Holcim

Strength. Performance. Passion.

# The Water Demand of Cement – Is There Any True Application-Relevant Parameter Existing?

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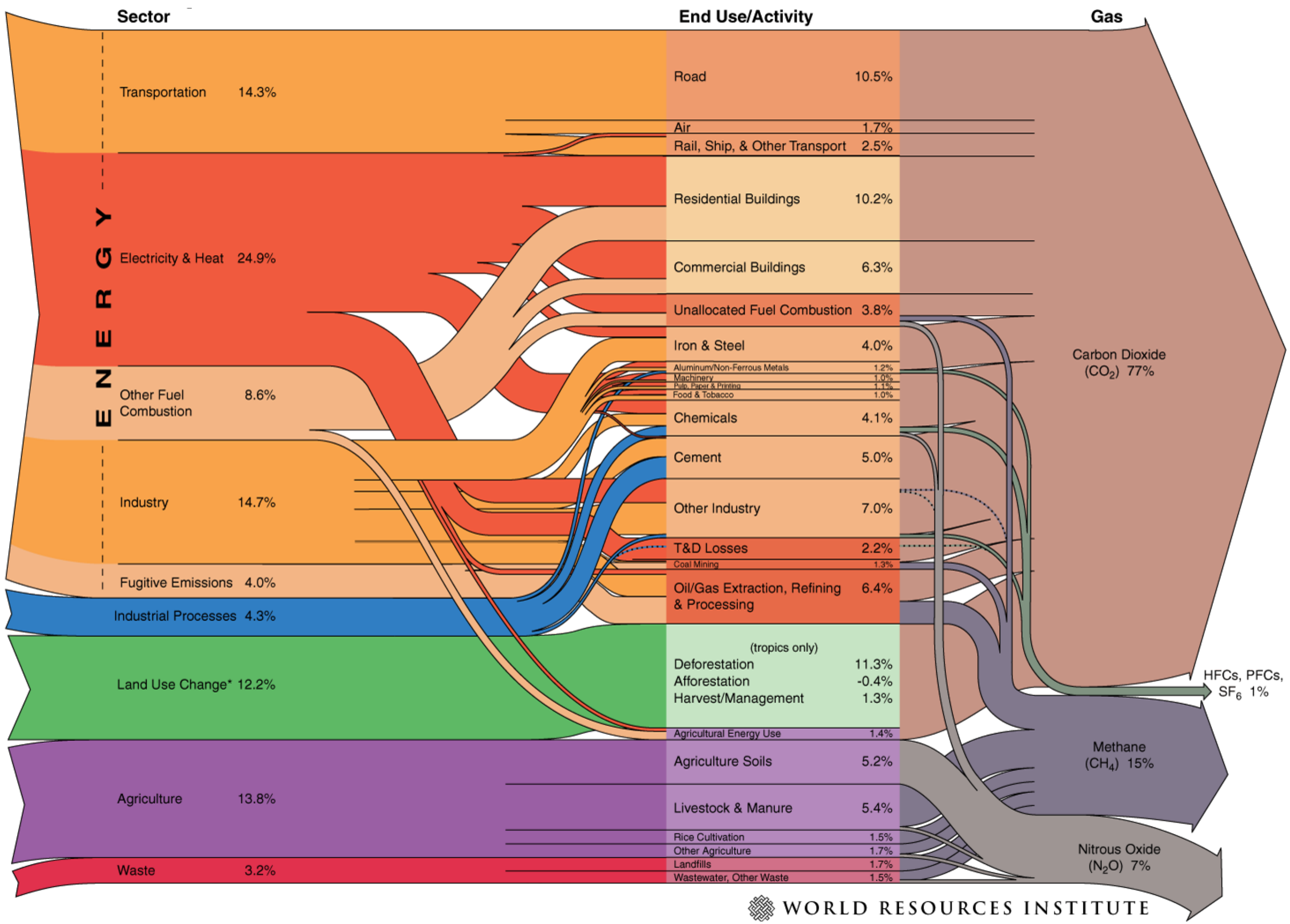
# World Greenhouse Gas Emissions



