25. Workshop und Kolloquium: "Rheologische Messungen an Baustoffen"
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Rheology Testing of Deep Foundation Concrete

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Sponsored by:

European Federation of
Foundation Contractors

TU München
Centre for Building Materials (cbm)

Motivation

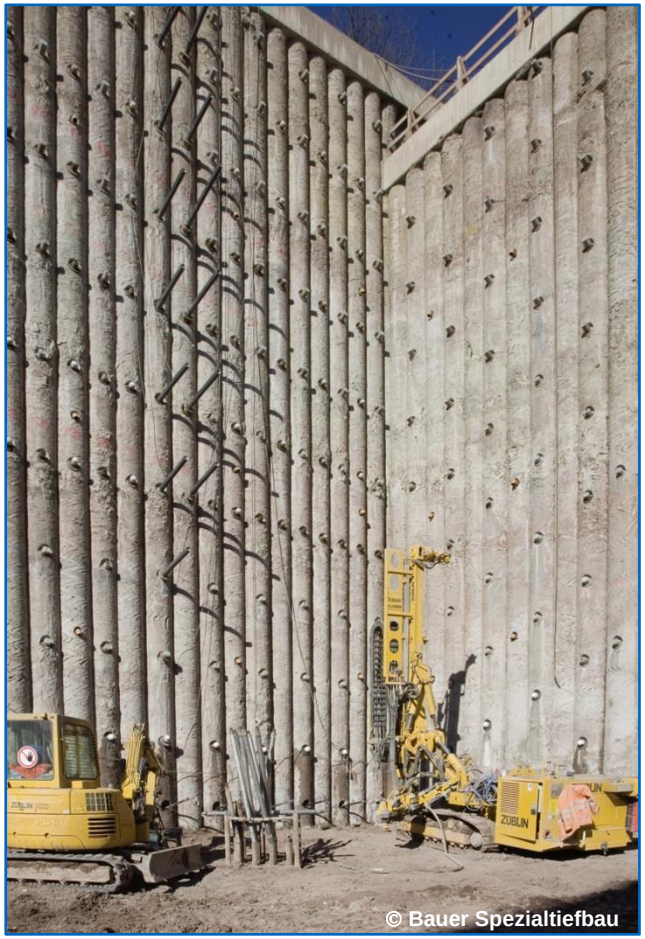
In situ made concrete piles and diaphragm walls

Basic requirements for hardened concrete:

Structural demands	Low water permeability

Resulting requirements for fresh concrete:

Complete form filling of the cross-section	Full embedment of reinforcement
High segregation resistance / low bleeding tendency	Sufficient cohesion to avoid mixing with bentonite



Motivation

Defects and segregation

Inclusions	Bleed channels	Mattressing	Segregation


Brown, Turner & Castelli:
FHWA-Report No. NHI-10-016. 2010


EFFC/DFI:
Best Practice Guide to Tremie Concrete
for Deep Foundations, 1st edition, 2016


EFFC/DFI:
Best Practice Guide to Tremie Concrete
for Deep Foundations, 1st edition, 2016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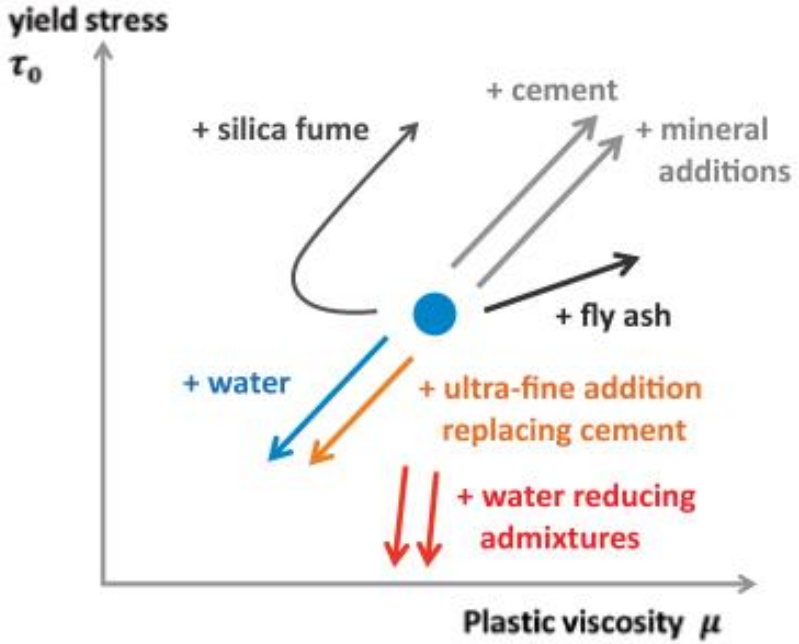
To avoid these defects:

Detailed knowledge on concrete flow inside the foundation elements during the whole placement process essential

Problem

Recent changes in the DFC mix design



Wallevik O.H.: Rheology – A Scientific Approach to Develop Self-Compacting Concrete. Pro 3rd Int. Symposium on SCC. 2003

- **Reduction of portland cement clinker**
- CEM I → CEM II → CEM III
  (reduced hydration heat development)

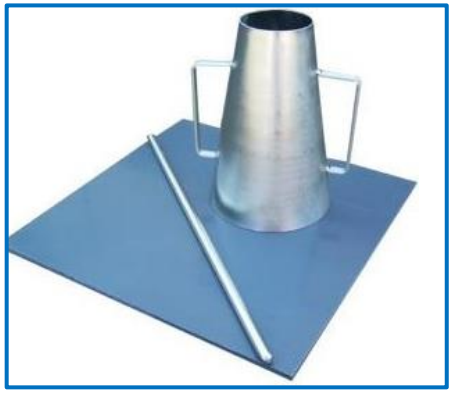
- **Increasingly amounts of additions and (chemical) admixtures**
- Fly ash, limestone powder
- Combination with superplasticizer, retarding and/or workability retaining admixtures

Specially for excavations in great depths

- concrete placement is a considerably time-consuming process

Problem

Recent workability testing on construction site



Slump flow test

Flow table test

- **Slump or flow table test often only acceptance tests**
- *Advantage:*
  - Easy handling on-site,
  - Well known
- *Limitation:*
  - Only indirect characterization of yield stress,
  - No information on viscosity and thixotropy
- *Problem:*
  - Yield stress, viscosity and thixotropy affect form filling

