Quo vadis caementum – nothing goes without rheology

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Kolloquium Rheologische Messungen an mineralischen Baustoffen, Regensburg 29.02.2012

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Content

- Sustainability – Modern trends or duty of enterprise strategy?
- Cement production and CO2 emission – CEM II and CEM III become standard
- M-cements – optimised for performance, durable and uniform
- Rheology of cement paste vs. cement standard parameters
- Rheology of cement paste – Experience from 5 years RheoZ
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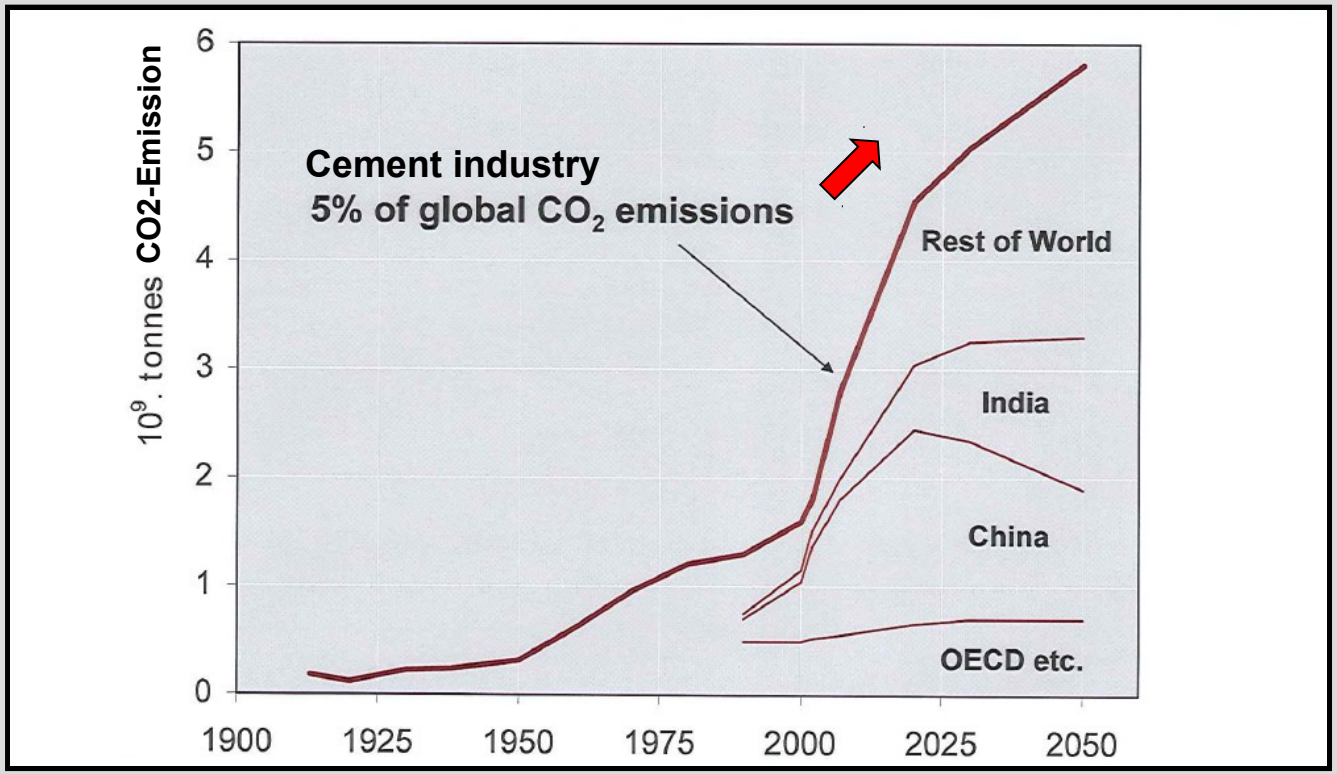
CO2 Ranking industry



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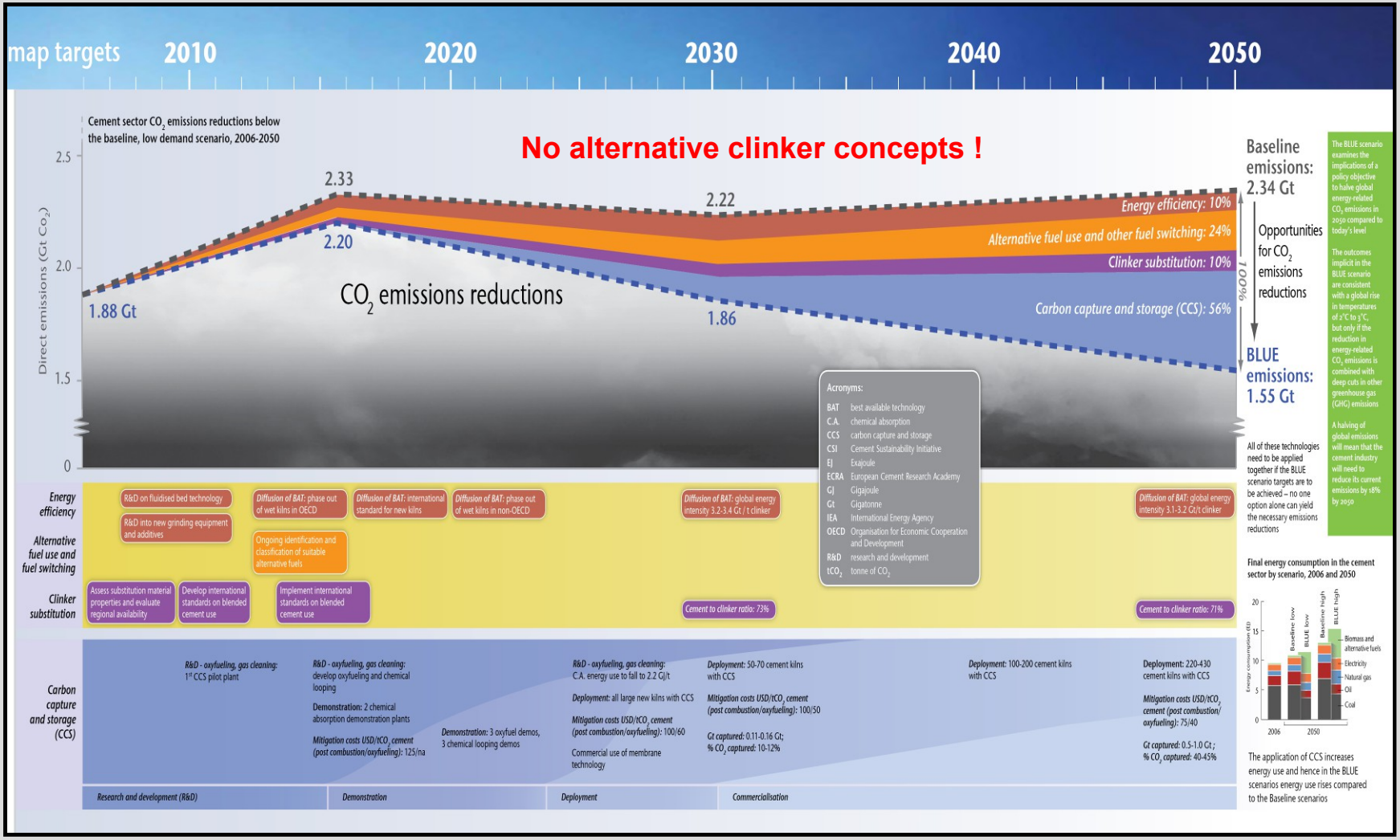
Cement Technology Roadmap 2009

World Business Council for Sustainable Development

International Energy Agency



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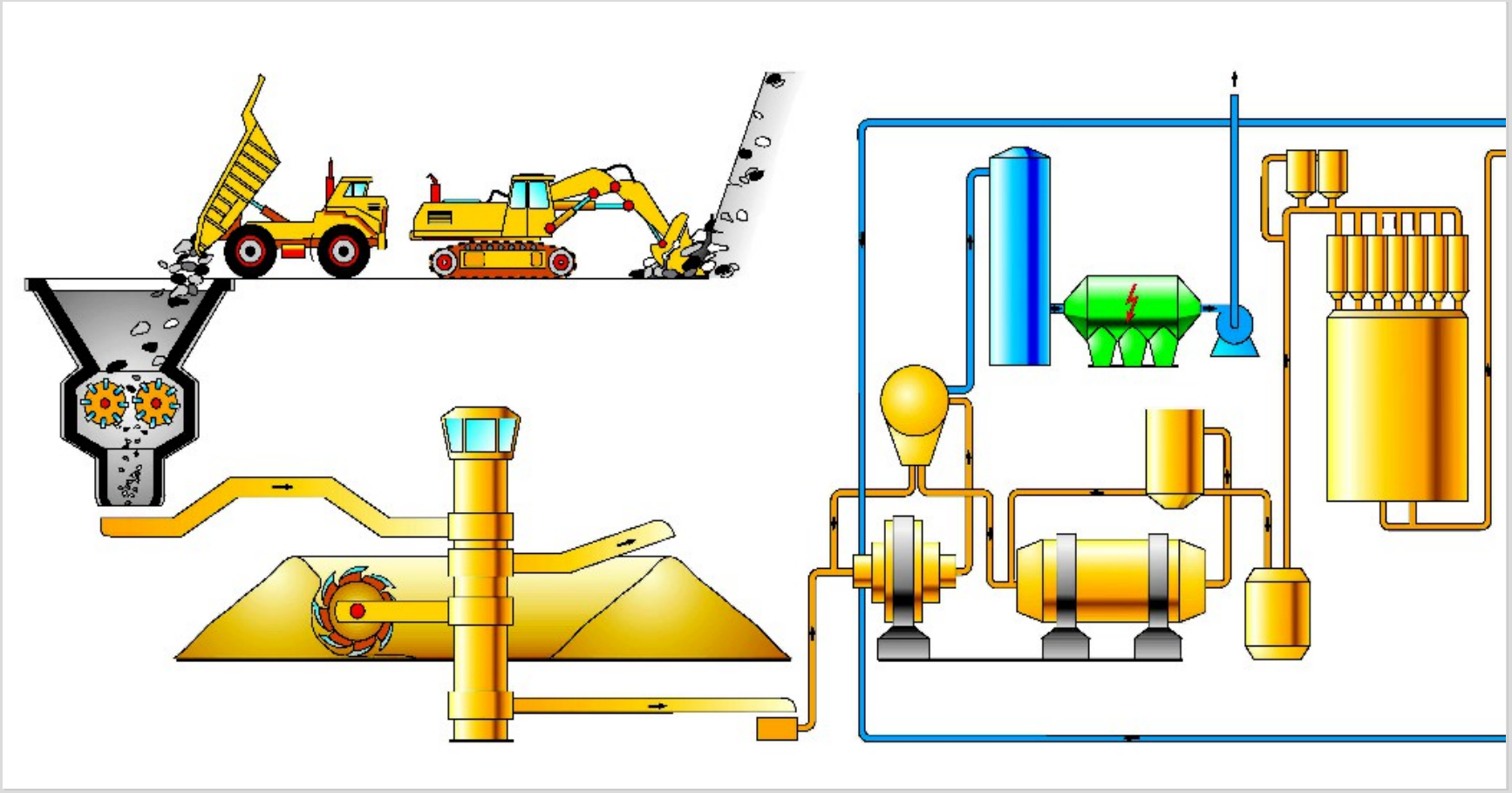
Raw material for cement production