# Principal Relation between Water Cement Ratio and Strength

## Walz (1958)

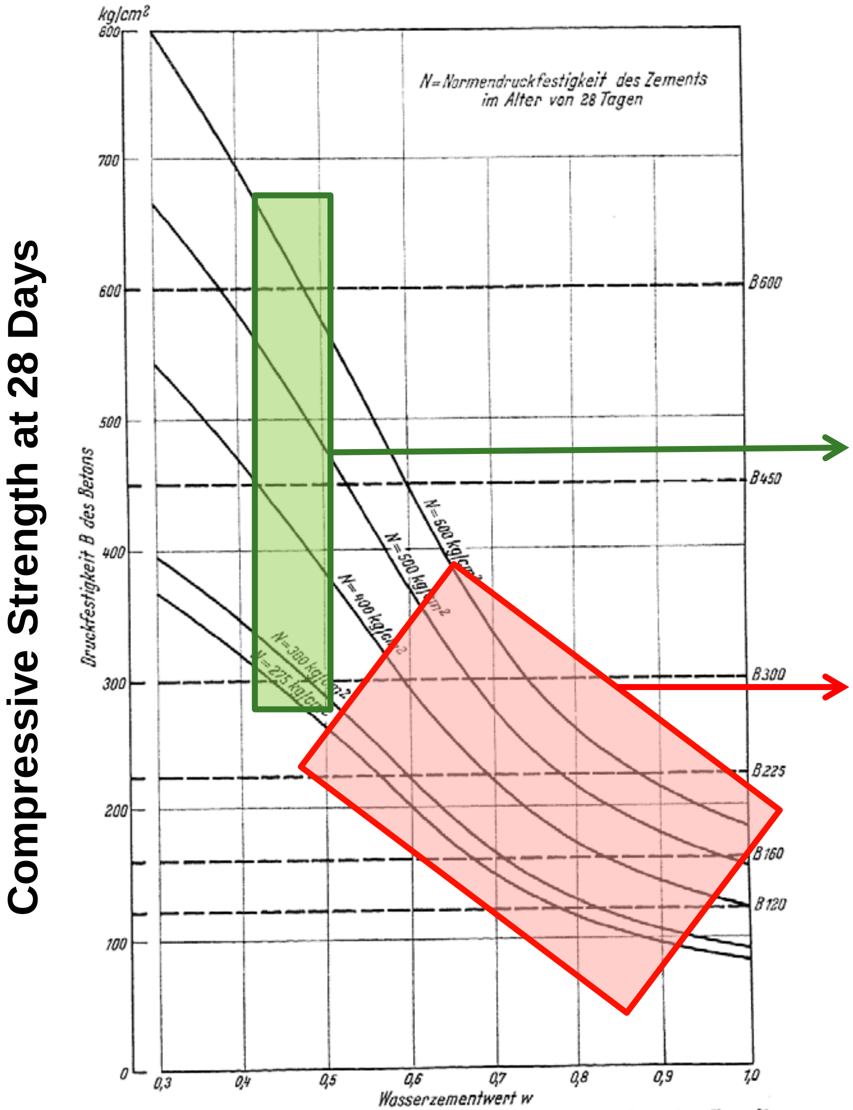



Bild 4. Beziehung zwischen Wasserzementwert w und Betondruckfestigkeit B (Würfel mit 20 cm Kantenlänge im Alter von 28 Tagen)

**Water Cement Ratio**

The parameter ‘Water Demand’ is decisive when considering the substitution of clinker !

Range of Clinker (“fool-proof”)

- Particles have low intrinsic porosity
- Low water cement ratio
- High compressive strength