No suitable test concept to measure rheology/workability of fresh DFC onsite

- Reliable prediction of form filling based on common onsite testing impossible

Aim

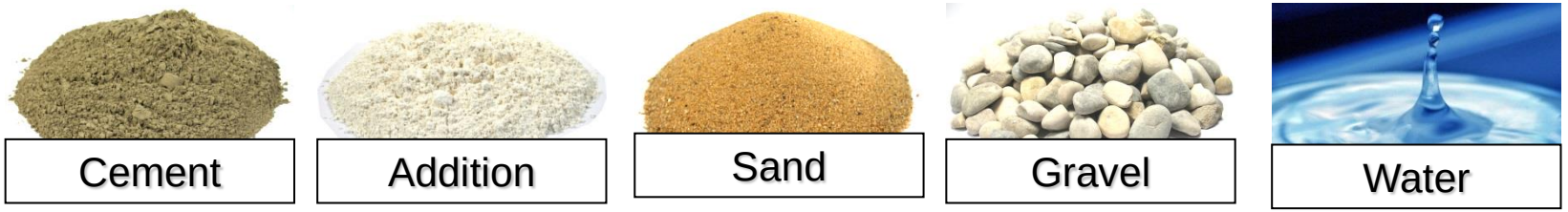
Set of tests for workability testing on construction site

- **Advanced concept for characterization of fresh Deep Foundation Concrete** (DFC)
  - Practicable usability (on-site testing) concerning testing of
    - Workability,
    - Rheology and
    - Robustness properties
- **Ensure a reliable prediction of form filling properties in deep foundations** (bored piles and/or diaphragm walls)

Work packages

- **WP 1: Testing on construction site**
  - State of technology concerning rheology, workability and robustness of DFC

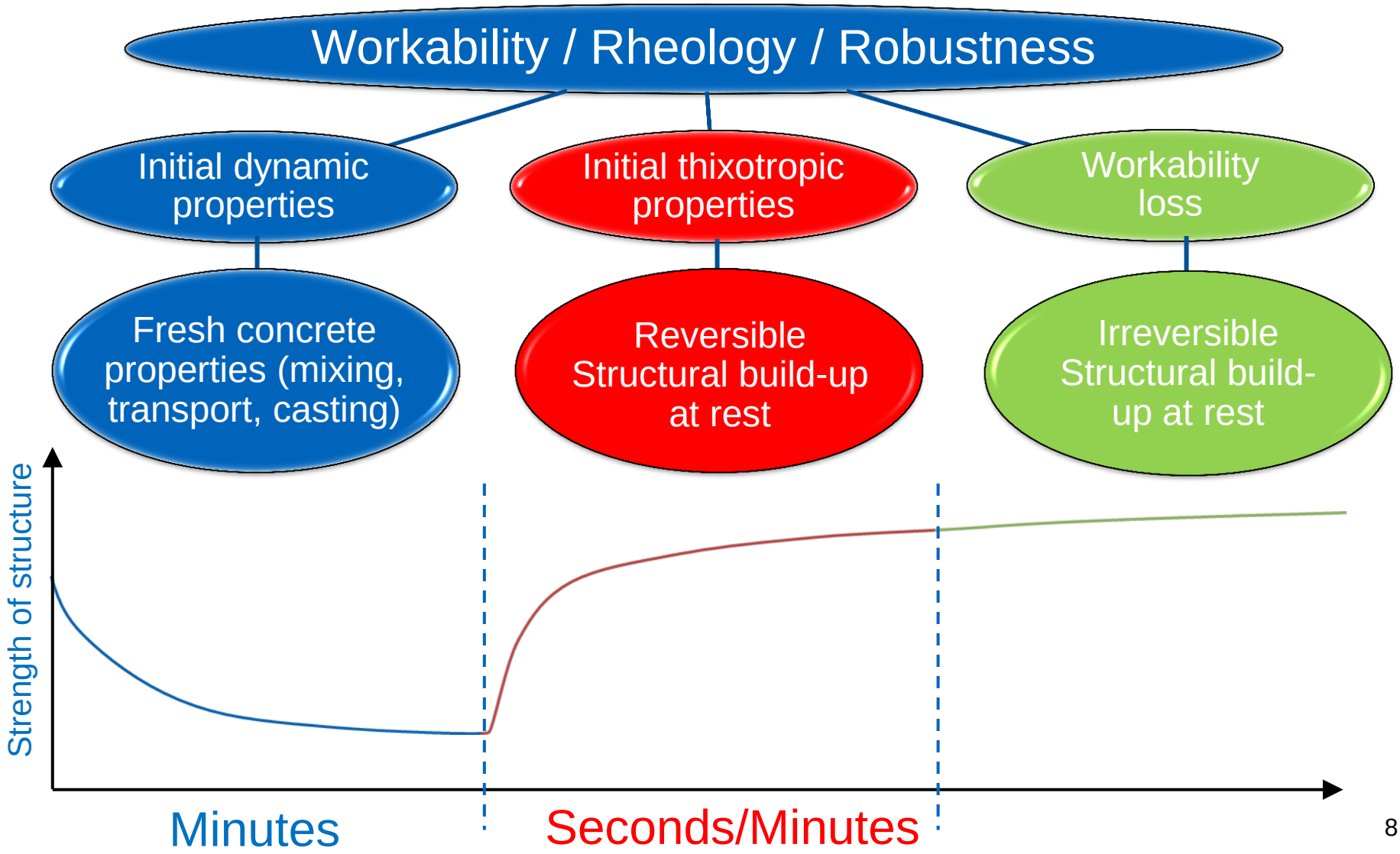
- **WP 2: Laboratory testing**
  - Effect of concrete composition on rheology, workability and stability



- **WP 3: Rheological characterization by means of simple onsite tests**
  - Correlation between onsite workability and rheological parameters