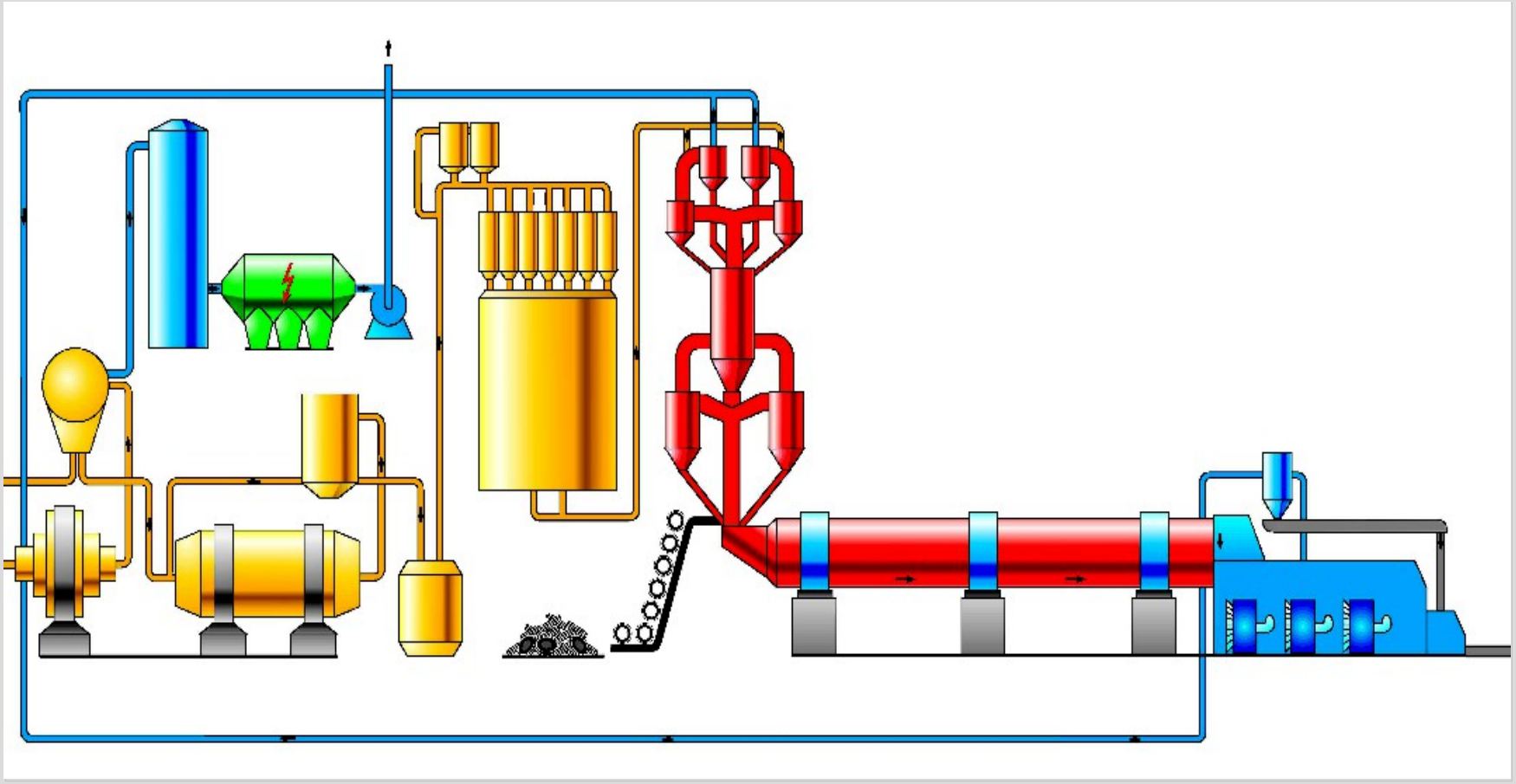
Raw material quarrying

Raw material preparation



Preparation and sintering

Raw material preparation **Clinker sintering**



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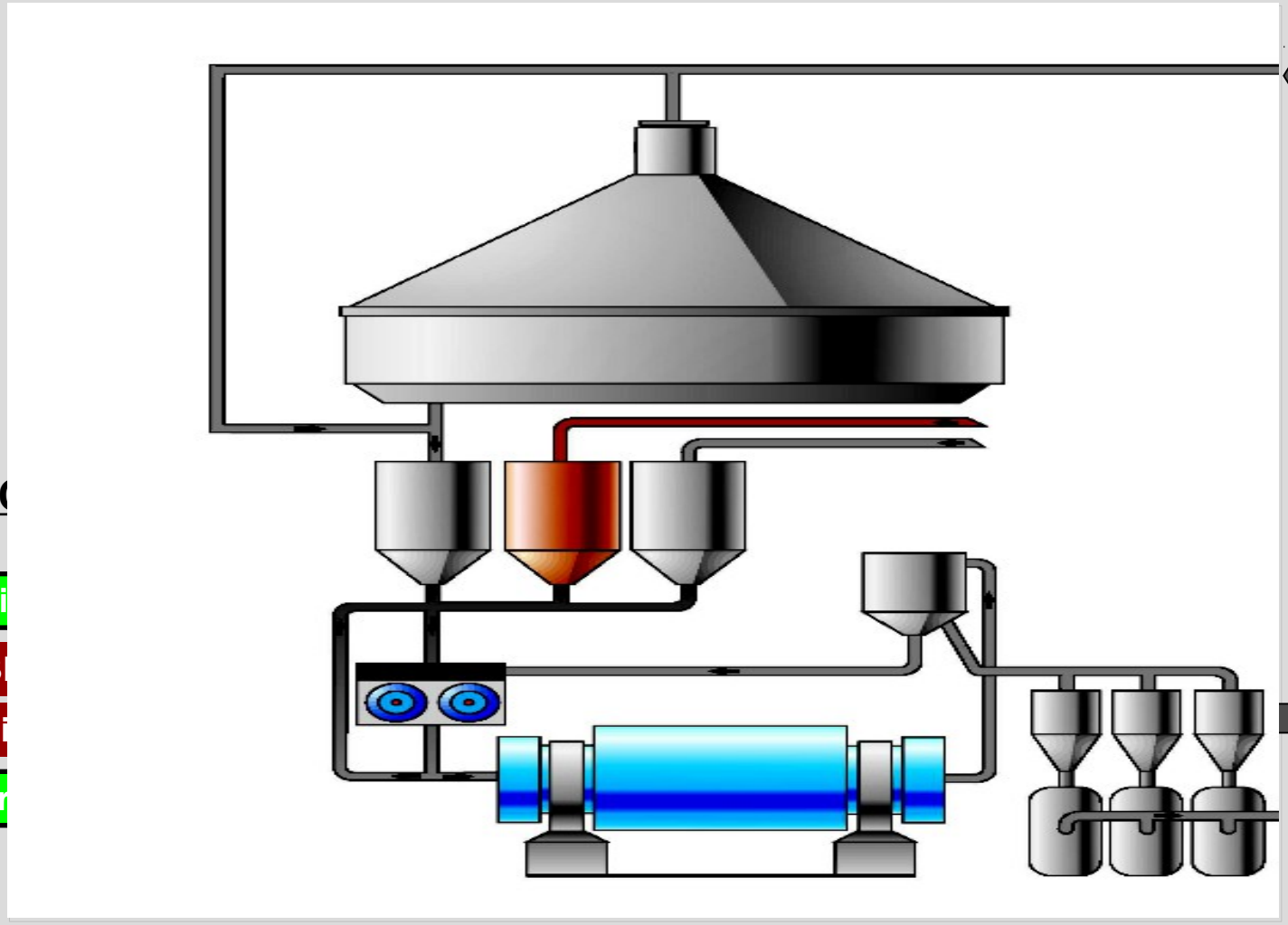
Cement grinding



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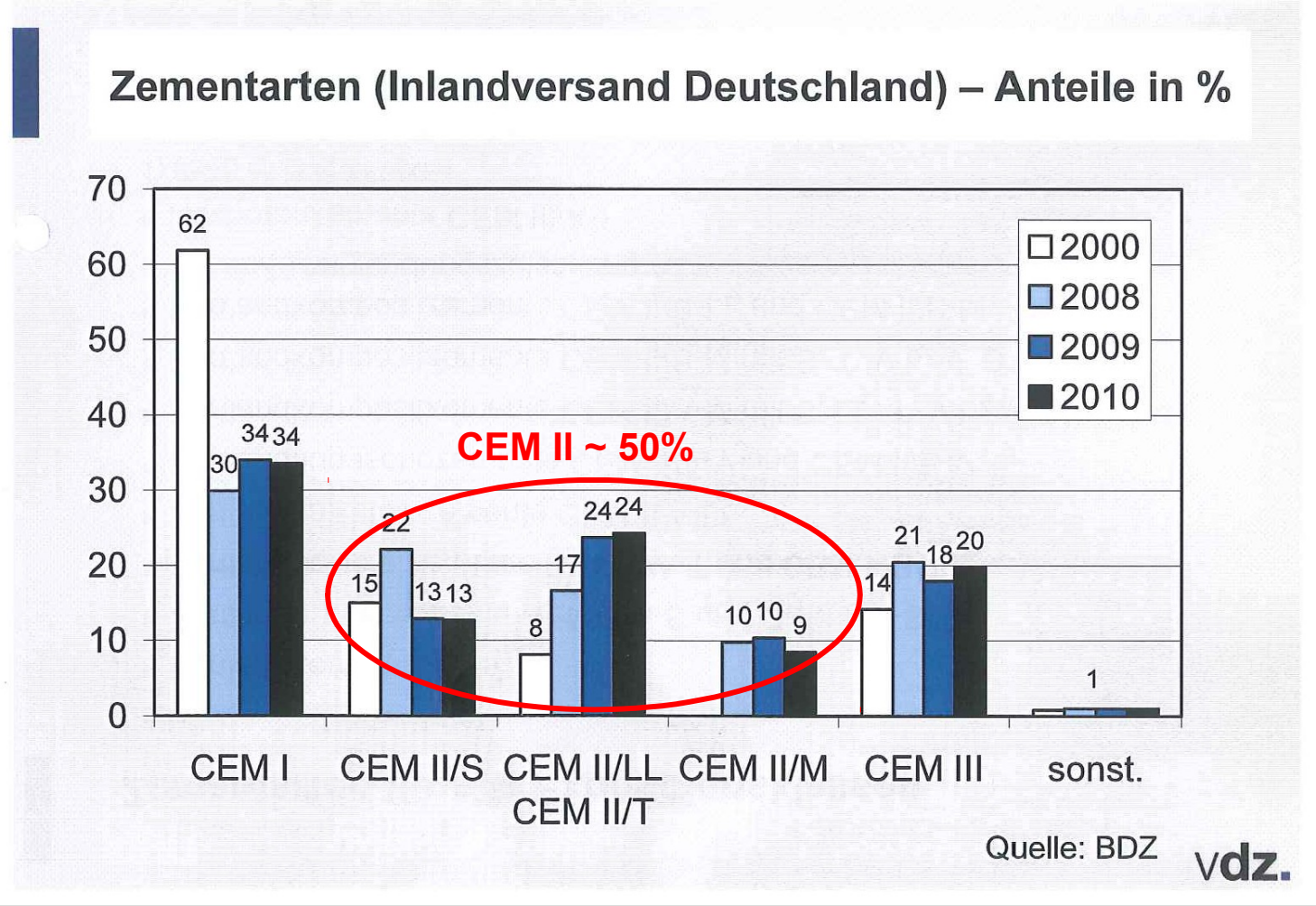
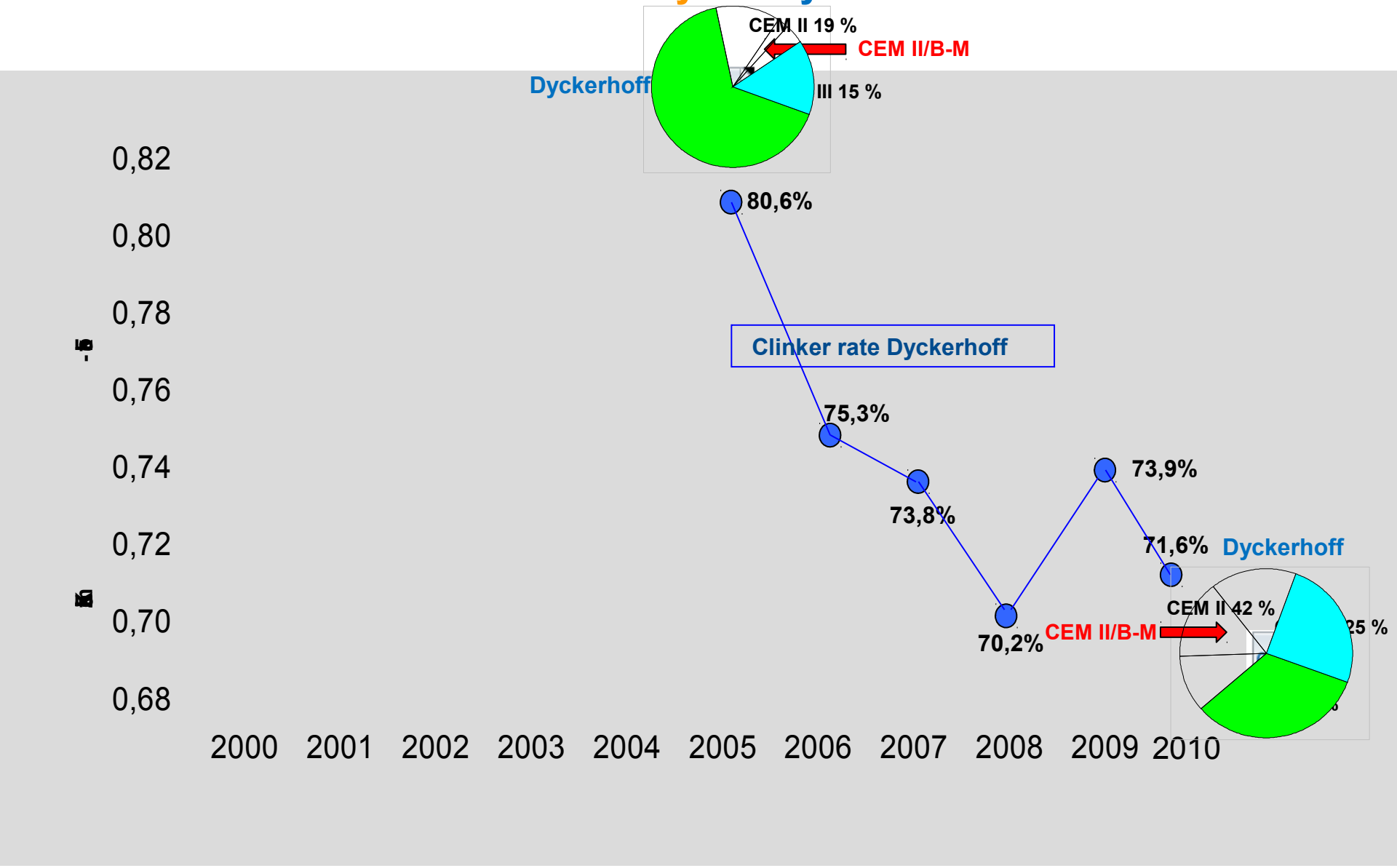
CEM II = Standard cements in Germany



Dyckerhoff

Clinker rate – Cements Germany vs. Dyckerhoff



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CEM II = Composite cements

CEM II / CEM III = CEM I + other materials with hydraulic properties

S	Blast-furnace slag (finely ground, granulated blast-furnace slag)
V	Pit coal fly ash (finely ground/not ground/separated)
LL	Limestone (finely ground, increased requirements)
P	Trass (finely ground)

Long-time experience with S, V, LL, P in cement/concrete

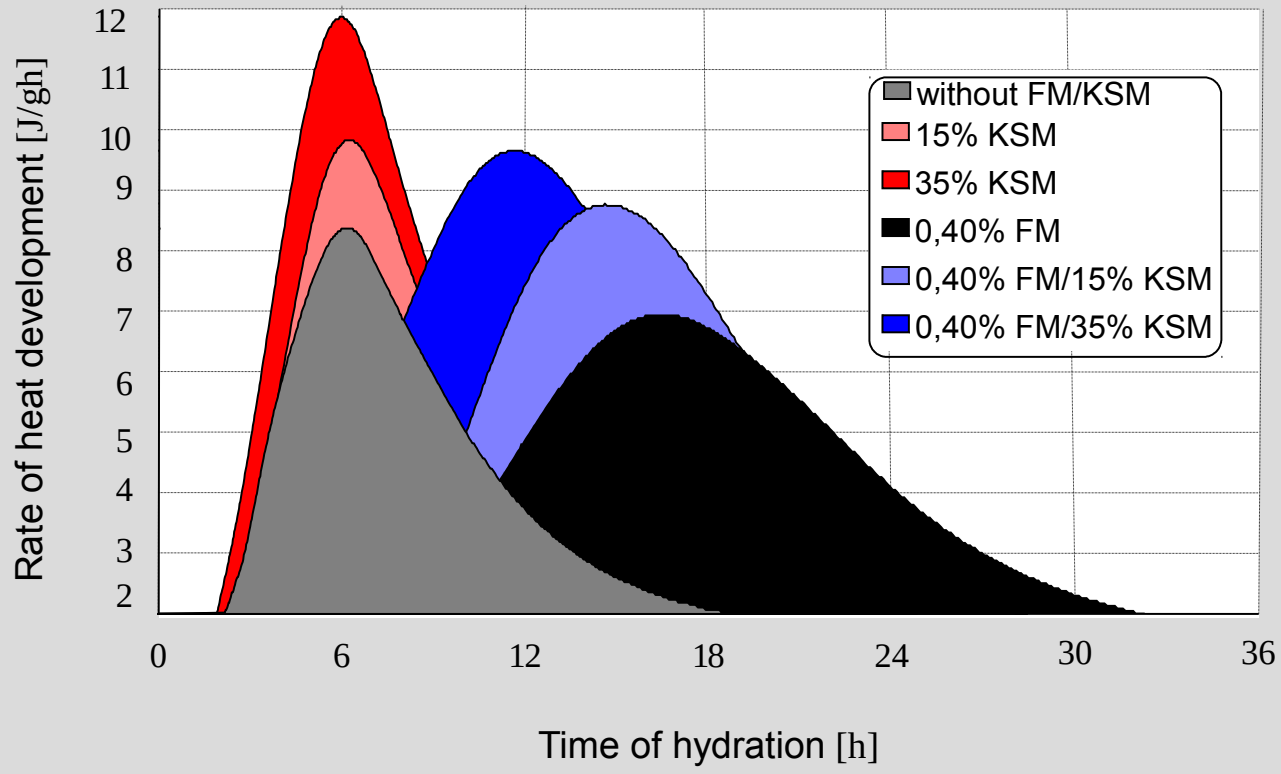
Expanded normative requirements for cement/concrete