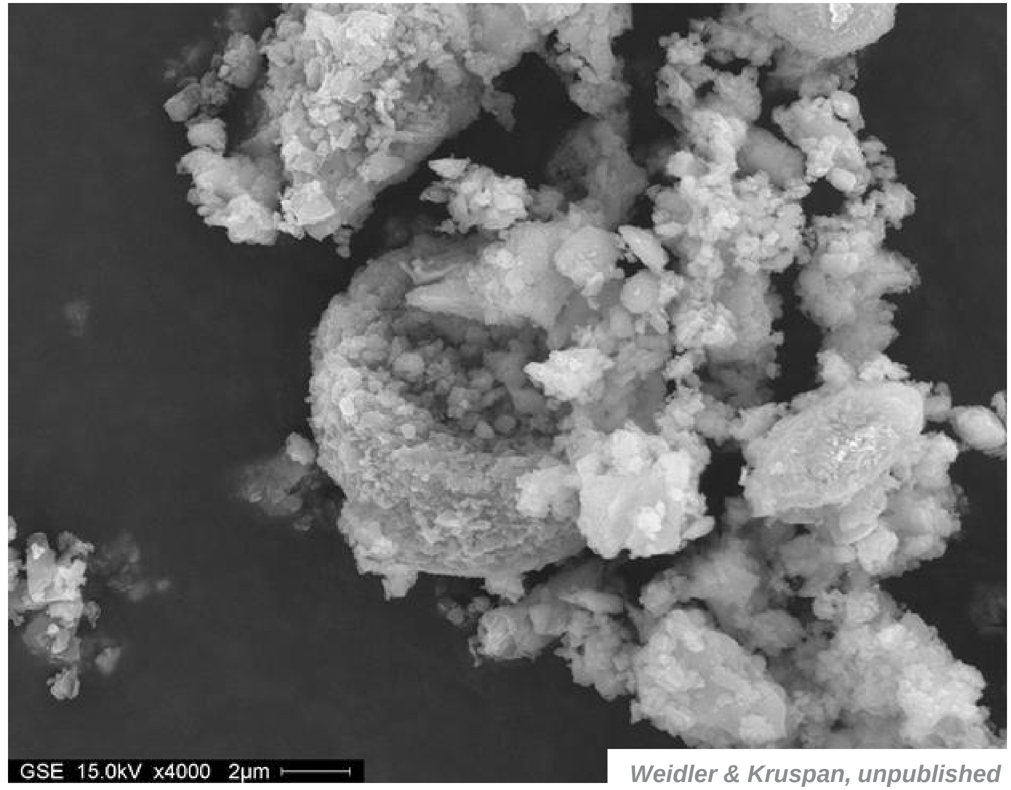
Range of (most) Mineral Components MIC

- Particles have high intrinsic porosity
- Higher water cement ratio
- Lower compressive strength

→ (Simple) clinker substitution limited
→ Admixtures / Cement Additives required
→ Concrete technology no longer “fool-proof”