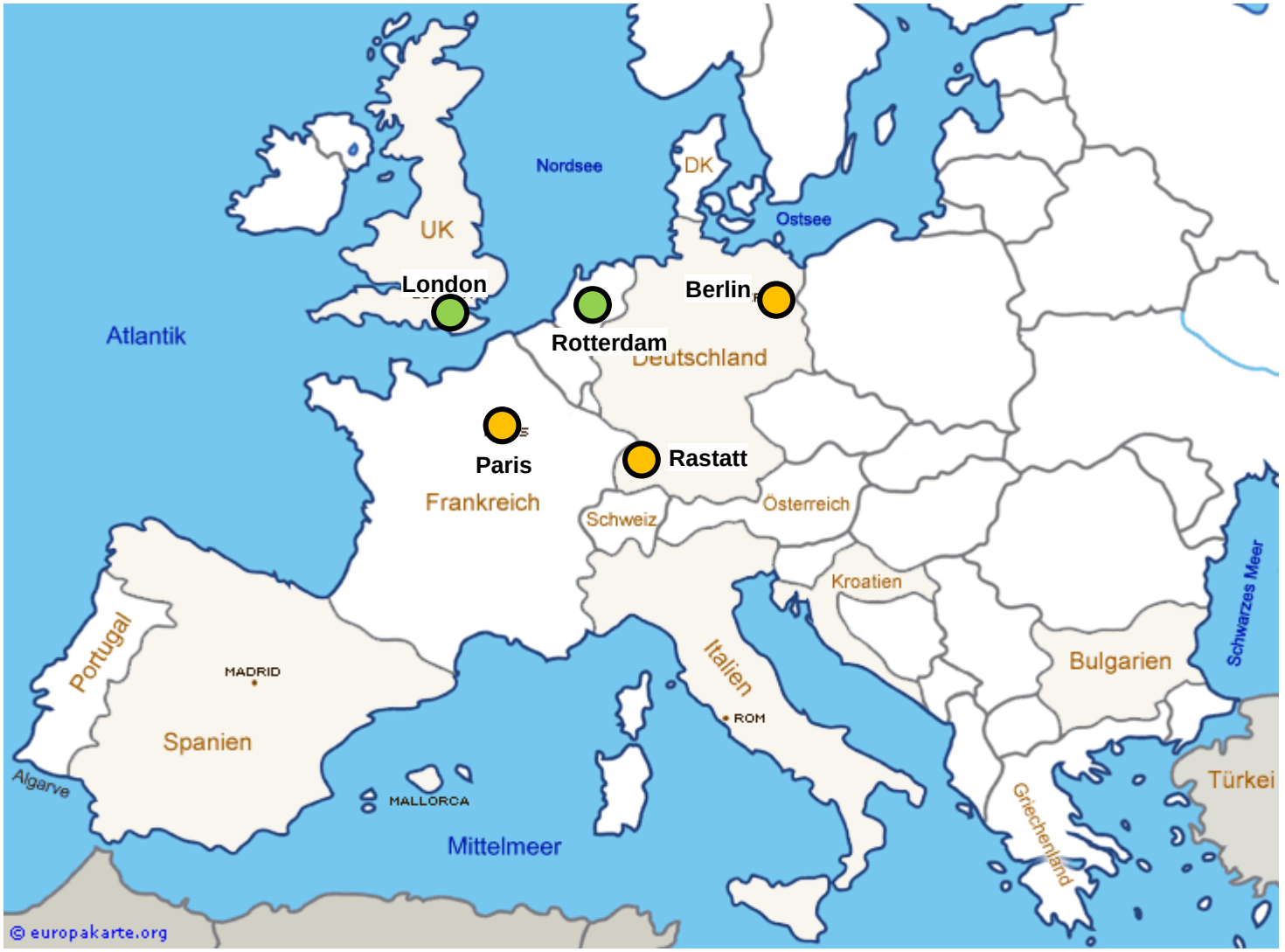
- **WP 4: Suitable test concept for fresh DFC based on rheology**
  - Development of a set of tests and corresponding acceptance criteria
    - ensure completely filling of the cross-section,
    - fully embedment of reinforcing steel,
    - avoid segregation and excessive bleeding

Working plan for on-site and laboratory testing



WP1: Testing on construction site

State of technology concerning workability, rheology and robustness of DFC



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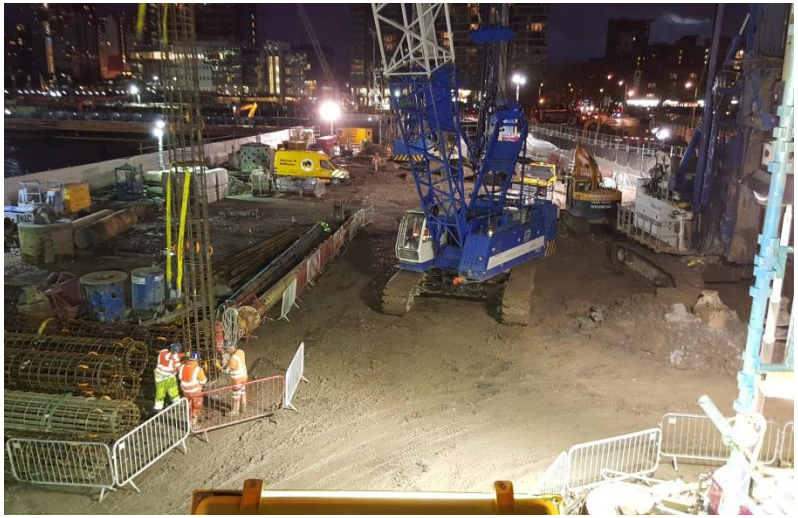
WP1: Testing on construction site – D-Walls

Strengthening work on two dikes in the Netherlands

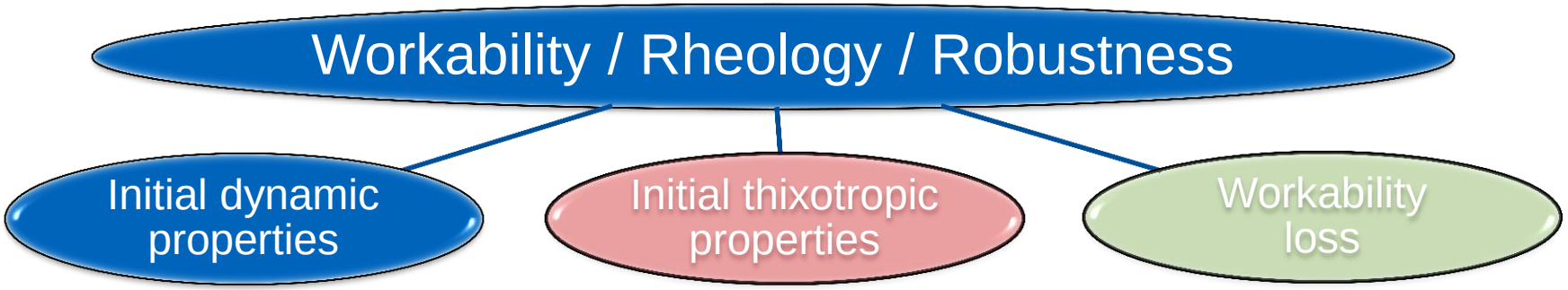
WP1: Testing on construction site – Bored piles

