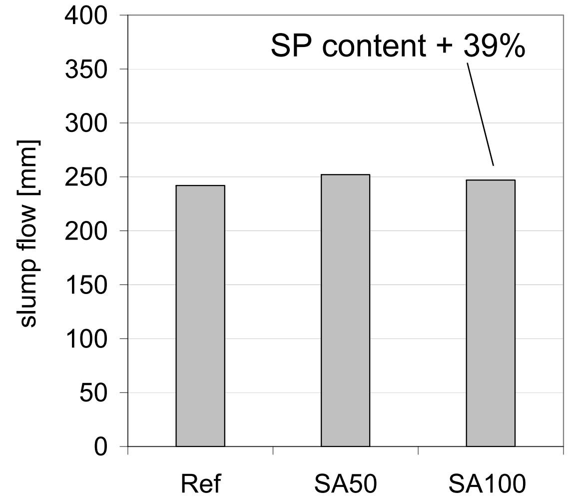
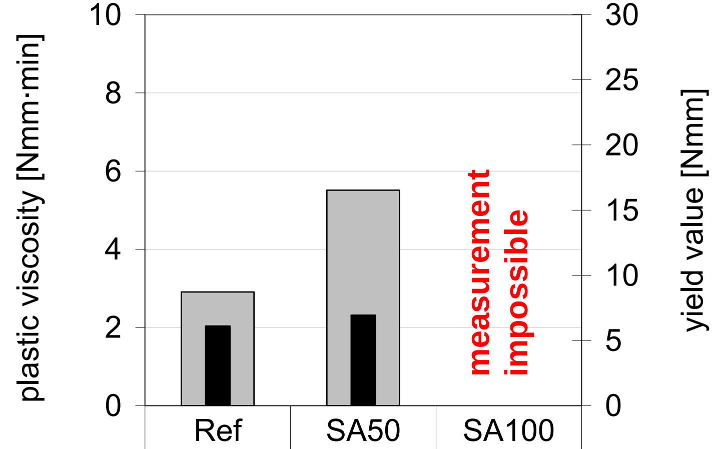
replacement of silica fume by ultra-fine fly ash (UFFA)

- Reduction in packing density
  SA50: - 2.8%
  SA100: - 5.4%
- Increased plastic viscosity at constant yield value ↔ doesn´t relate to slump flow test as expected
- Workability seems to be more affected by the reduced packing density than by the lower surface area of mixture
- Replacement of silica fume by UFFA not recommended





	Ref	SA50	SA100
plastic viscosity	2.9	5.5	0.0
yield value	6.1	6.9	0.0

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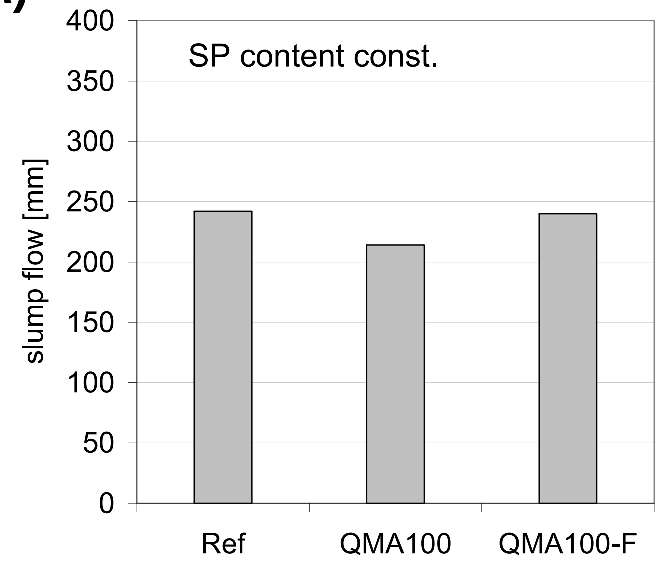
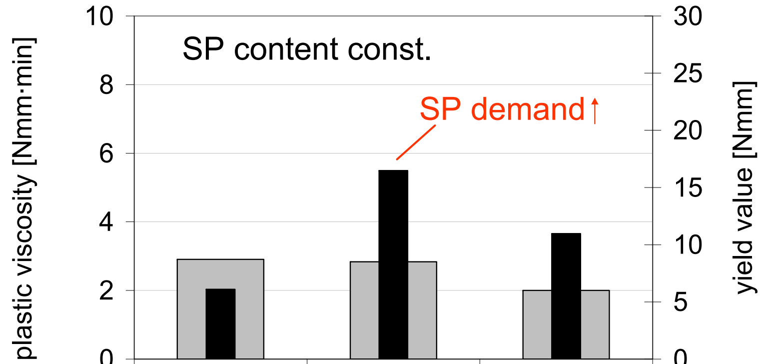
Replacement of quartz powder by fly ash (FA) and ultra-fine fly ash (UFFA)