# Examples of Clinker Substitution Materials (MIC)
## ESEM Images


*Weidler & Kruspan, unpublished*



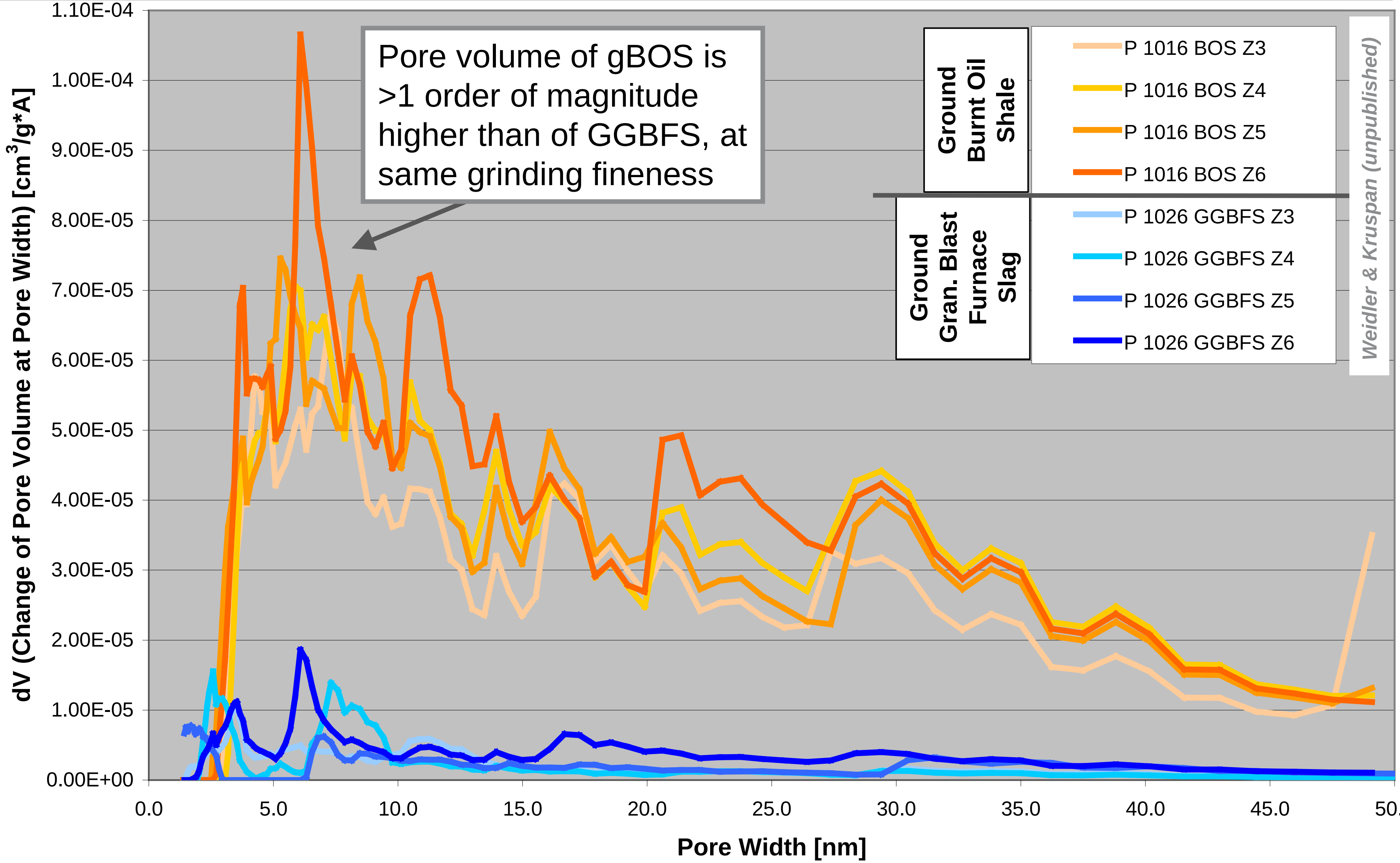

*Weidler & Kruspan, unpublished*

High intrinsic porosity
Low grinding fineness

High intrinsic porosity
High grinding fineness

# Examples of Clinker Substitution Materials (MIC)

## 'Pore Volume' – BET $N_2$



# Methods for Assessing the Water Demand

## A Simplified View from the Industry

in red: standardized methods in the cement industry

| Scale | Some Examples | Effort and Effect |
|---|---|---|
| **Cement (Powder)** | • Specific Surface (Blaine EN 196-6, BET, …)<br>• Granulometry / Particle Size Distribution (Laser Diffractometer)<br>• Fineness (Alpine Sieve Residue EN 196-6)<br>• Particle Packing Dry (Litre Weight Boehme) | ❖ Low manual effort<br>❖ Result generation rather fast<br>❖ (often) statistically robust data<br>❖ …but limited practical relevance of interpretation |
| **Paste** | • Standard Consistence EN 196-3<br>• Particle Packing Wet (Puntke)<br>• Schleibinger Viskomat NT<br>• Anton Paar / Physica Viscometer | ↕ DILEMMA 1 |
| **Mortar** | • EN 459-2 (Haegermann Shock Table)<br>• ASTM C 311 (Shock Table)<br>• Holcim Cone<br>• MBE Mortier de Béton Equivalent<br>• Lafarge Liftomat<br>• Torque Mixer<br>• Schleibinger Viskomat NT / XT | |
| **Concrete** | • Concrete Rheomat O. Wallevik ConTec BML 4<br>• Schleibinger Viskomat XT<br>• Schleibinger eBT2 (mobile Rheometer)<br>• Concrete Workability Methods acc. EN 12350<br>➢ Slump (SM) – EN 12350-2<br>➢ Slump Flow (AM) – EN 12350-5<br>➢ Compaction Degree Walz (VM) – EN 12350-4 | ❖ High / huge manual effort<br>❖ Result generation rather slow<br>❖ (often) statist. fluctuating data<br>❖ …but strong practical relevance of interpretation |

# … but There is Still Another Level of Complexity when Upscaling from Controlled Lab Environment to the ‘Real (Industrial) World’…

Many constraints / high complexity

“Real World” / Final Target

Industrial Cement

Industrial Concrete

**DILEMMA 2**

Laboratory Cement

Laboratory Concrete

Laboratory Mortar

Some constraints


*Images: M. Holpert (2006)*

The ‘Mk I Apparatus’ of G.H. Tattersall (1970) University of Sheffield, U.K.