Foundation for a 60-storey residential skyscraper (London)

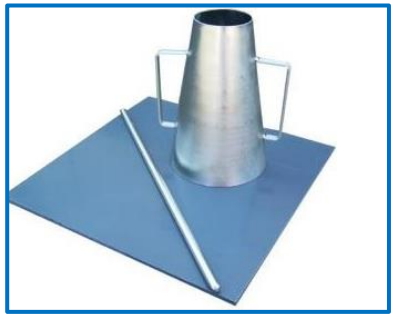


WP1: Testing on construction site

State of technology concerning workability, rheology and robustness of DFC



Flow table test



Slump flow test

L-Box test

Dynamic vane test

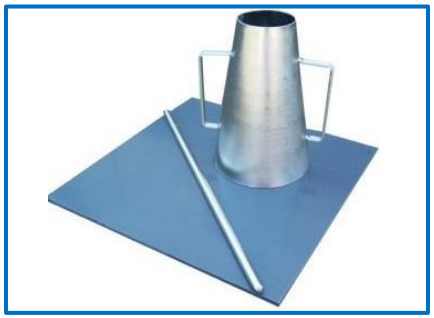
Filtration test

WP1: Testing on construction site

State of technology concerning workability, rheology and robustness of DFC

Workability / Rheology / Robustness

- Initial dynamic properties
- Initial thixotropic properties
- Workability



Slump flow test

L-Box test

1st Measurement

- Right after mixing
- Filling of slump cone and L-Box
- Rapid measurement after filling

Strength of sheared structure

2nd Measurement

- Right after mixing
- Filling of slump cone and L-Box
- **240 Seconds at rest** (concrete remains undisturbed in the specimen)
- Delayed measurement

Strength of structure at rest

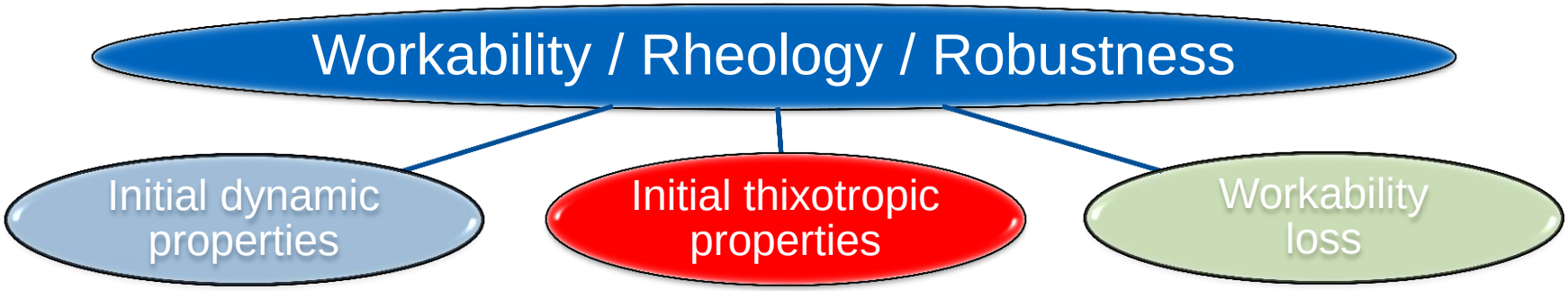
Result:

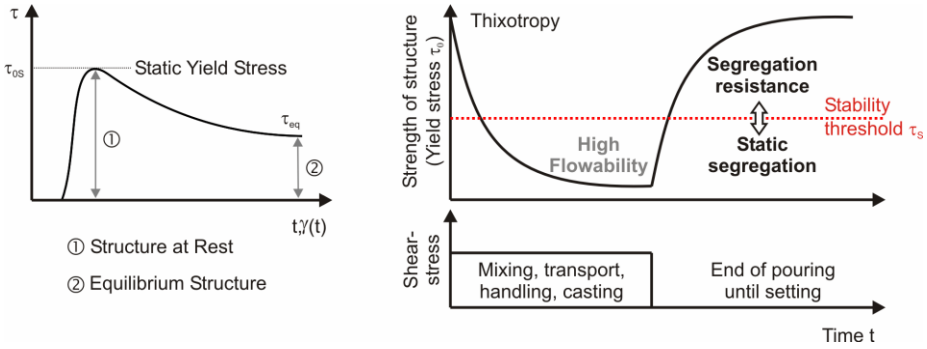
Reversible increase of structural strength of the concrete at rest

- Measured by the reduced workability at 2nd measurement

WP1: Testing on construction site

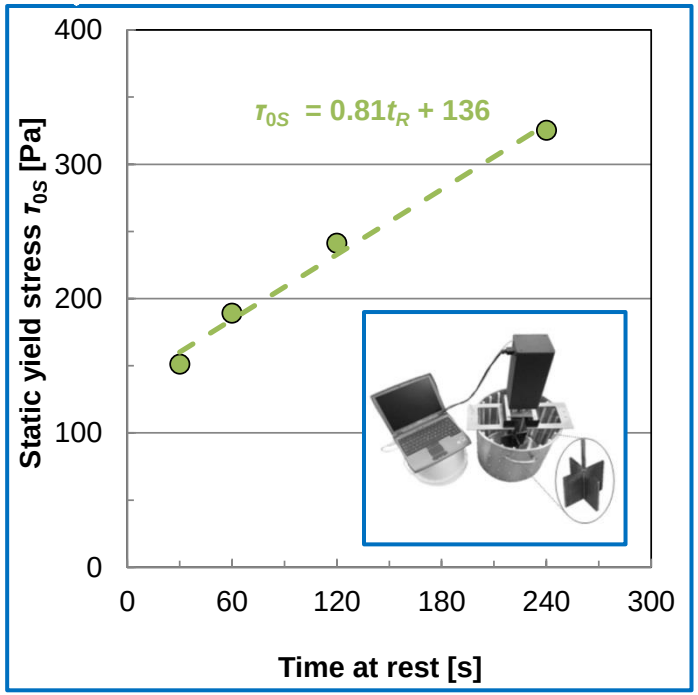
State of technology concerning workability, rheology and robustness of DFC