Increased R & D for composites in cement/concrete

Good durability properties

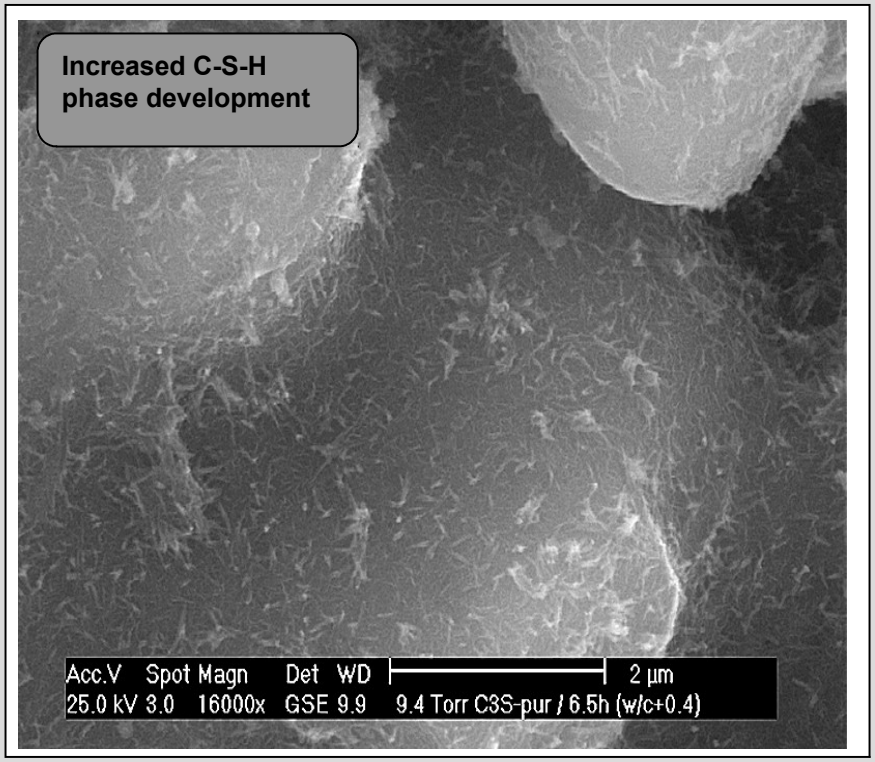
Reaction of C3S + finely ground limestone

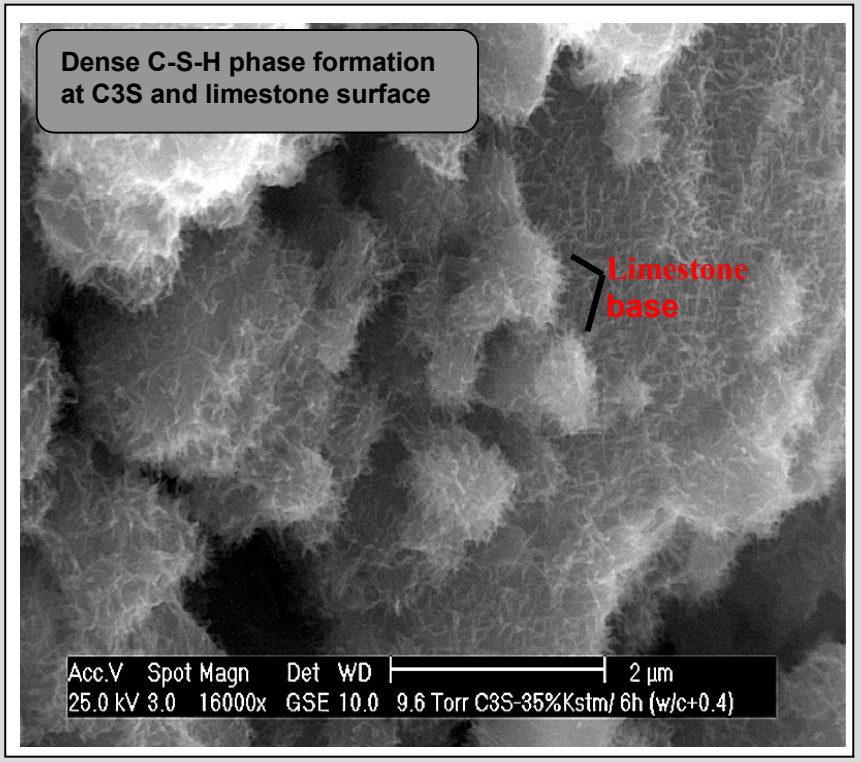
Influence of limestone on hydration



Dyckerhoff

Reaction of C3S + finely ground limestone





ESEM image **without** and **with** ground limestone

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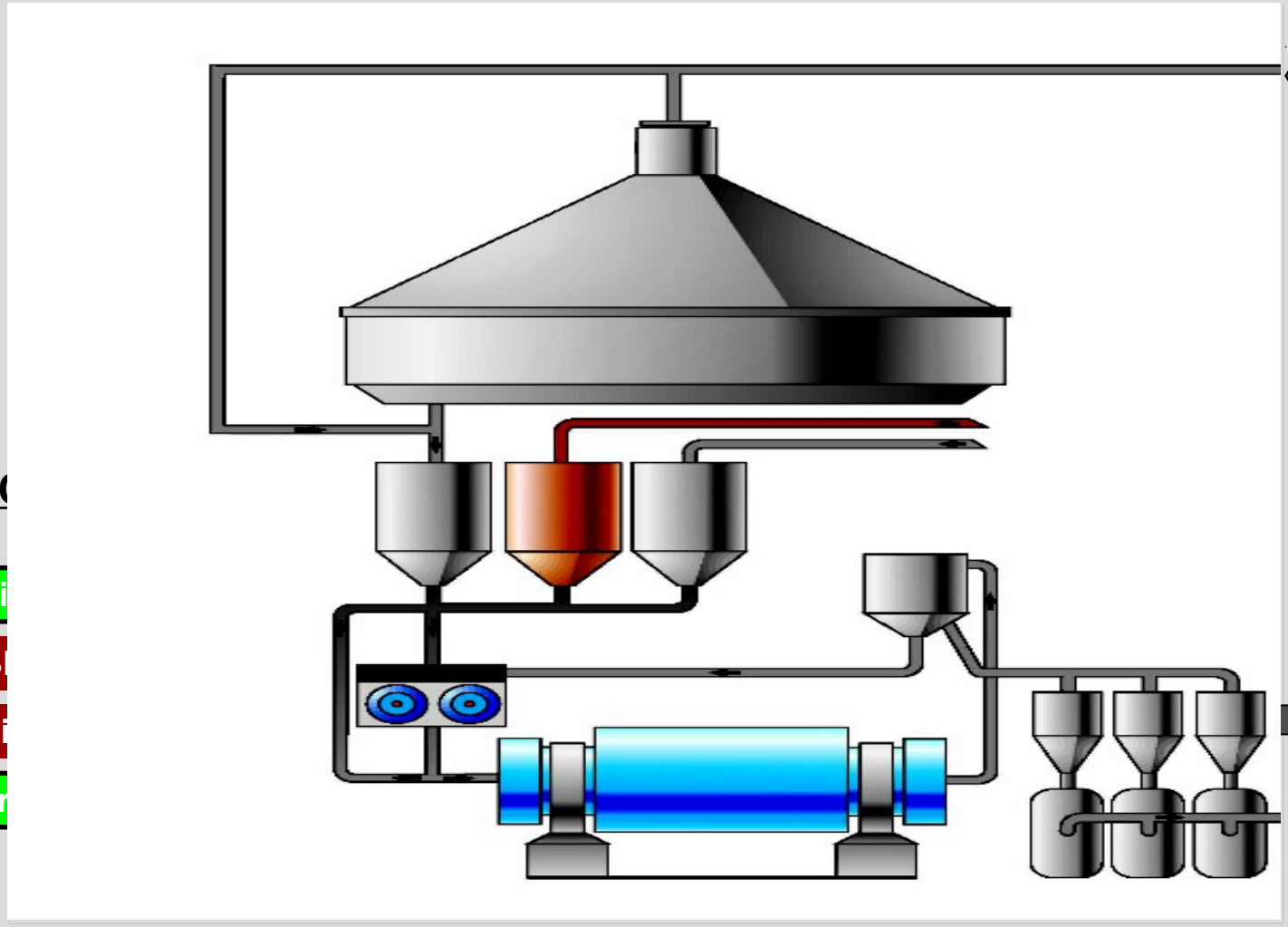
CEM II in cement standard EN 197

Zement	**PZ –** Klinker Minimum	Hüttensand **S** Maximum	KalksteinLL Maximum	SFA **V** Maximum	Trass **P** Maximum
CEM I	**95**	-	-	-	-
CEM II/A-S	**80**	**20**	-	-	-
CEM II/B-S	**65**	**35**	-	-	-
CEM II/A-LL	**80**	-	**20**	-	-
CEM II/B-LL	**65**	-	**35**	-	-
CEM II/A-V	**80**	-	-	20	-
CEM II/B-V	**65**	-	-	35	-
CEM II/A-M (S-LL)	**80**	20 (S + LL)		-	-
CEM II/B-M (S-LL)	**65**	**35 (S + LL)**		-	-
CEM II/A-M (V-LL)	**80**	-	20 (V + LL)		-
CEM II/B-M (V-LL)	**65**	-	**35 (V + LL)**		-
CEM II/B-P	**65**	-	-	-	**35**

CEM III/A, CEM III/B, CEM III/C, CEM IV, CEM V

Cement grinding common milling



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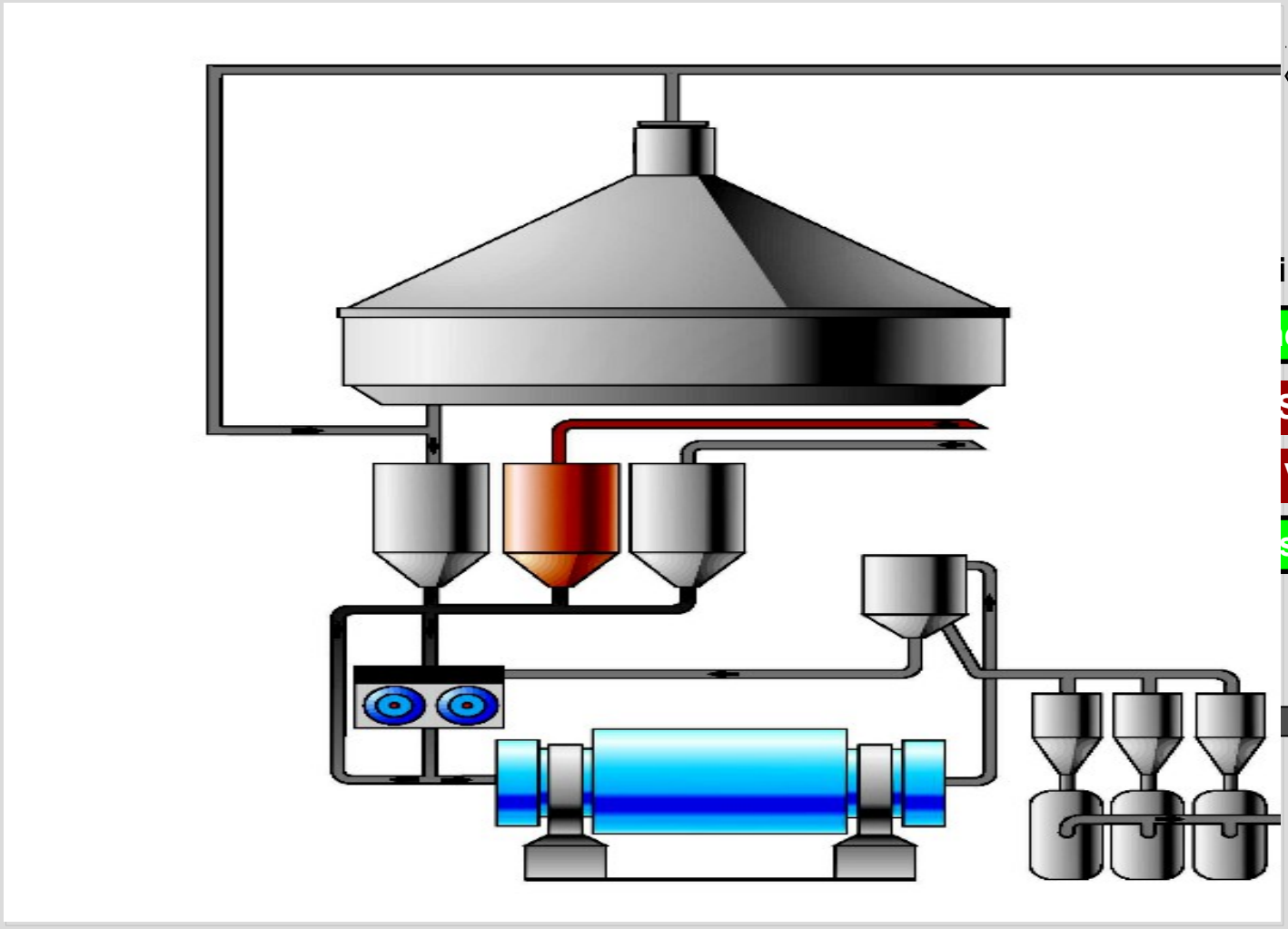
Cement grinding separate milling/mixing



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Cement grinding
common milling vs. separate milling/mixing

Advances separate milling/mixíng

- Finenesses of components can be adjusted individually
- Optimisation of grain size distribution of mixed cements
- Optimisation of packing density/water demand/workability
- Optimisation of hardening reactions
- Improvement of durability

→ **Custom-tailored cements**

Dyckerhoff CEM II/B-M(S-LL) 32,5 R / 42,5 R / 52,5 R (MZ-S)
Dyckerhoff CEM II/B-M(V-LL) 32,5 R (MZ-V)

Optimised combination of LL and S/V

Characteristic LL components

-Acceleration early strength development, heat development
-decreased late strength development
-Inert on durability properties (< 30% ?)