Figure 4.1 The original set-up using a Hobart foodmixer and a dynamometer wattmeter.

Zabel Magdeburg / Niehoff Weimar
8th Regensburg Colloquium 1999

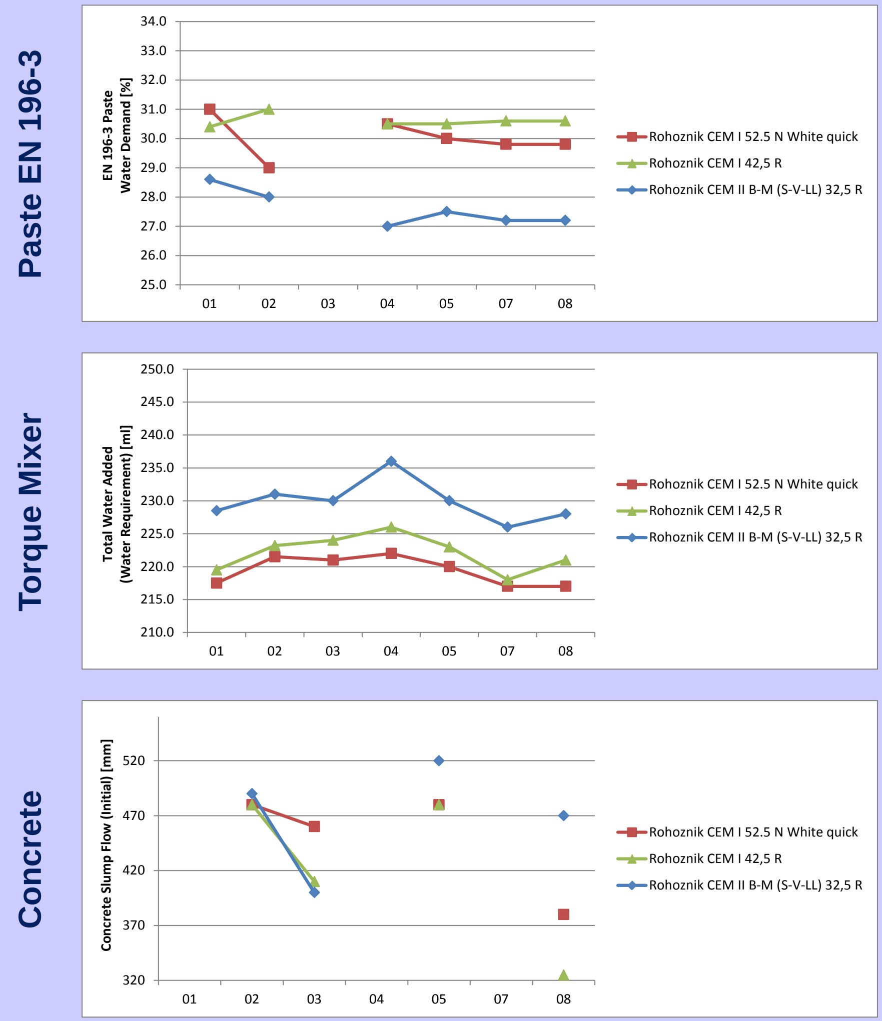

Testing / TomTomTools (2014)

# Key Result of Holcim RRT: “Torque Mixer is very precise, initial procedure however does not allow sufficient correlation to (our) concretes”

- Good repeatability / reproducibility of water demand when tested on **paste** (EN 196-3) and **mortar** (Torque Mixer).
- Water demand as tested in **concrete** does not allow for any consistent conclusions: the term ‘standard concrete’ does not exist! → direct comparison or even correlation of EN 196-3 and Torque Mixer to concrete slump flow is therefore not feasible.
- The sequence of EN 196-3 data (from lowest water demand to highest) is exactly opposite to the one of Torque Mixer !