Static vane test

- Static yield stress τ_{0S} after different times at rest t_R (t_R = **30, 60, 120** and **240 sec at rest**)
- Temporal increase in is a measure of Thixotropy

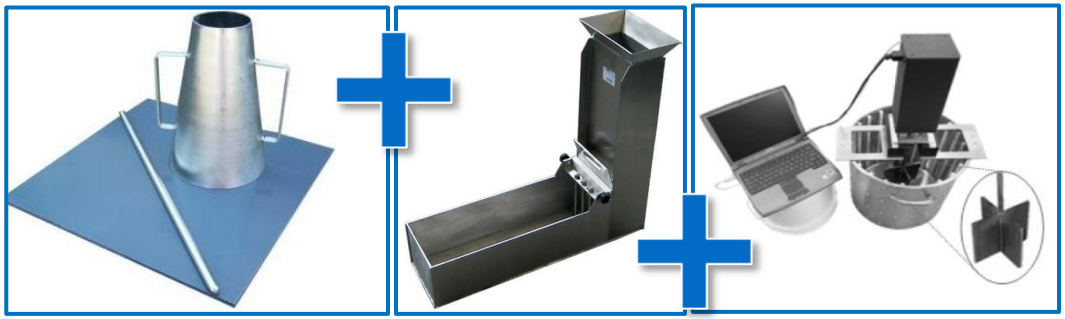


WP1: Testing on construction site

State of technology concerning workability, rheology and robustness of DFC

Workability / Rheology / Robustness

- Initial dynamic properties
- Initial thixotropic properties
- Workability loss



Slump flow test | **L-Box test** | **Dyn. vane test**

1st Measurement

- Right after mixing
- Filling of specimen
- Rapid measurement after filling

Initial dynamic properties

2nd Measurement

- **2 - 6 hours at rest** (concrete remains undisturbed in the specimen)
- Delayed Measurement

Delayed dynamic properties

Result:

Flow retention

- Measured by the reduced workability at 2nd measurement

WP1: Testing on construction site

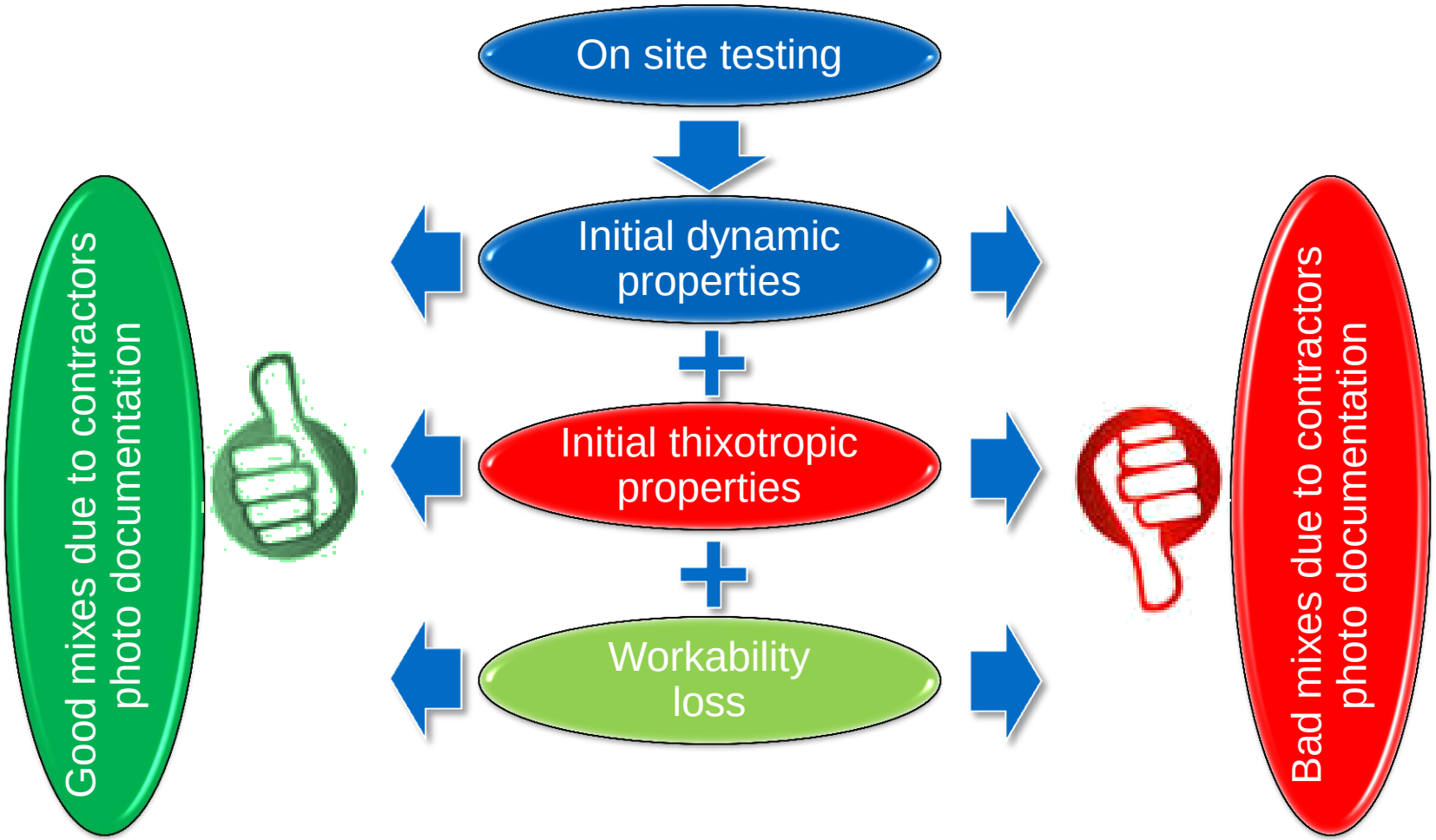
State of technology concerning workability, rheology and robustness of DFC

- **Documentation to be done by participating contractors:**
  - Wall has to be exposed and its quality (photo) documented

  - Information on Concrete composition
  - All parameters influencing the concrete flow