+

Characteristic S, V components

-Decelerated setting/hardening and heat development
-increased late strength development
-Improved durability properties (Pore microstructure and intrusion resistance)

Optimised combination of LL and S/V

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Characteristic S, V components

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-increased late strength development
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CEM X – Continuation of CEM II/B-M

EN 197-1 Expansion / Bauaufsichtliche Zulassung

	Cement	**PZ –** Clinker Minimum	BFS **S** Maximum	Limestone **LL** Maximum	PFA **V** Maximum	Trass **P** Maximum
	CEM I	**95**	-	-	-	-
	CEM II/A-S	**80**	**20**	-	-	-
	CEM II/B-S	**65**	**35**	-	-	-
	CEM II/A-LL	**80**	**-**	**20**	-	-
	CEM II/B-LL	**65**	-	**35**	-	-
	CEM II/A-V	**80**	-	-	20	-
	CEM II/B-V	**65**	-	-	35	-
	CEM II/A-M (S-LL)	**80**	20 S + LL		-	-
CEM X →	**CEM II/B-M (S-LL)**	**65 (40-50)**	**35 (60-50) S + LL**		-	-
	CEM II/A-M (V-LL)	**80**	-	20 V + LL		-
CEM X →	**CEM II/B-M (V-LL)**	**65 (40-50)**	-	**35 (60-50) V + LL**		-
	CEM II/B-P	**65**	-	-	-	**35**

CEM III/A, CEM III/B, CEM III/C, CEM IV, CEM V

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Customer benefit analysis cement

„Welche Nutzenfaktoren sind Ihnen am Zement/Lieferanten besonders wichtig?“

1. Quantitative assessment of benefit criteria:

1. Position Price (30%)

2. Position Product uniformity (13%)

.

. < 10% (Reliability, logistics, references, R & D, consulting, …)

.

„Very high evalution of product uniformity regarding customer benefits“

2. Improvement potentials for customer benefits:

„In all markets (ready-mix, conctruction elements, plaster and mortar) the improvement of product uniformity achieves the strongest positive effects amongst all criteria.“

(Except price reduction)

Product strategy Dyckerhoff = . . . + Product uniformity

Product uniformity cement = Constant

1. **Workability** of cements (Cement paste)

2. Mechanical **strength properties** of the cements (hardened cement)

5. **Durability** of the cements (hardened cement)

7. **Additional properties** (Colour, fineness, composition, rheological properties of dry cement, heat development, etc.)

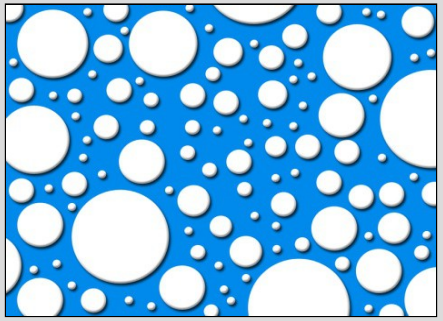
Product uniformity

Increasing **<u>importance of product uniformity:</u>**

- automated, fast production processes
- increased quality requirements on final products concrete, …
- Cost pressure at the cement customer (Minimisation of failures and reserves)

- Increased rate of sensitive and softer concretes
- Reduction of cement content in concrete
- Increased application of concrete chemistry

Produktgleichmäßigkeit Verarbeitungseigenschaften Beton



Workability of concrete:

Rheological properties of fresh concrete between mixing and setting (stiffening, concrete binding, …)

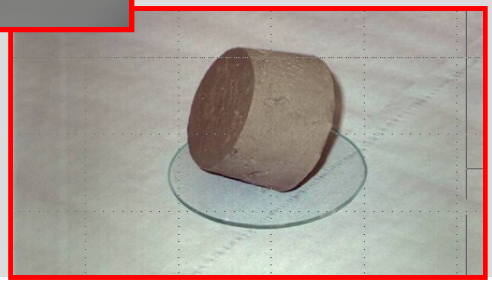
Rheological properties of fresh concrete are strongly dependent on the rheological properties of the fluid phase of the fresh concrete (mortar/**cement paste**)

Other influences: Concrete composition, mortar content, paste content
additives
temperature
.
.

→ **Rheology/workability cement paste**

Workability parameters cement acc. DIN EN 196 Teil 3

Water demand, begin of setting



- not relevant to practice
- w/c 0,25 – 0,35 (without SP, „tamped
- concrete“)
- static, insensitive method
- no continuous rheological information during setting
- Standard parameters are not the practical workability parameters

- In the market: Introduction of own methods
- General critisism in the market regarding workabilty

Product uniformity – Workability of cement paste

Product uniformity

=

Uniformity of cement standard parameters

+

Uniformity of additional properties

Duty

+

Volantary

Hydraulic binder rheology with the Viskomat NT

Principal:

Der Viskomat is a universal viscometer for measuring the consistancy/stiffness of fluid binder mixes.

The cement paste rotates in a pot mit with a fixed paddle. The torsional force is measured, depending on the stiffness of the cement paste.

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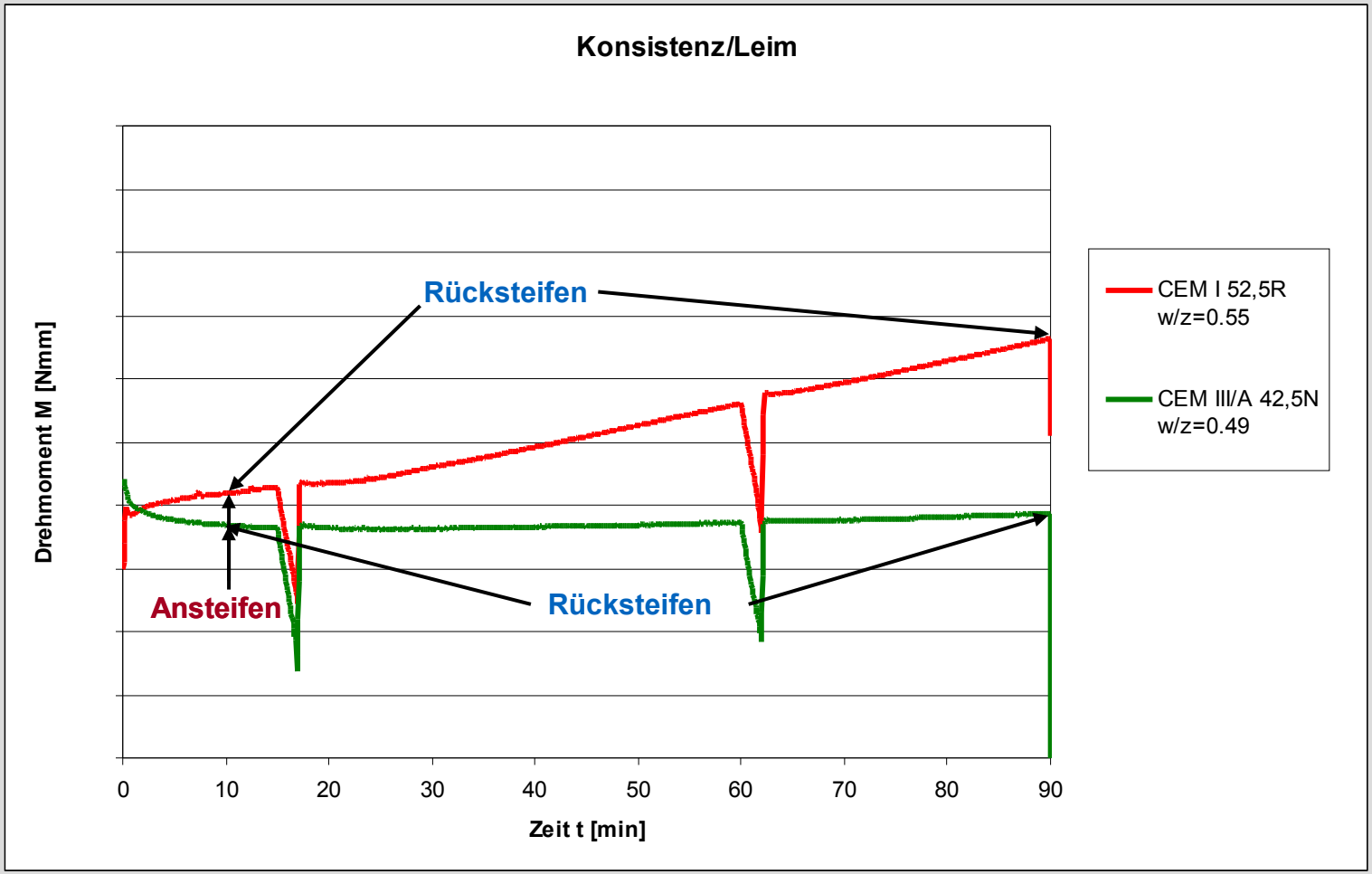
Rheometry cement paste with Viskomat NT



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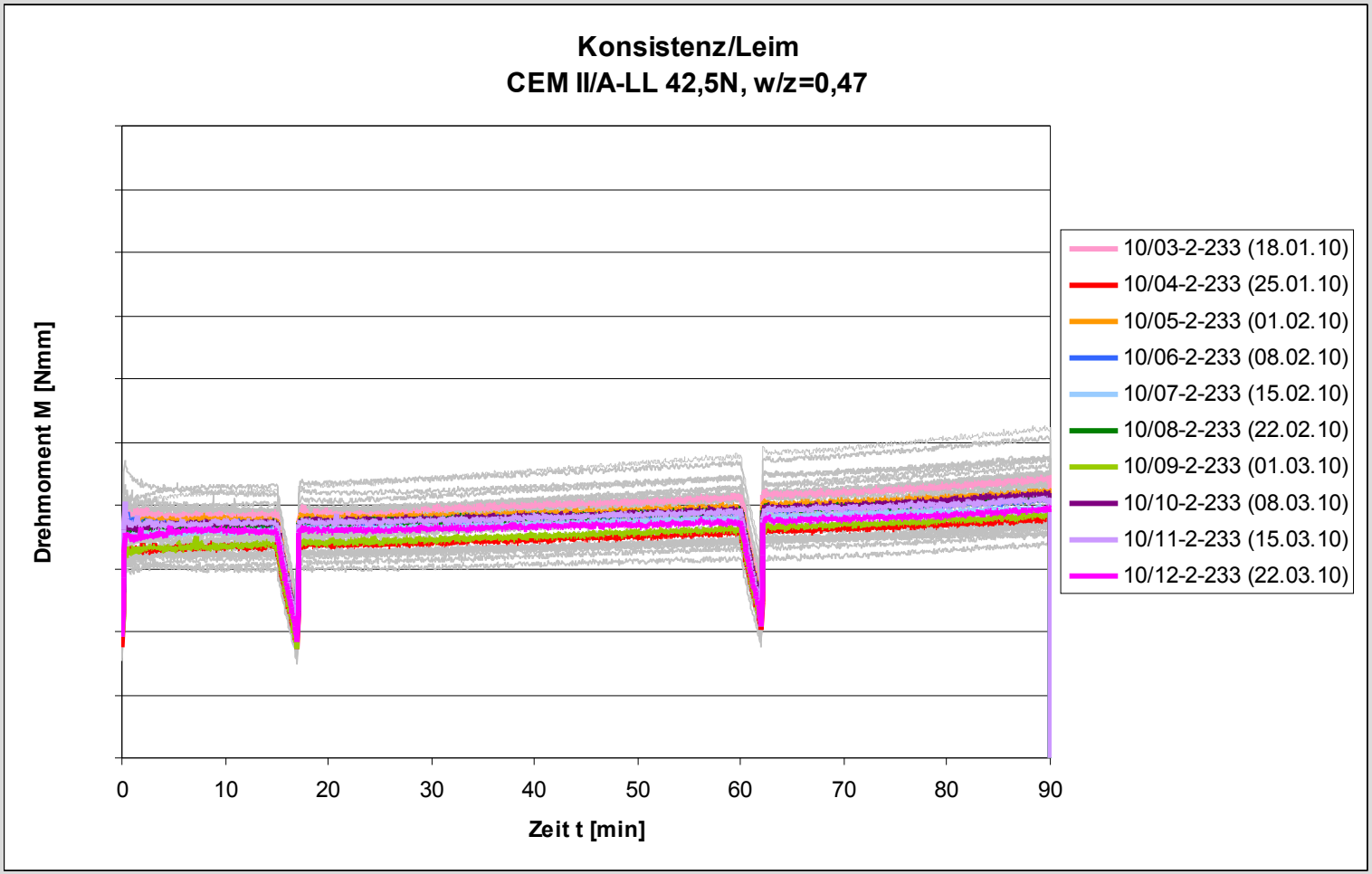
Rheomety in quality control:

Torque M = f (time t)



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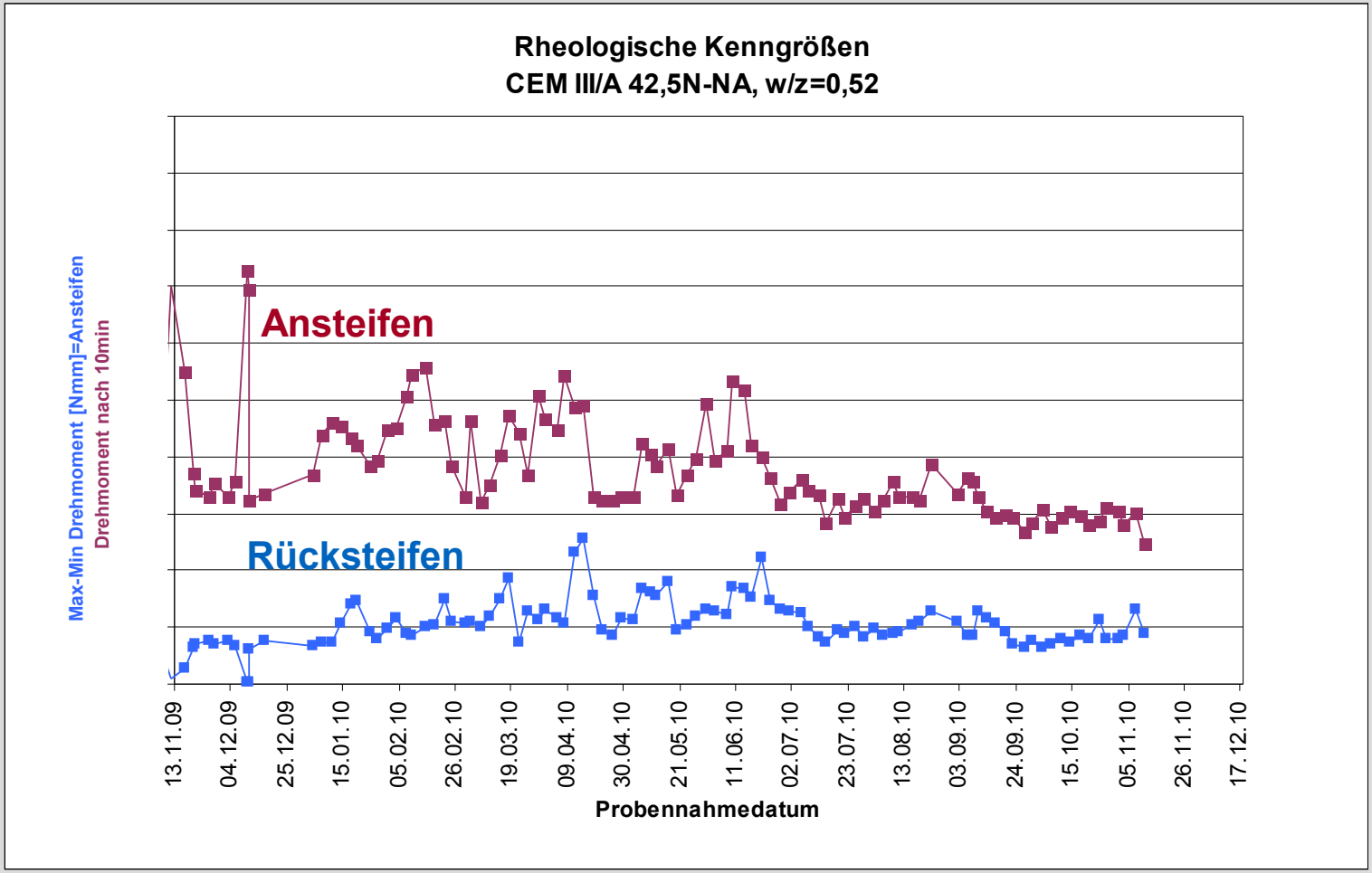
Rheometry in quality control:

Ansteifen/**Rücksteifen** = f (shipping date)



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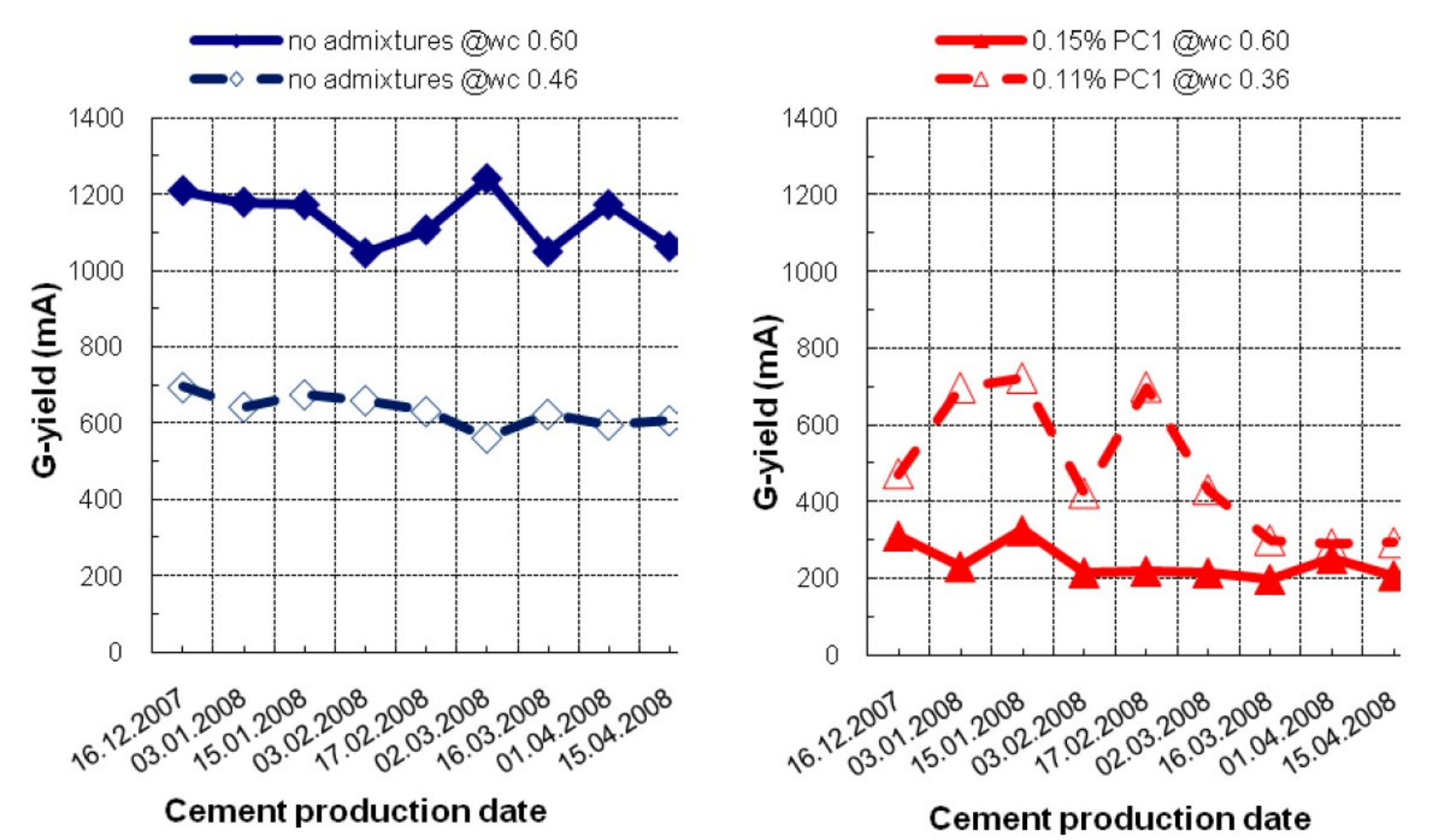
Changing workability



Kubens, Katz, Bentur, Wallevik, 2010

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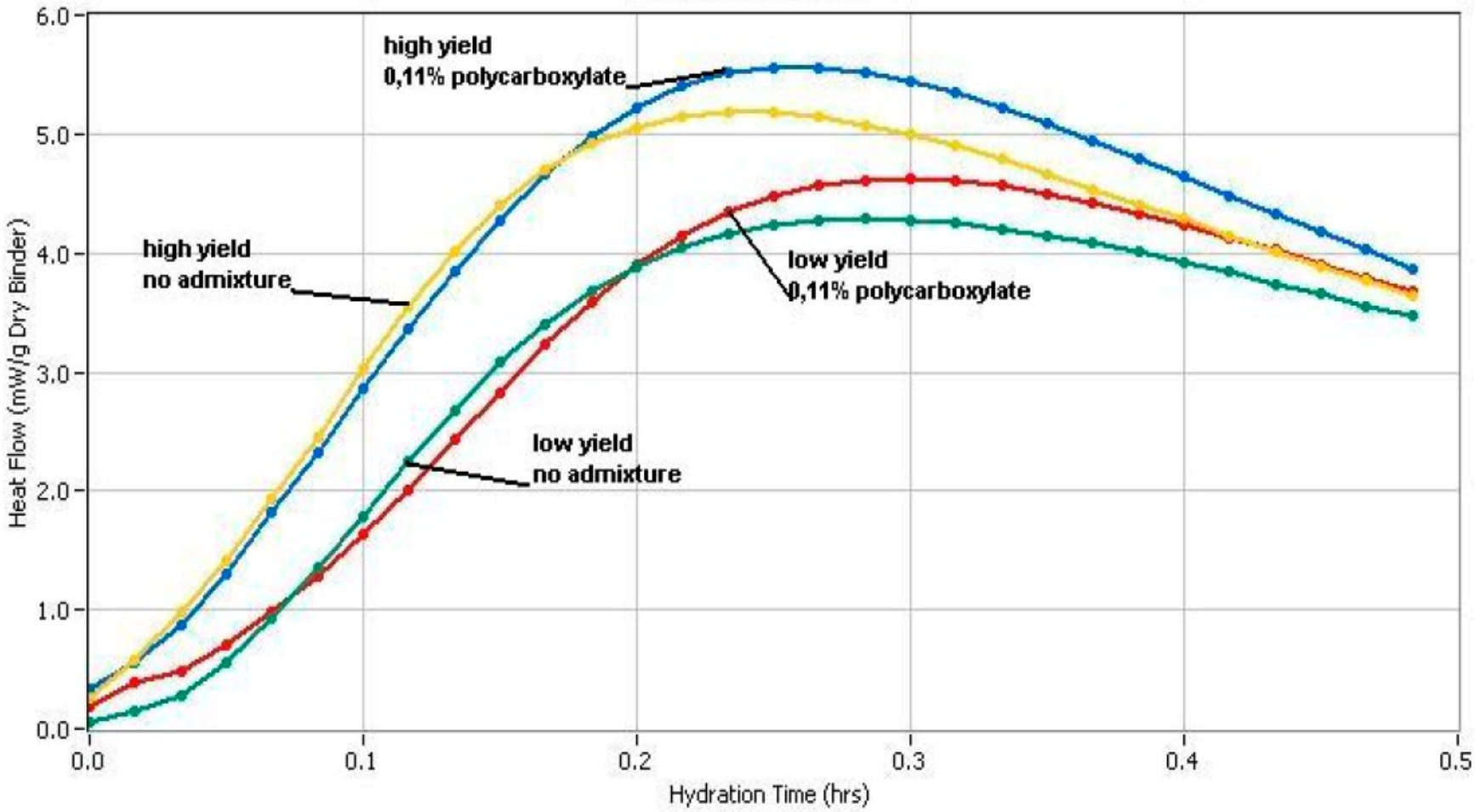
Yield stress vs. heat development/reactivity clinker



Kubens, Wallevik, 2010

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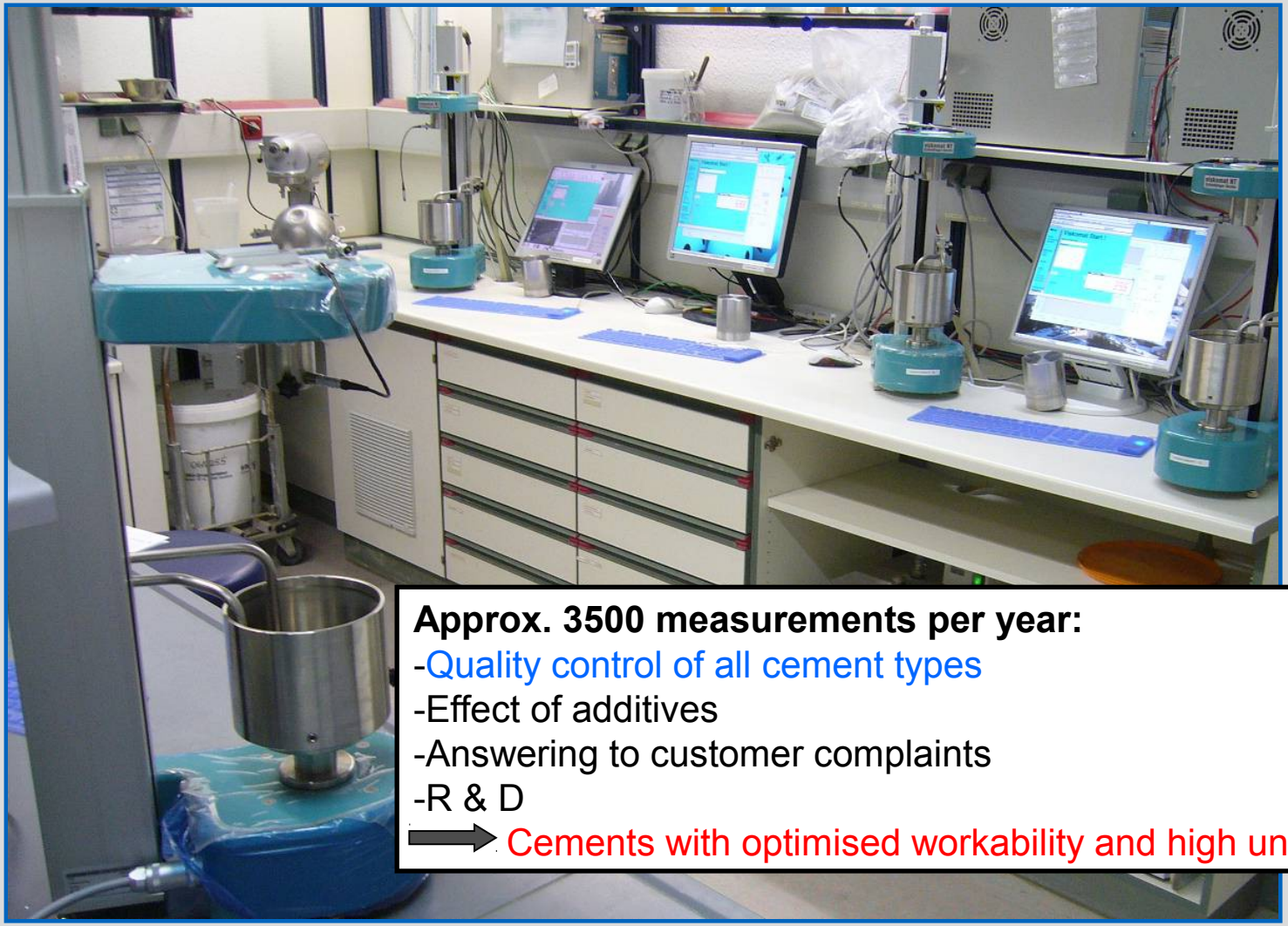
Rheology laboratory Dyckerhoff



Approx. 3500 measurements per year:

-Quality control of all cement types

-Effect of additives

-Answering to customer complaints

-R & D

→ Cements with optimised workability and high uniformity

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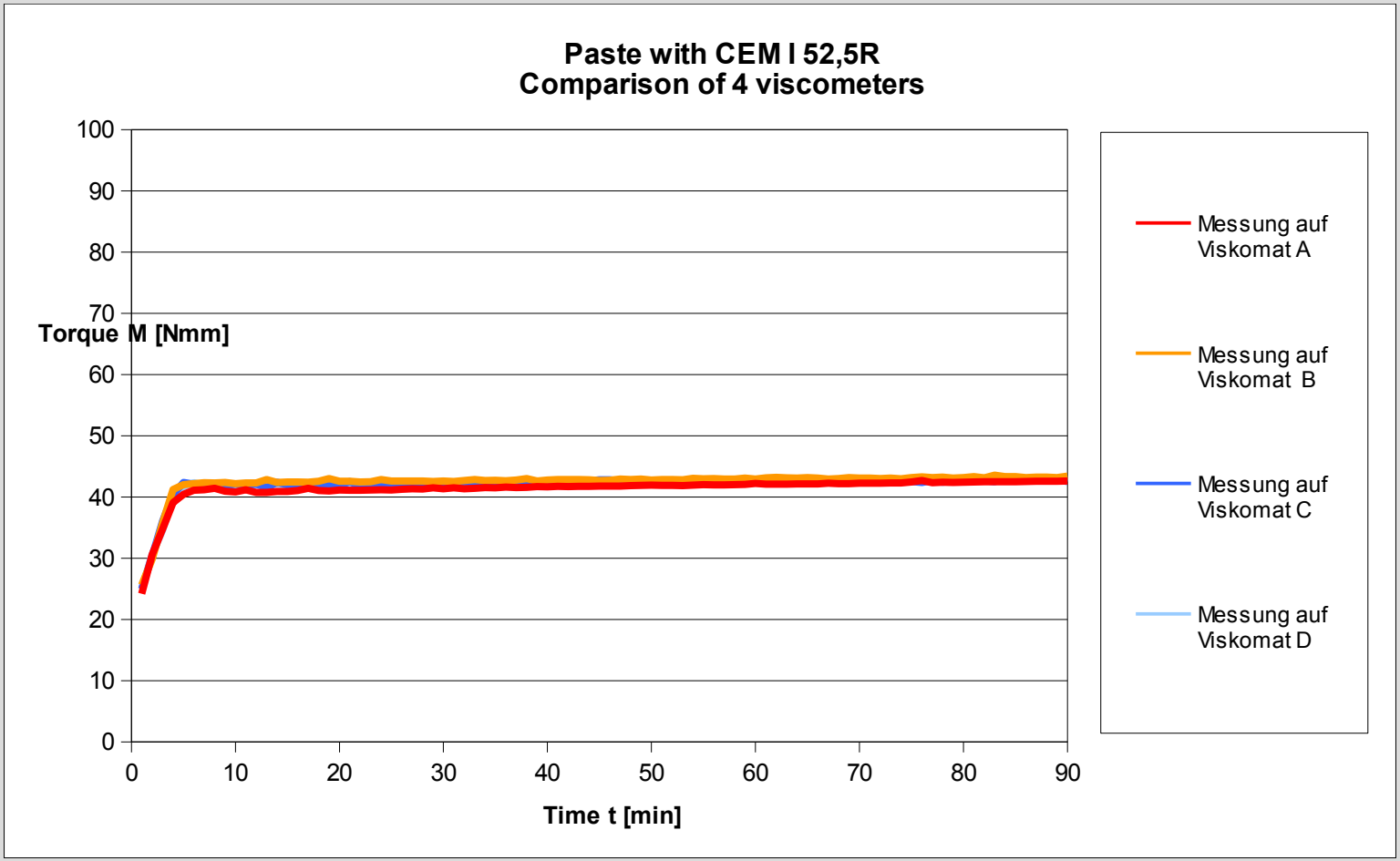
RheoZ – Precision and accuracy

Paste made with CEM I 52,5R (four cement mixes, four viscometers)



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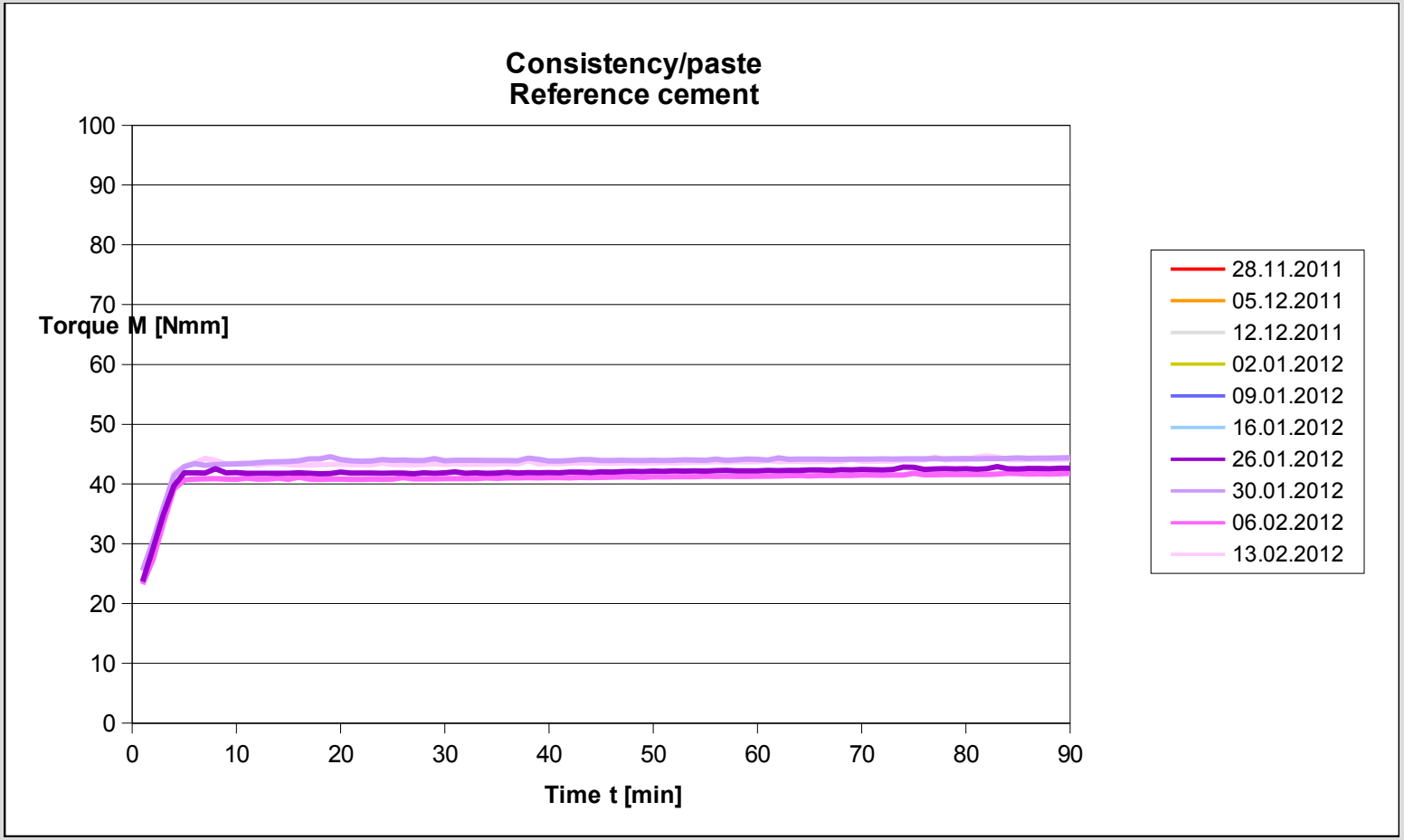
RheoZ – Reference cement



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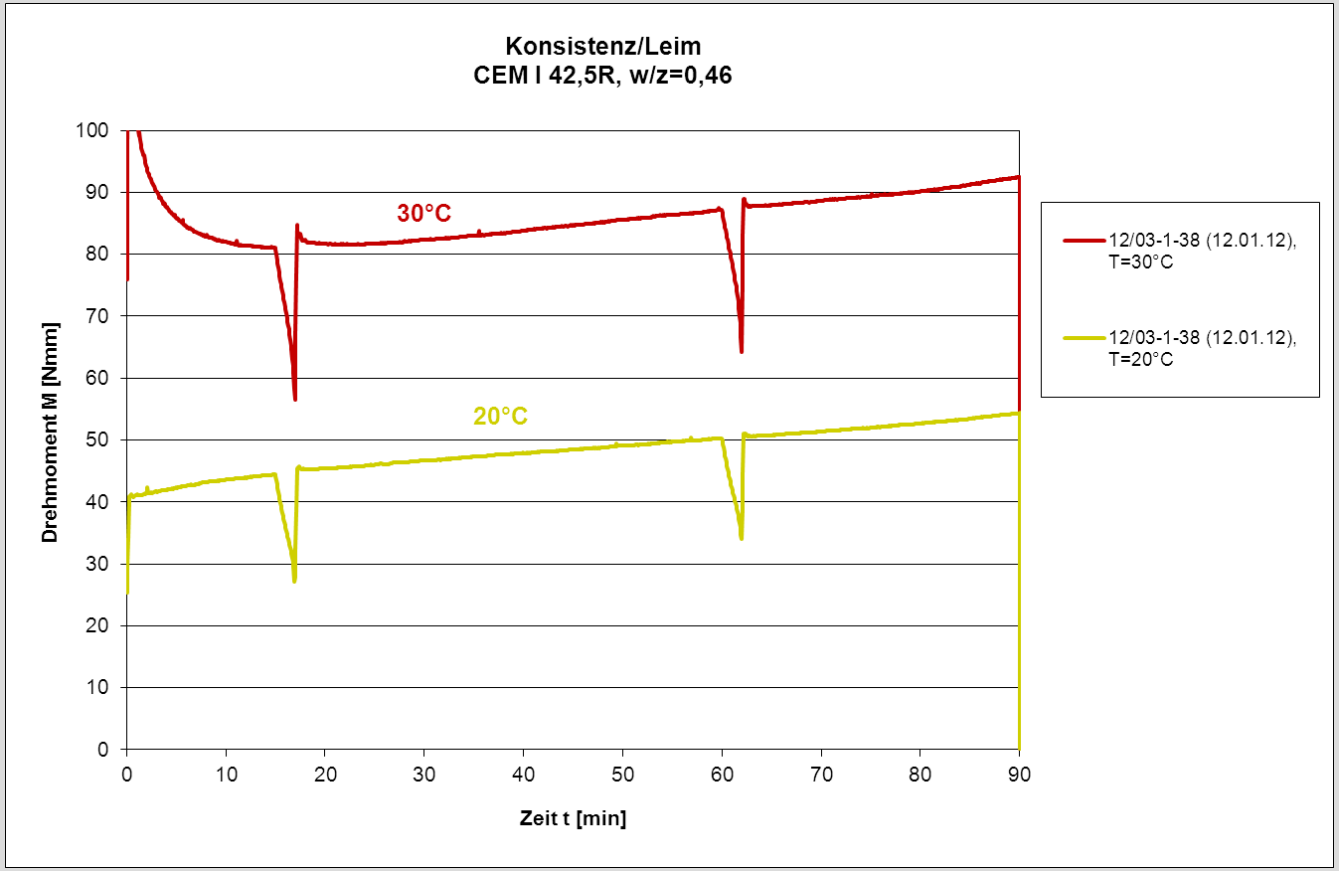
RheoZ – Sensitivity temperature



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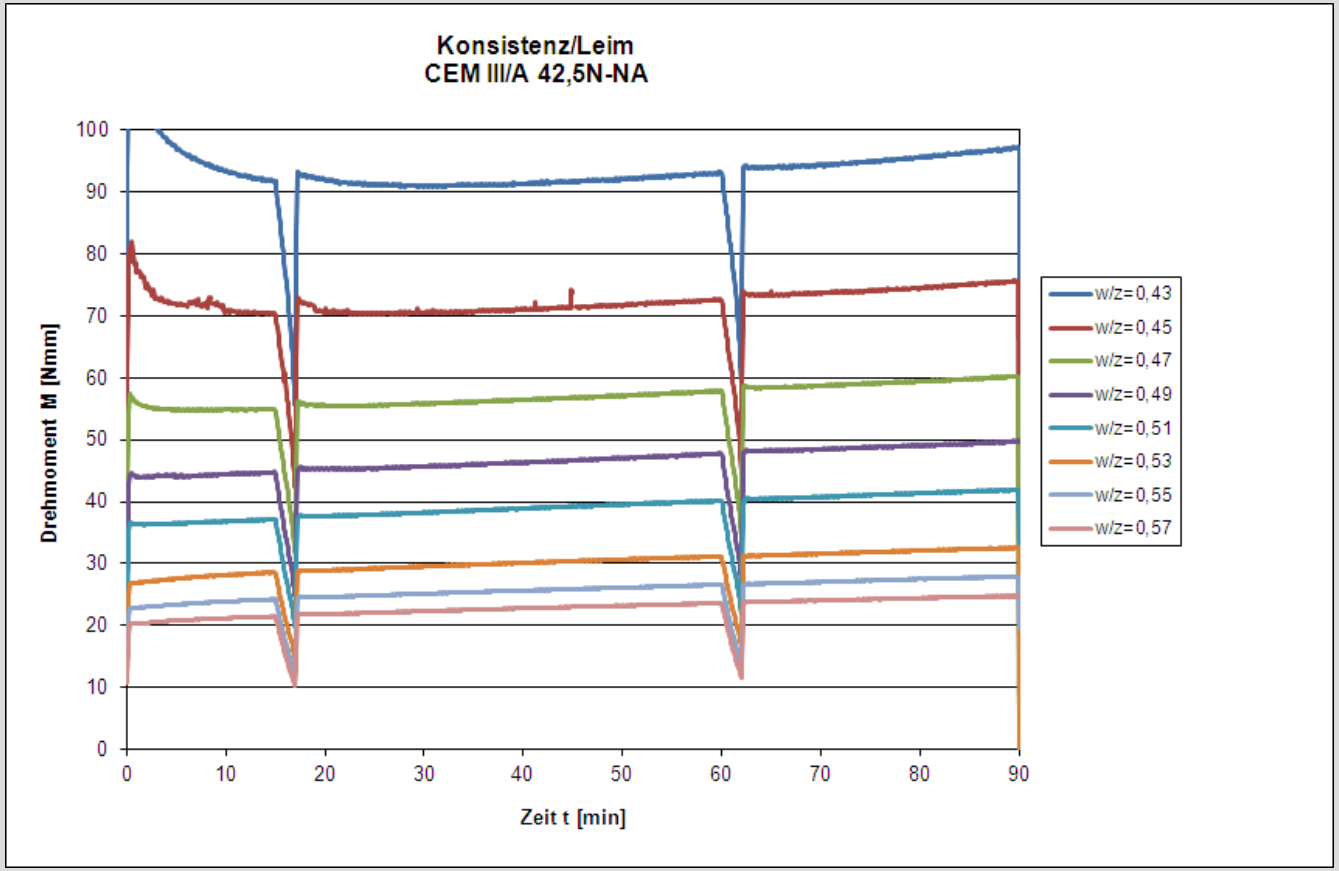
RheoZ – Sensitivity w/c-ratio