- Replacement of 100 vol.% quartz powder by FA and UFFA
- Packing density changed
  QMA100: +0.3%
  QMA100-F: - 0.2%
- Loss of workability when FA is used
  → probably adsorption of superplasticizer molecules on unburnt carbons in FA[1]
  → increased yield value
- Similar workability with UFFA





	Ref	QMA100	QMA100-F
plastic viscosity	2.9	2.8	2.0
yield value	6.1	16.5	11.0

[1]According to Laskar and Talukdar: Rheological behavior of high performance concrete with mineral admixtures and their blending. Construction and Building Materials 22, 2008

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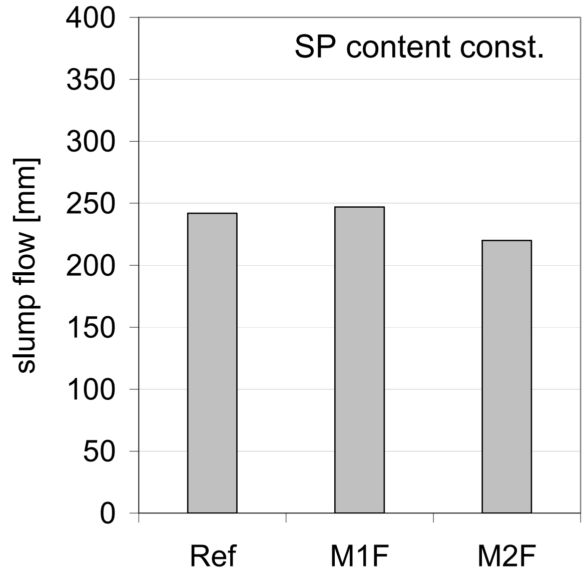
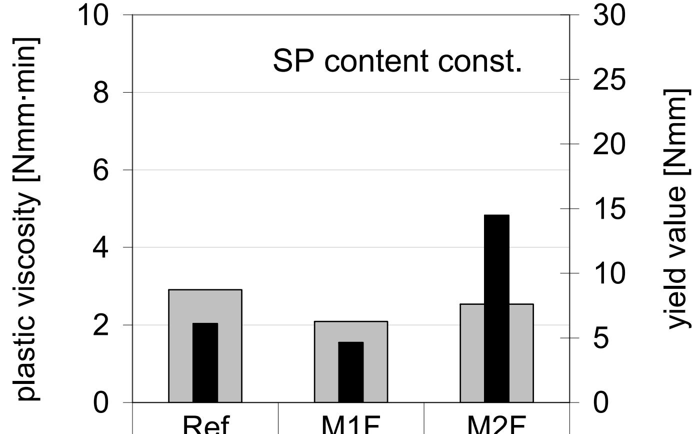
Optimized mixtures - rheology

Component		Reference	M1F	M2F
Cement	*kg/m³*	876	747	572
Fly ash	*kg/m³*	-	244	487
Silica fume	*kg/m³*	142	121	144
Quartz powder	*kg/m³*	218	-	-
Quartz sand	*kg/m³*	985	1039	871
Superplasticizer	*kg/m³*	16.7	16.7	16.7
Water	*kg/m³*	187	187	187
Surface (BET)	*m²/m³*	$355 \cdot 10^4$	$312 \cdot 10^4$	$358 \cdot 10^4$

- Combined replacement of cement, quartz powder and silica fume by fly ash at constant packing density
- Improved workability for M1F
- Small loss of workability for M2F





	Ref	M1F	M2F
plastic viscosity	2.9	2.1	2.5
yield value	6.1	4.7	14.5

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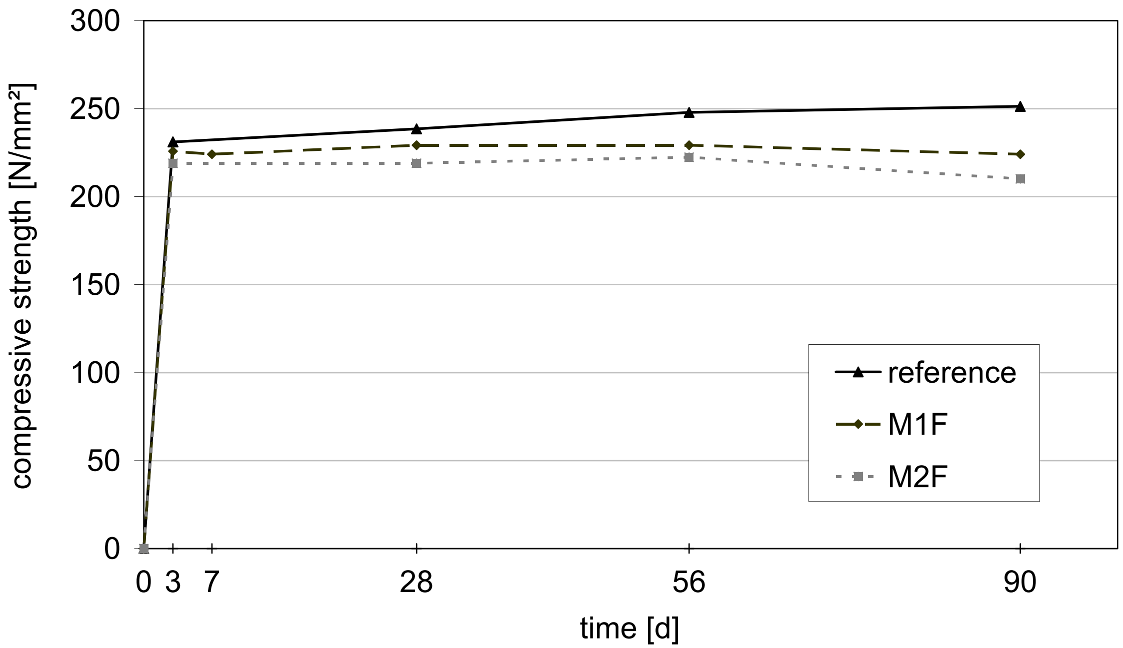
Optimized mixtures – compressive strength after heat treatment