WP1: Testing on construction site

State of technology concerning workability, rheology and robustness of DFC



WP3: Rheological characterization of DFC by means of simple onsite tests

- **Correlation between onsite workability and rheological parameters**

- Slump, slump flow
- Flow time
- Reduced workability

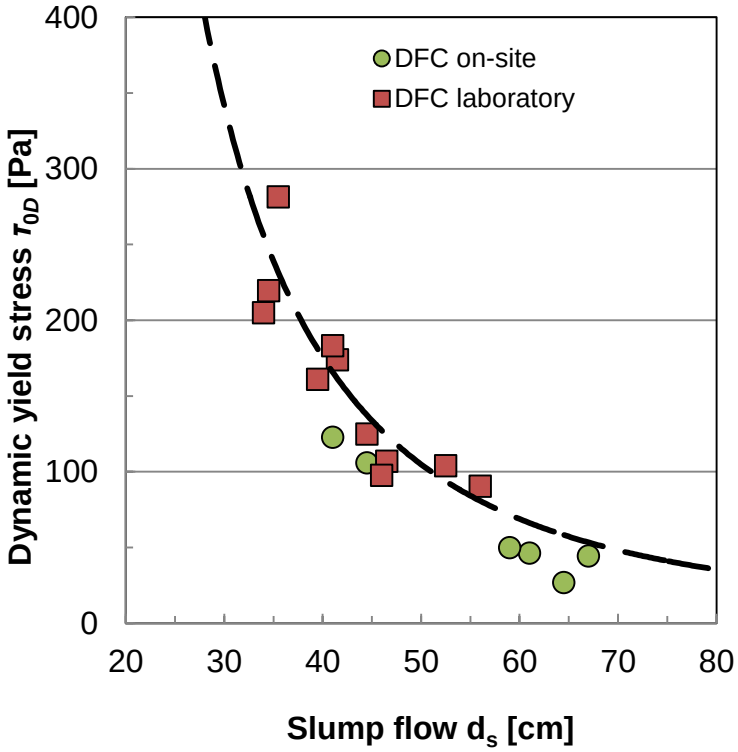
vs.

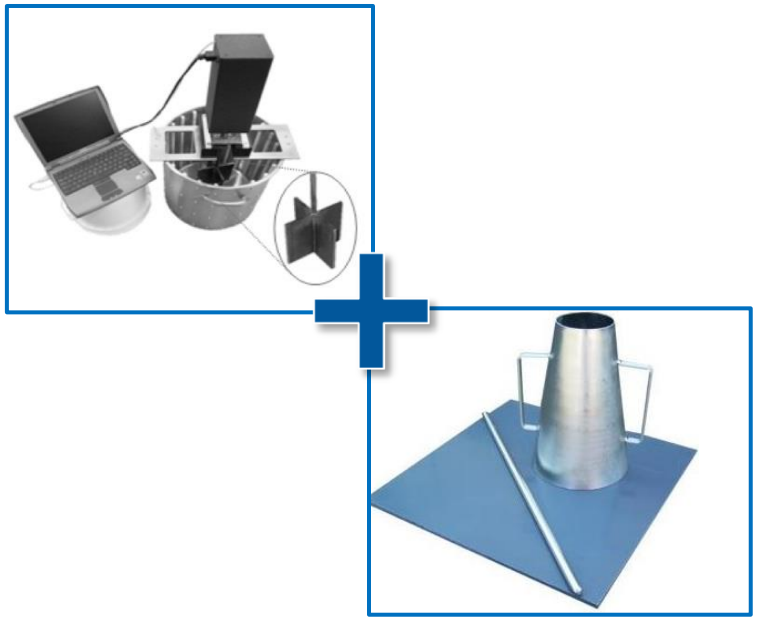
- Dynamic yield stress
- Plastic viscosity
- Thixotropy

- **Find parameters for a realistic description of concrete flow in bored piles and/or diaphragm walls**

WP3: Rheological characterization of DFC by means of simple onsite tests

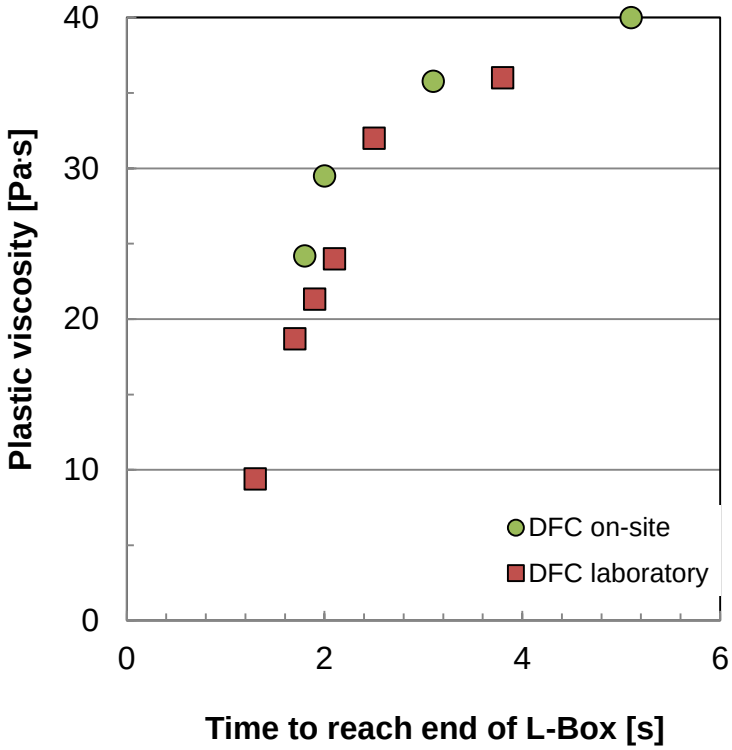
- **Correlation between onsite workability and rheological parameters**
  - Dynamic yield stress τ_{0D} and Slump flow diameter d_s