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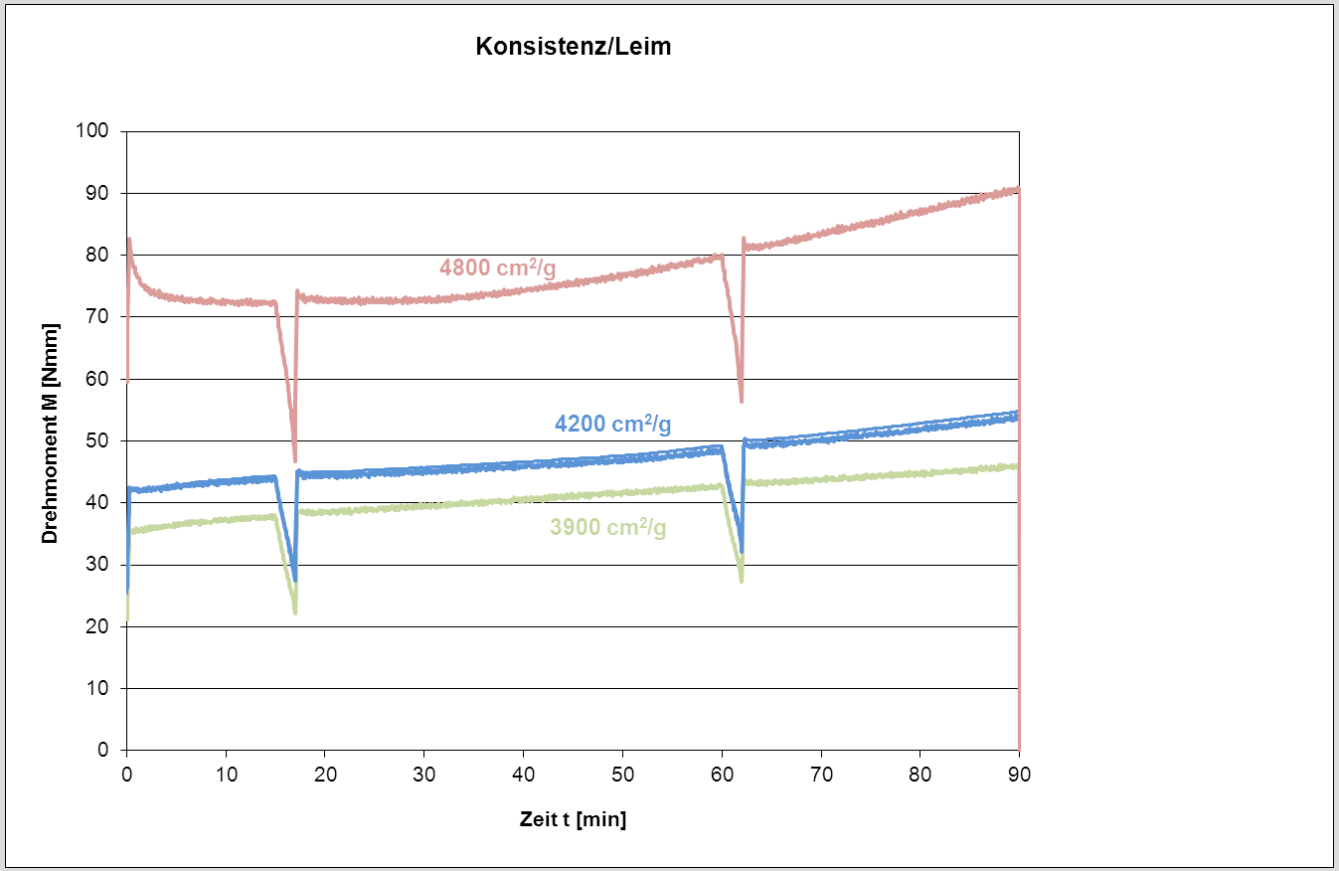
RheoZ – Sensitivity technology (fineness)



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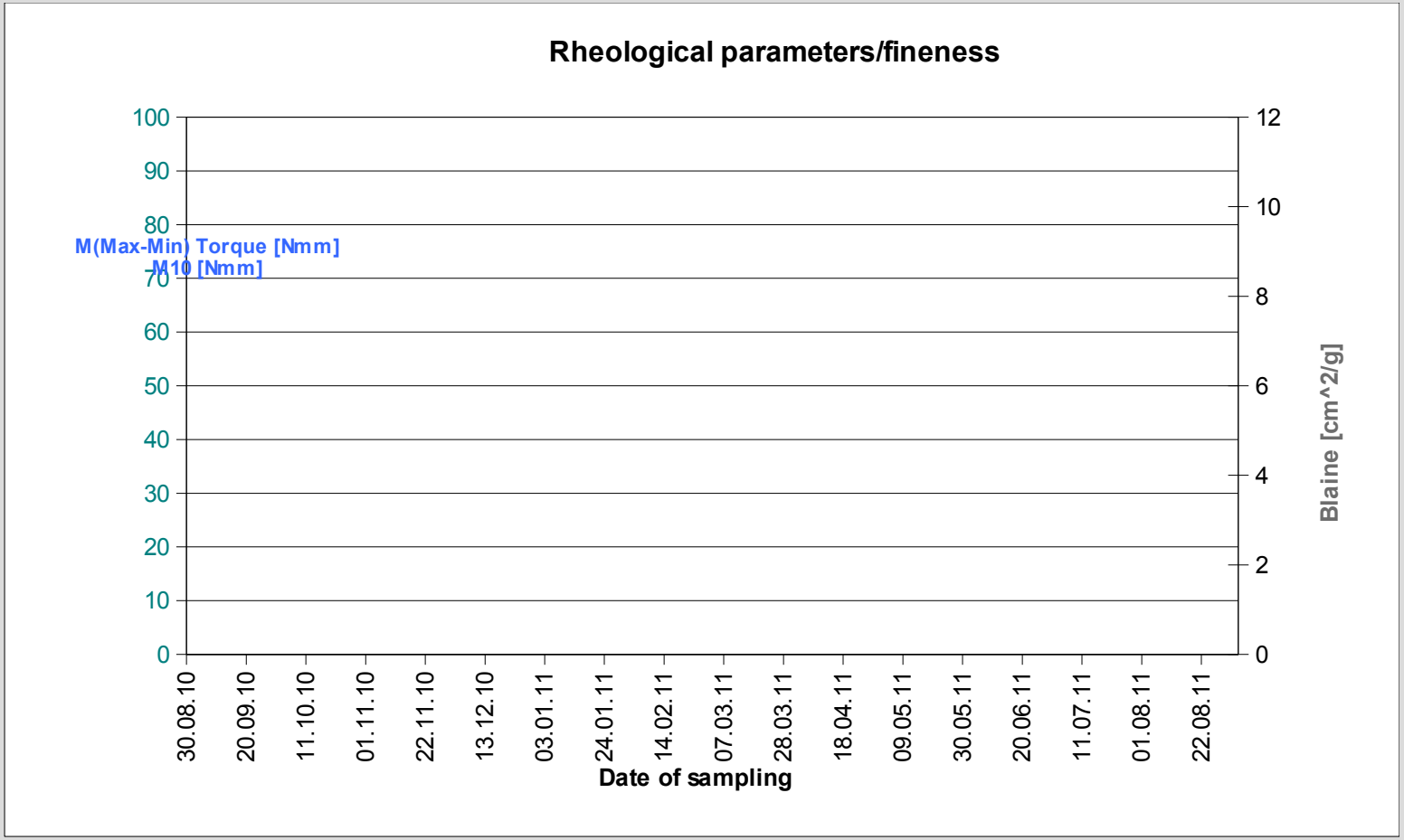

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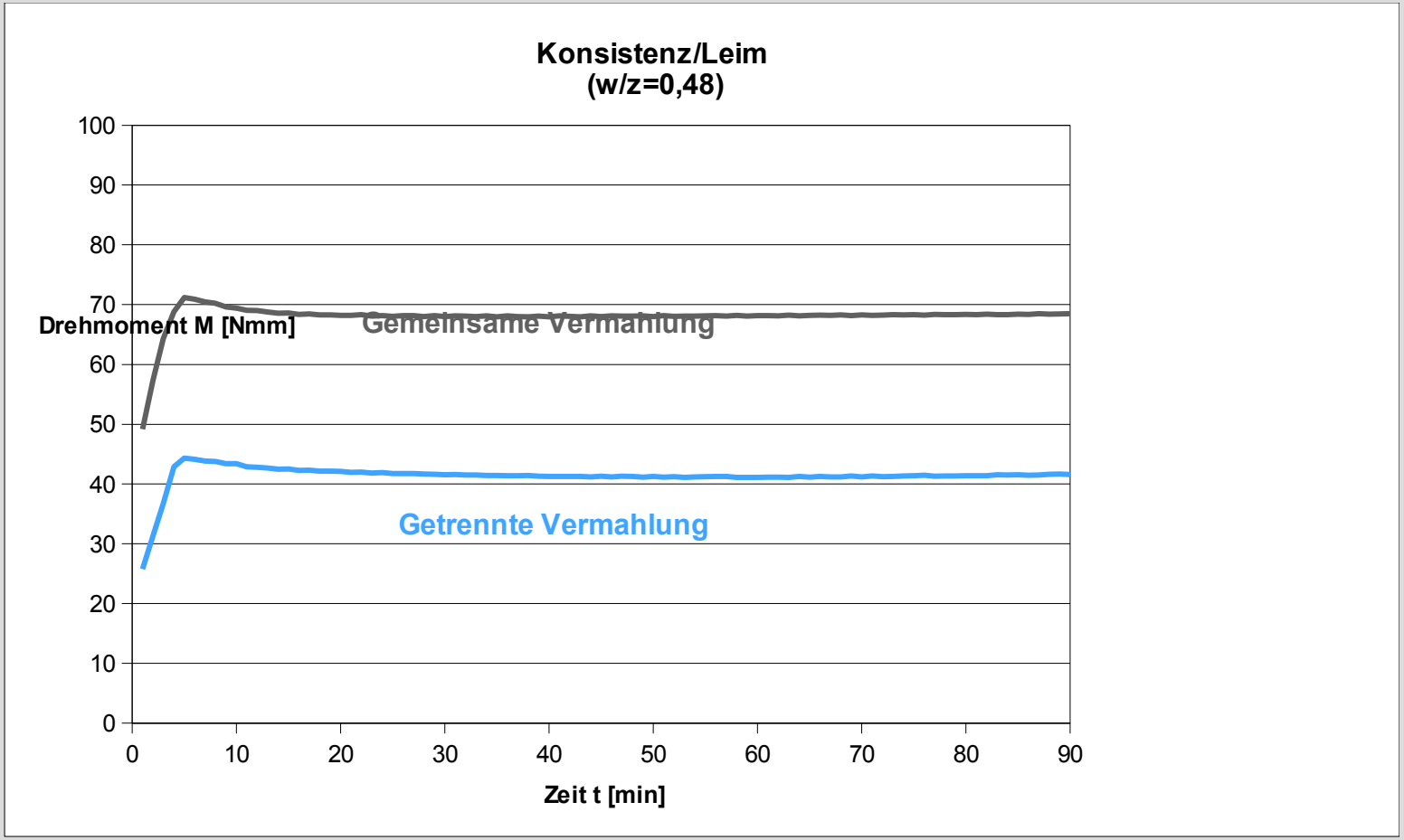
RheoZ – Sensitivity technology
(common/separate milling CEM III/B 42,5 N)



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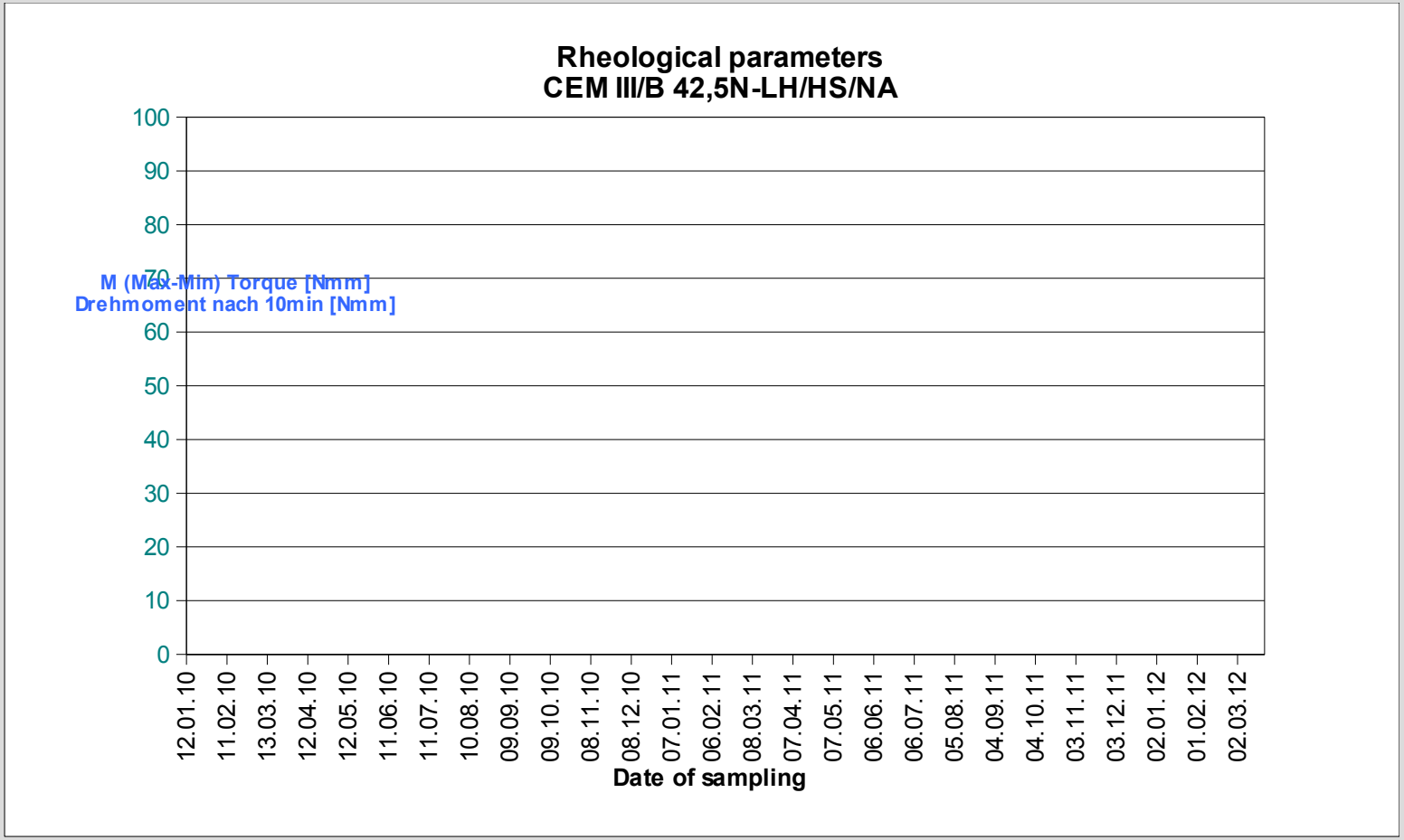
RheoZ - CEM III/B over a period of 2 years