  Hypothesis: **EN 196-3** responds to pure fineness / **Blaine** values (higher Blaine leading to higher EN 196-3 water demand) whereas **Torque Mixer** responds much more to the **content on (porous) Mineral Components**.

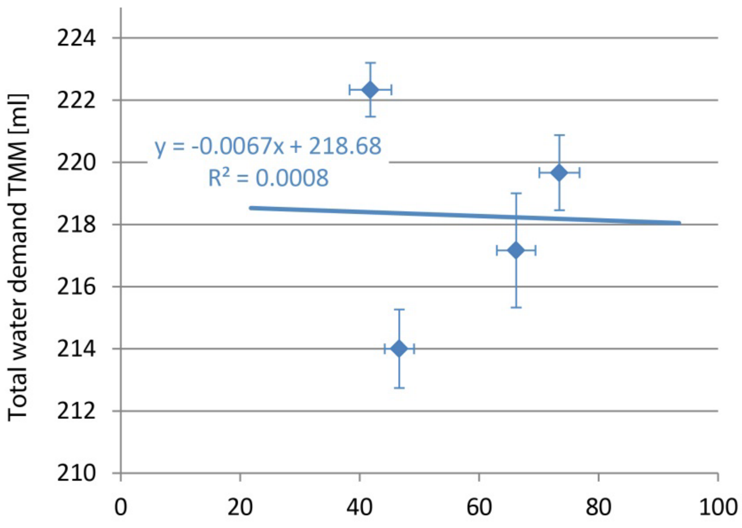
**Water Demand of 3 Cements from RN tested in Labs 01 to 08**



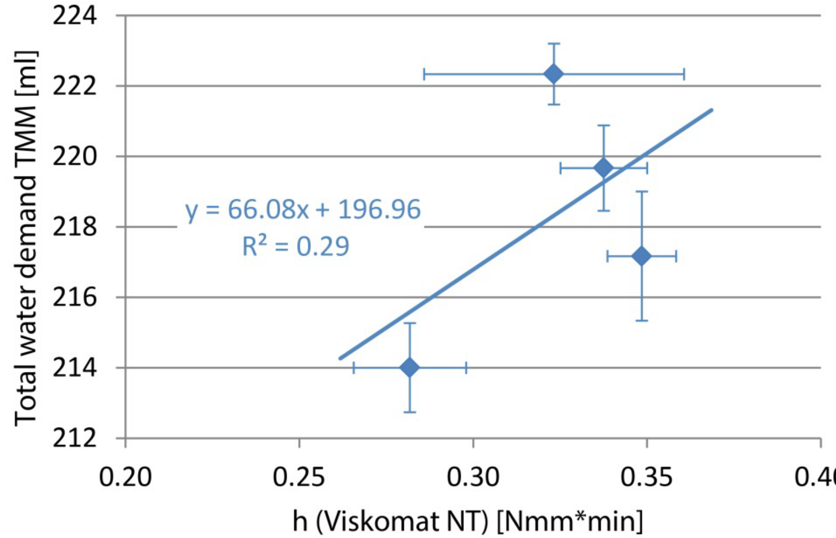
# Detailed Investigation of Initial Procedure for Torque Mixer

## → No Correlation to Both Fundamental Rheological Parameters

- 4 Different Commercial (Industrial) Cements
- at least 4 Repetitions per Parameter