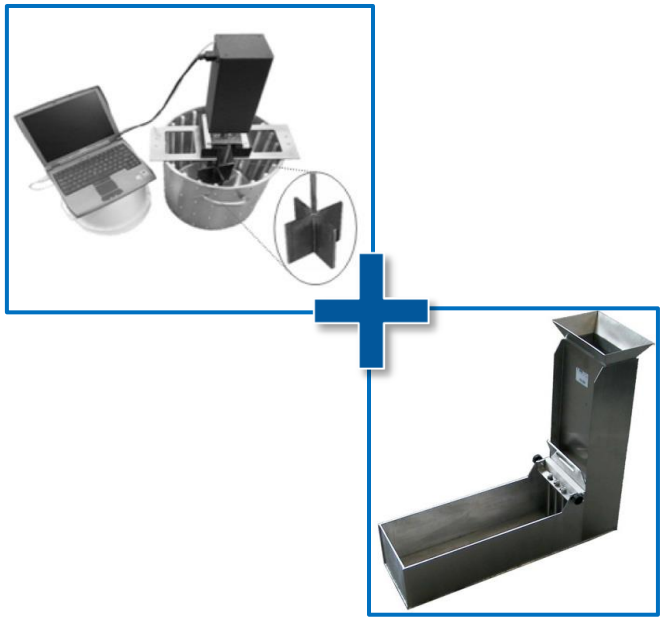




WP3: Rheological characterization of DFC by means of simple onsite tests

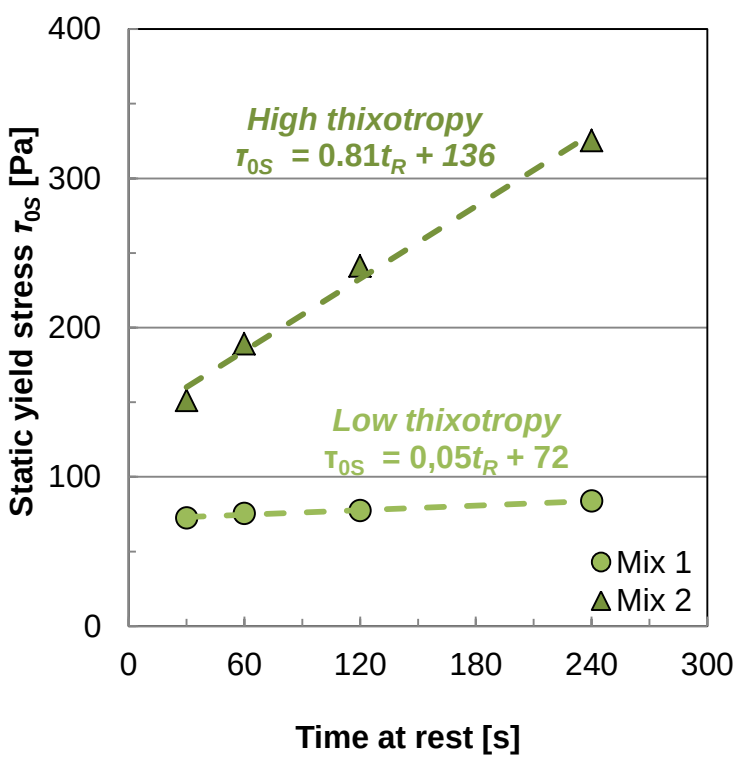
- **Correlation between onsite workability and rheological parameters**
  - Plastic viscosity μ and time to reach end of horizontal compartment of L-Box

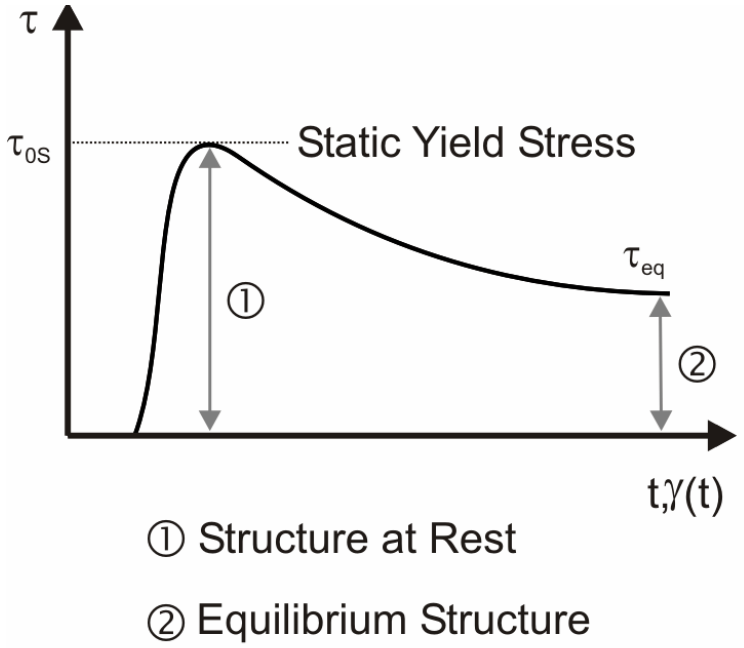




WP3: Rheological characterization of DFC by means of simple onsite tests

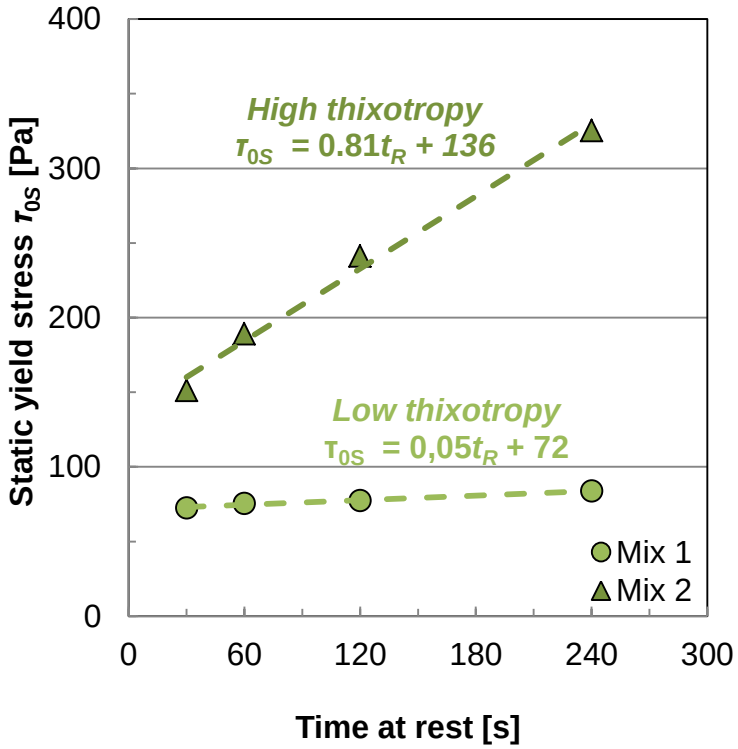
- **Correlation between onsite workability and rheological parameters**
  - Thixotropy A_{thix} and …