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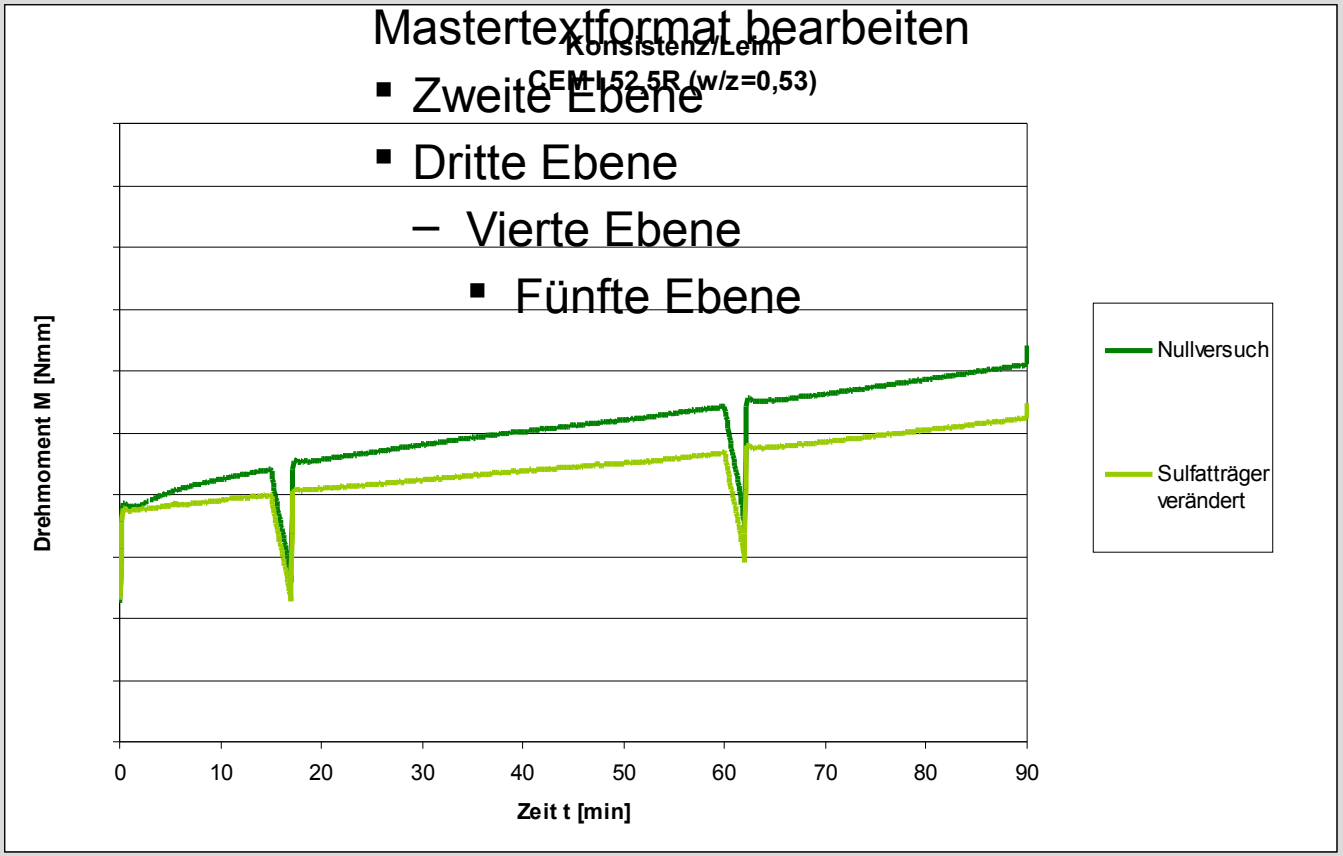
RheoZ – Sensitivity technology (gypsum phases)



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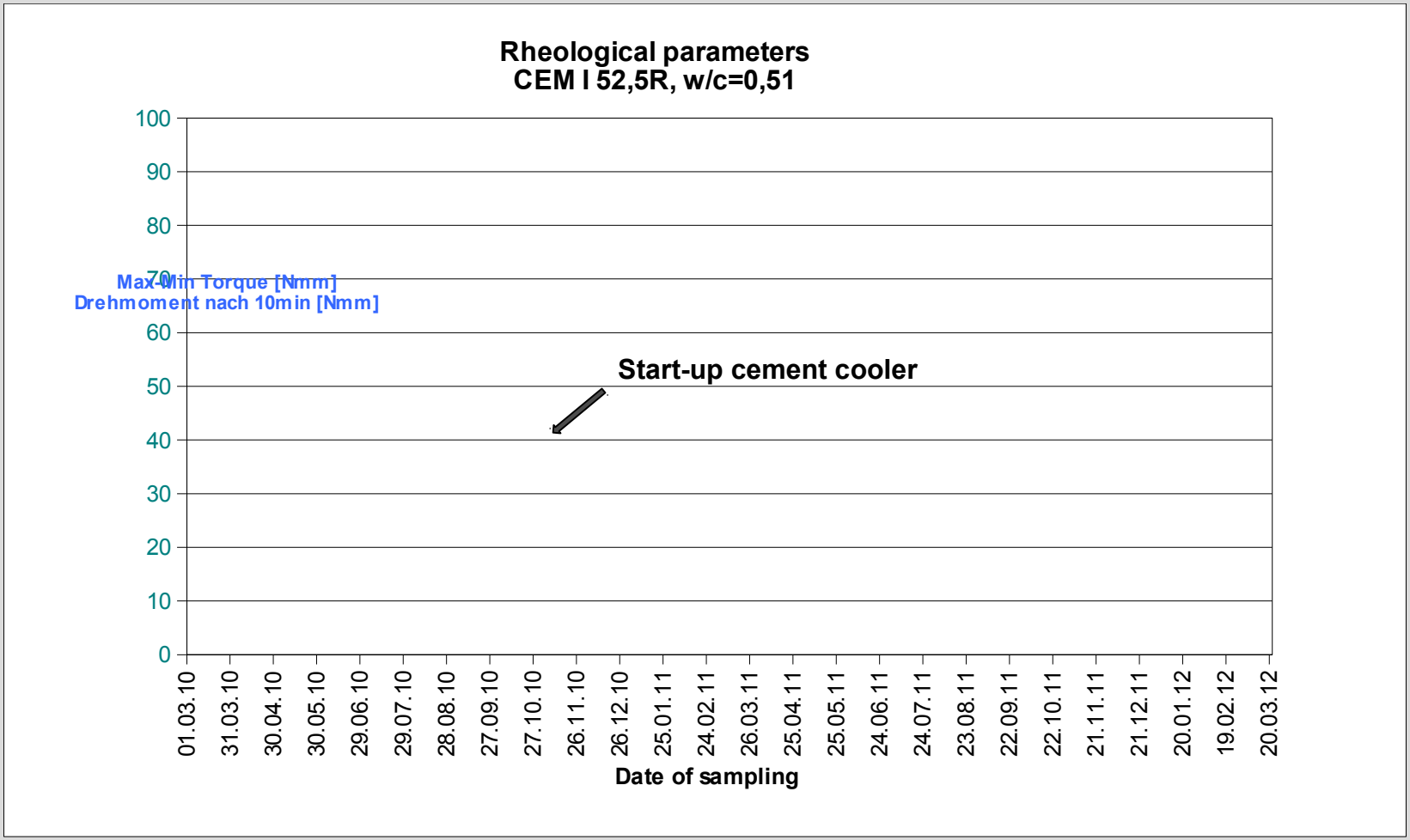
RheoZ – Sensitivity technology



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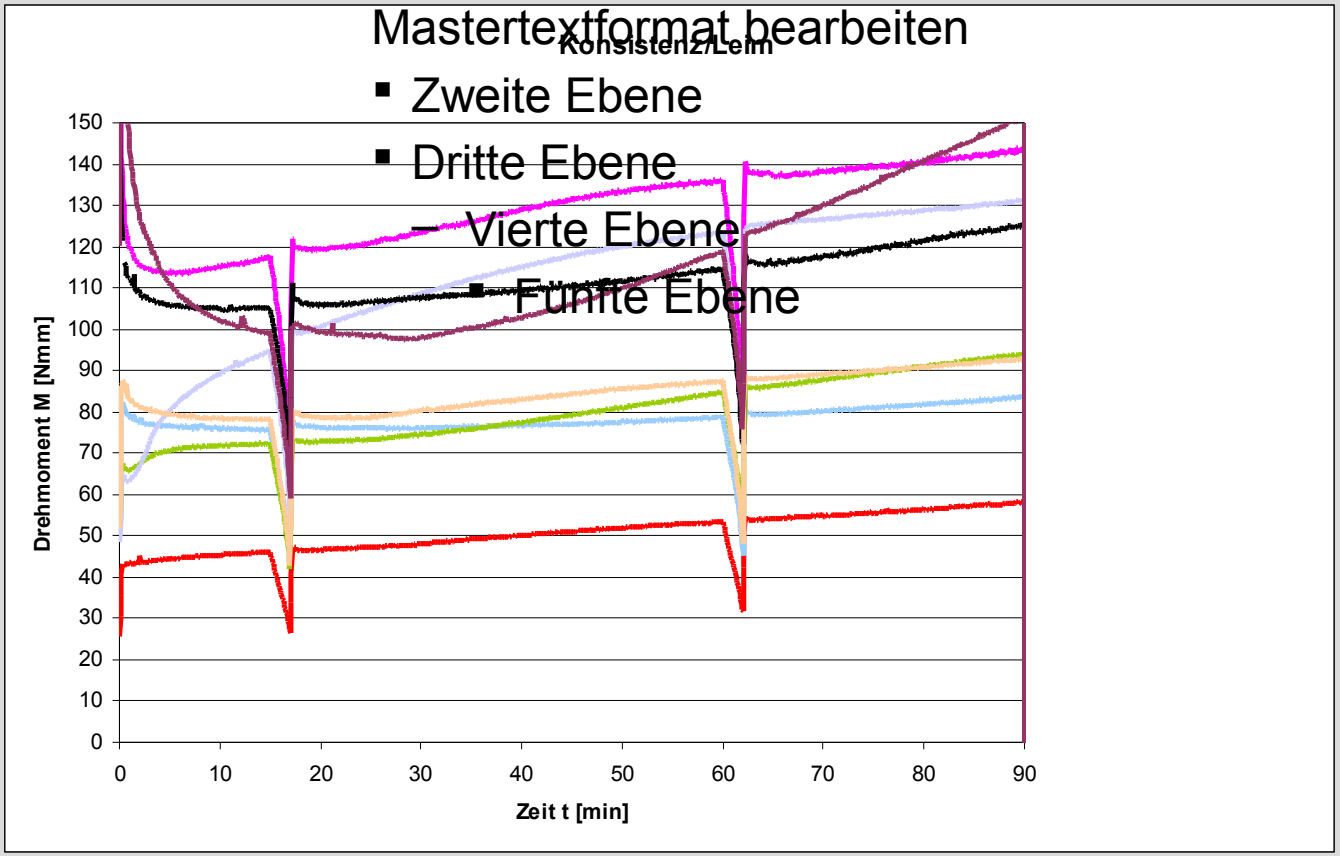
Comparison CEM I 52,5 R – w/c rate constant 0,485



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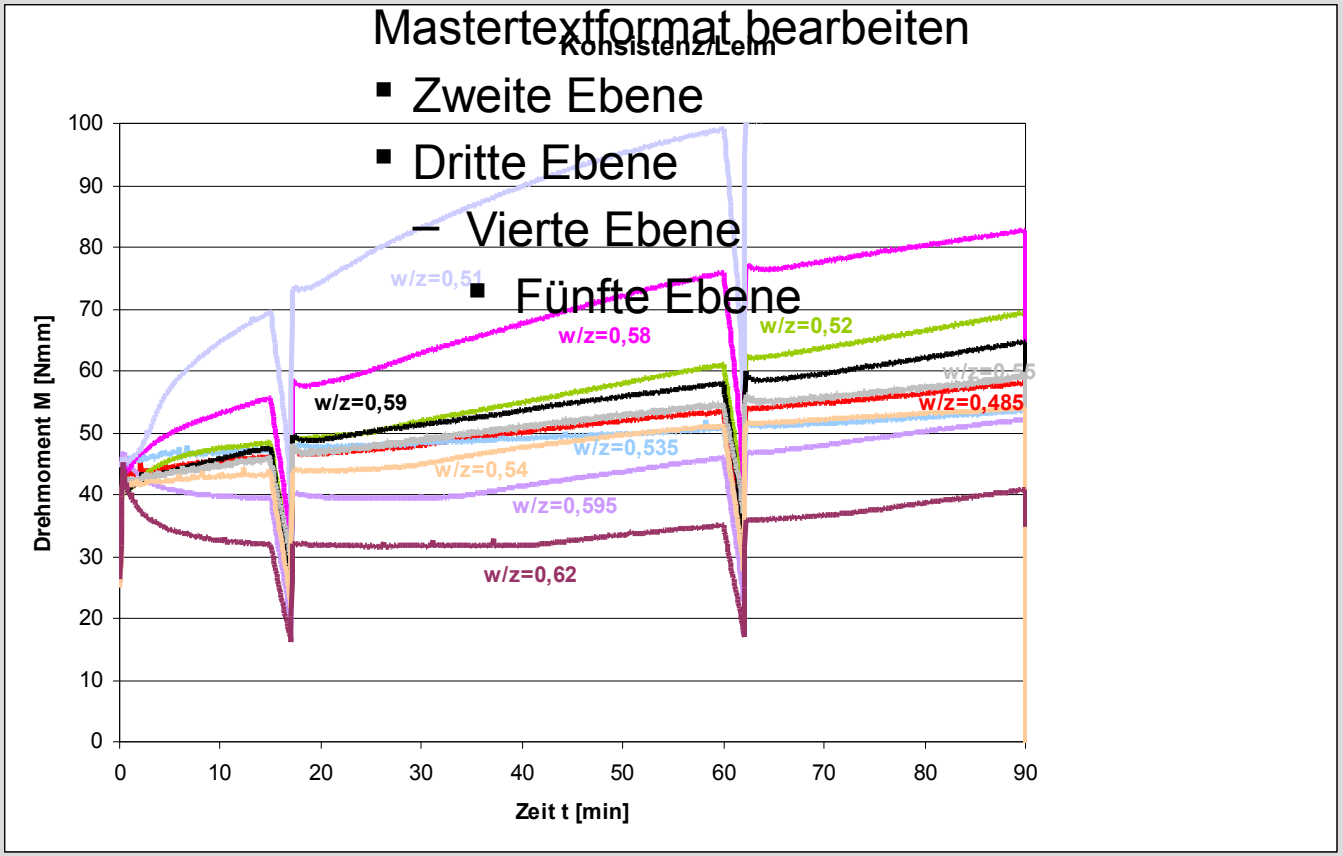
Comparison CEM I 52,5 R – Consistence at beginning constant



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Summary

- Sustainability = no modern trend, but duty of the enterprise strategy
- CEM II and CEM III are the standard cements, CEM X will emerge
- Dyckerhoff uses for composite cements S, LL, V and P

- Seperate milling enables high performance, durability and uniformity of multi-component cements
- M-cements combine the positive properties of clinker and composites

- Part of the product strategy is the high uniformity (assessed with new measurement techniques for the optimisation of workability)
- Five years Dyckerhoff RheoZ => Cements with high optimised uniformity regarding workability
- Aim: To bridge the gap between cement rheology and rheology of mortar and concrete

Thank you for your attention!

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