Cylinder 50/50 mm

- Reduced compressive strength with increased content of fly ash
- But all compressive strengths higher than 200 N/mm²

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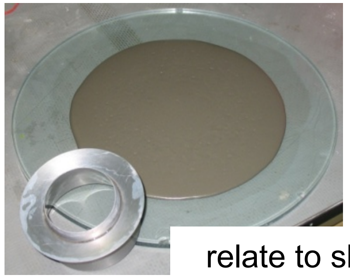
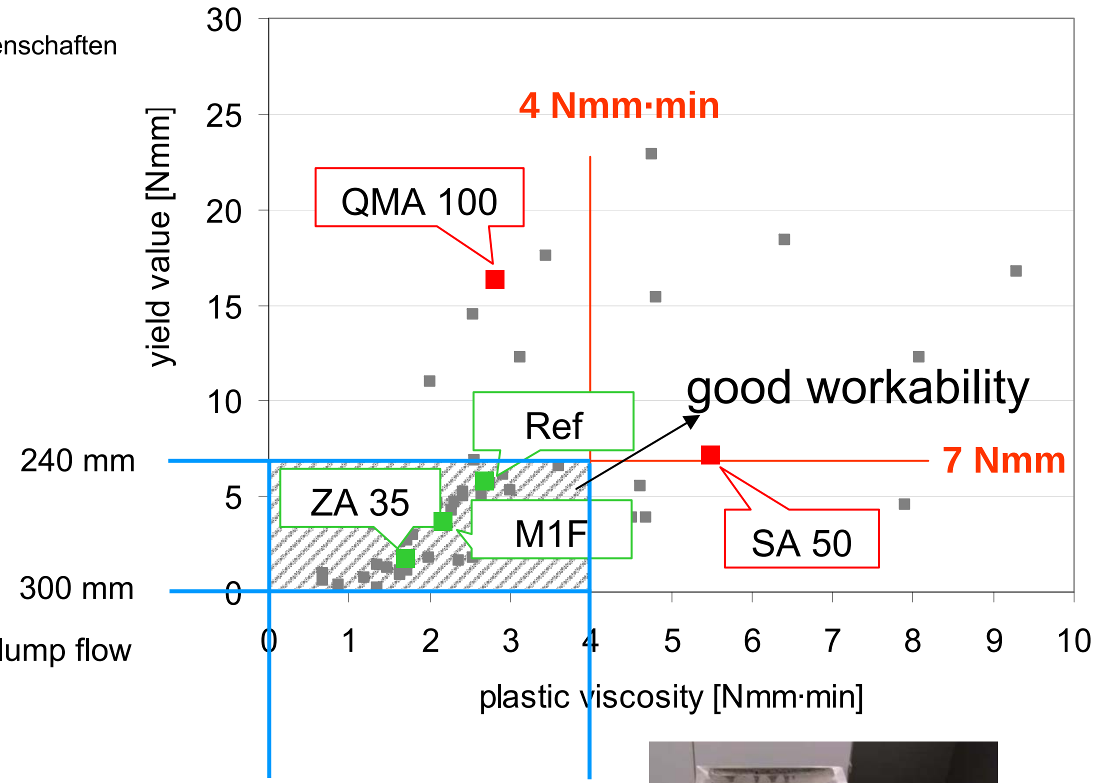
Rheological properties of all measured mixtures – range of workability

According to Kordts and Breit:
Beurteilung der Frischbetoneigenschaften
von Selbstverdichtendem Beton
Beton 53 (11), 2003



relate to slump flow



perspective: time x time y

determine with
V-funnel test

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Conclusions

- It is not possible to predict all aspects of workability with the slump flow test
- Knowledge of plastic viscosity and yield value is sufficient to describe workability of UHPC
- Improved workability
  - with increasing replacement of limited portion of cement by fly ash
  - optimized mixture with combined replacement
- Loss of workability
  - with increasing replacement of silica fume by ultra-fine fly ash
  - complete replacement of quartz powder by fly ash
- Determination of a range of workability for UHPC with good workability properties

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