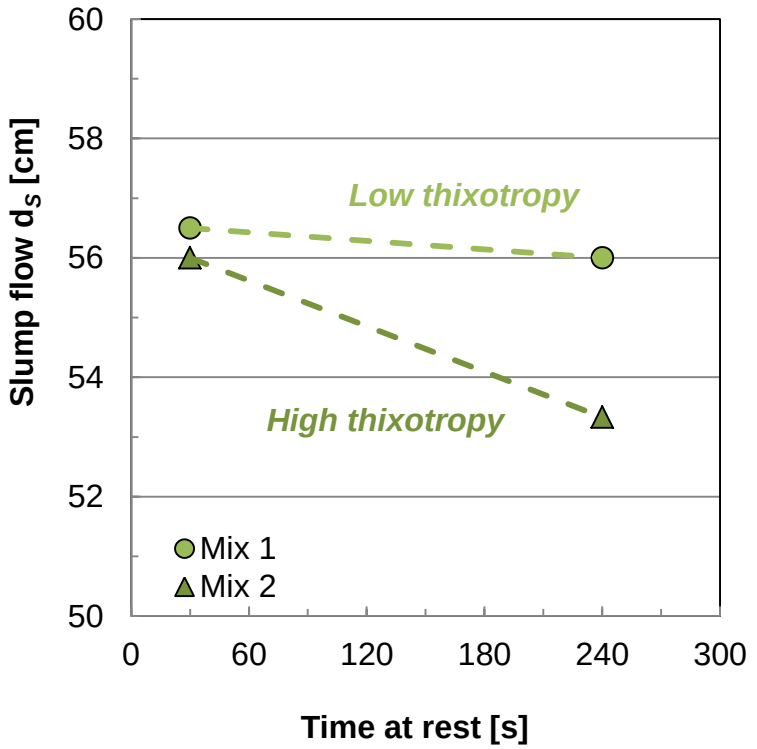




WP3: Rheological characterization of DFC by means of simple onsite tests

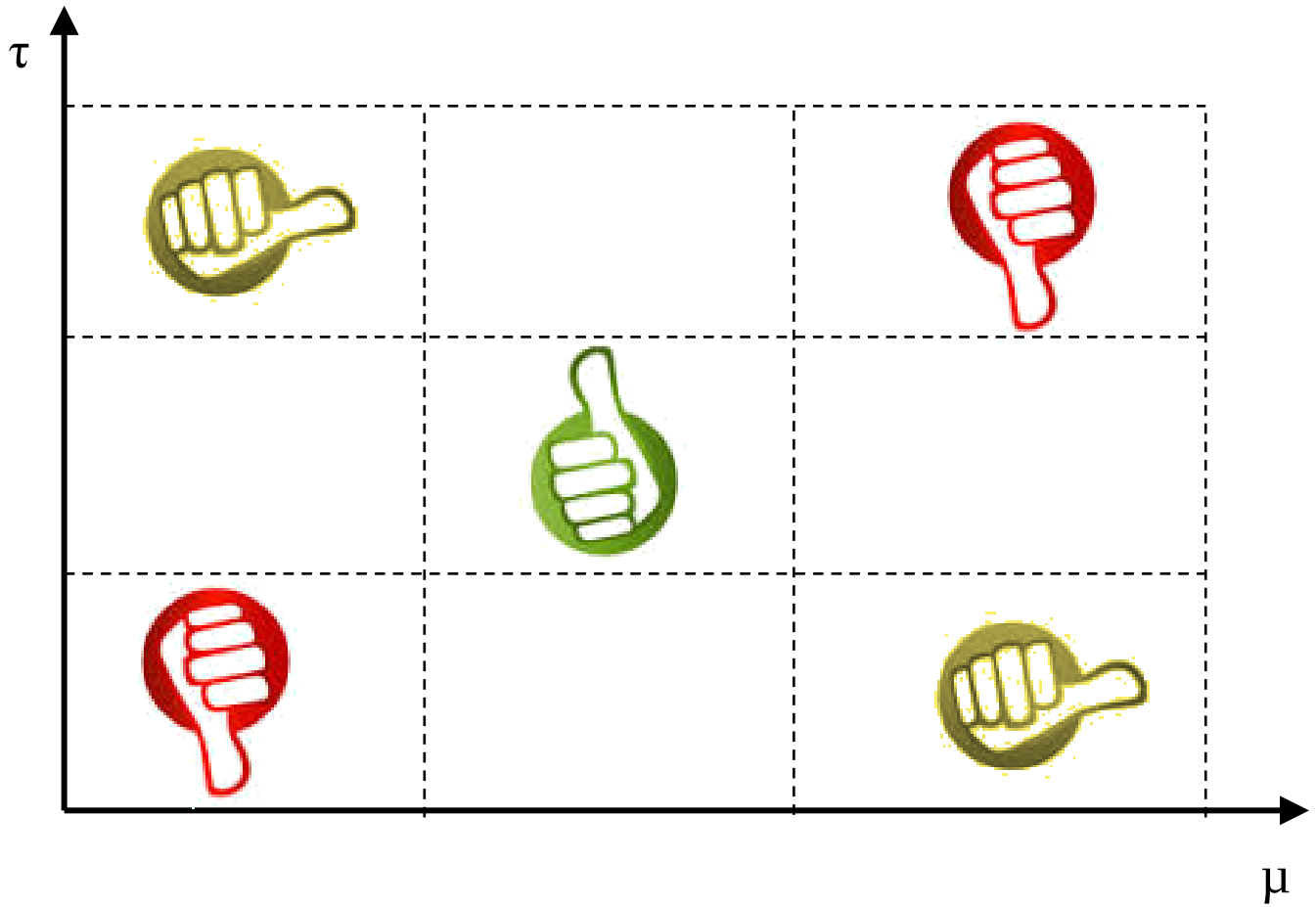
- **Correlation between onsite workability and rheological parameters**
  - Thixotropy A_{thix} and e.g. reduction of slump flow diameter at time at rest





WP4: Suitable test concept / onsite workability test set for fresh DFC based on rheology

- **Set of onsite tests and acceptance criteria for these tests**



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