**Yield Stress (Fine Mortar)**

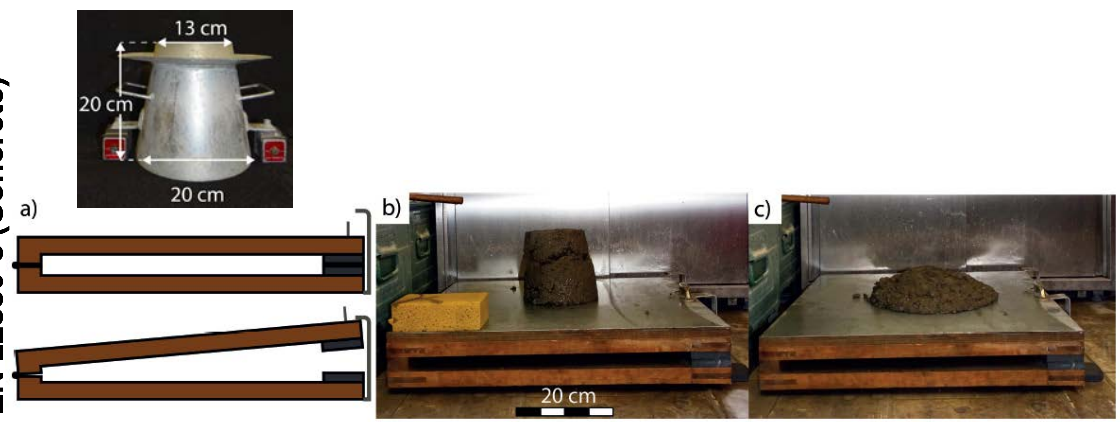



**Plastic Viscosity (Fine Mortar)**

**Torque Mixer**

**Viskomat NT (Fine Mortar)**


**EN 12350-5 (Concrete)**



# First Results of Modified Procedure for Torque Mixer

## → Good Correlation to (…One Particular Standard Lab…) Concrete

| | Torque Mixer | Concrete Slump Flow EN 12350-5 | | | | |
|---|---|---|---|---|---|---|
| | Final Torque [Nm] | at 5 minutes [cm] | at 15 minutes [cm] | at 30 minutes [cm] | at 45 minutes [cm] | at 60 minutes [cm] |
| Cement A | 3.4 | 44 | 43 | 42 | 41 | 39 |
| Cement A | 3.5 | 43 | 42 | 41 | 40 | 39 |
| Cement B | 2.8 | 45 | 44 | 43 | 42 | 40 |
| Cement C | 2.8 | 46 | 45 | 44 | 43 | 42 |
| Cement C | 2.8 | 45 | 44 | 43 | 42 | 41 |
| Cement D | 3.0 | 46 | 45 | 44 | 42 | 41 |
| Cement D | 2.9 | 46 | 45 | 44 | 42 | 40 |
| Cement E | 3.6 | 44 | 42 | 40 | 39 | 38 |
| Cement E | 3.5 | 45 | 44 | 43 | 42 | 40 |
| Cement F | 2.8 | 46 | 45 | 44 | 43 | 42 |
| Cement F | 2.7 | 45 | 44 | 43 | 42 | 41 |
| Cement G | 3.3 | 44 | 42 | 40 | 39 | 38 |
| Cement G | 3.3 | 44 | 42 | 40 | 39 | 38 |
| Cement H | 3.4 | 44 | 43 | 41 | 40 | 38 |
| Cement H | 3.4 | 44 | 43 | 42 | 40 | 38 |
| Cement I | 4.6 | 42 | 41 | 40 | 39 | 38 |
| Cement I | 4.5 | 42 | 41 | 40 | 38 | 36 |
| **Correlation** | **1.00** | **-0.89** | **-0.84** | **-0.74** | **-0.79** | **-0.80** |

…but: are these concrete slump flow values really the true reference (the true / ‘universal’ application-relevant parameter) …?

# Conclusions

1. The increasing addition of clinker replacement materials (MIC) into cement widen the gap between standard methods currently used in the cement industry ('ideal old world') and daily application-related phenomena observed in the field ('real new world').
2. From the many proposed 'alternative methods' (application-oriented mortar tests, more sophisticated rheological assessments etc.) none has so far reached standard character, not even for quite simple purposes
   - A 'device plus manual' alone is not sufficient, you need statistically robust procedure(s) valid for many different configurations (material-wise, regional-wise, application-wise) → 'a validated / approved standard'
   - Many stand-alone / non-harmonized solutions (or even dogmas) exist, not only *among* (cement) companies but also *within* (cement) companies. Too often labs only believe in their own concept → collaboration + compromises are required!
   - Chicken-egg dilemma: who is the first mover? Who invests time and resources? → Final target: acceptance of standardization bodies
   - For the time being EN 12350 testing is still our standard reference …
3. One single / true / universal application-relevant parameter is still not around
   - Exchange of information between producer and customer is based on expert dialogue

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