



# 4C-Rheometer

Research and Development

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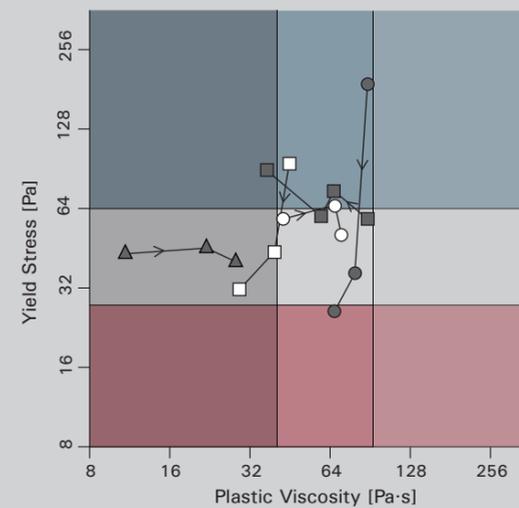
Determination of the Rheological Properties of Self-Compacting Concrete

## Research

Much research are being performed on SCC worldwide at universities and institutes. The 4C-Rheometer can be used for fundamental scientific research on the rheology of SCC. The equipment is a productive and cost-effective solution to the scientist that will investigate e.g. the effect of constituent materials on the rheological parameters of SCC, and has been shown to correlate well with the BML viscometer.

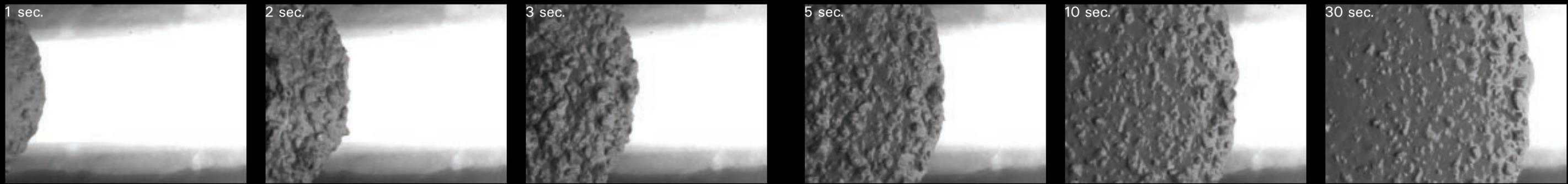
## Training Course

With the purchase of a 4C-Rheometer Danish Technological Institute will provide free of charge a one-day training course on the use of the equipment at your facilities. For a longer training course or a seminar arrangement can be made. Please contact DTI for details.



- **SP**, increasing dosage - The w/c-ratio and the paste content are constant.
- **Silica fume**, increasing content - The eqv. w/c ratio and the yield stress kept almost constant by varying the dosage of superplasticizer.
- ▲ **Fly ash**, increasing content - The eqv. w/c ratio and the yield stress kept almost constant by varying the dosage of superplasticizer.
- **Eqv. w/c**, decreasing value - The paste content is constant and the yield stress almost kept constant by varying the dosage of superplasticizer.
- **Paste**, increasing content - The eqv. w/c ratio and the dosage of superplasticizer are kept constant.





The 4C-Rheometer: A LCD camera captures the concrete flow at a frame rate of 15 s<sup>-1</sup>. For each frame the position of the concrete front is determined using a standard “find edge” image analysis algorithm.

# 4C-Rheometer

## Practical Application of Rheology

### 4C-Rheometer

The 4C-Rheometer is a system for automatic determination of the yield stress and plastic viscosity of Self-Compacting Concrete (SCC). The system is a PC automated slump flow test where the flow curve (spread vs. time) is determined using digital image analysis. The flow curve is subsequently compared to a database of simulated flow curves to give the yield stress and plastic viscosity.

The 4C-Rheometer can be applied:

- At the concrete plant or job site for quality assurance testing of SCC
- During development and optimisation of SCC mix designs
- In research and development for scientific studies e.g. to study the effect of concrete constituent materials on the yield stress and plastic viscosity of SCC.

The advantages of the 4C-Rheometer system are:

- Provides yield stress and plastic viscosity in fundamental units
- Provides slump flow and  $t_{500}$
- Less than 2 minutes to perform analysis
- User friendly and easy to operate and maintain
- Can be used in a laboratory and at the job site
- Test results are completely independent on the operator.

### From science to practice

One of the major challenges of Self-Compacting Concrete is to select the most appropriate flow properties for a specific type of application. Today, standard test methods are used to express the flow properties of SCC as these are often quick and easy-to-use compared to commercial rheometers. However, they are very operator dependent and do not provide sufficient information about the SCC. This often leads to misinterpretations of why some SCC castings are successful while others suffer from segregation, blocking, poor surface quality, and insufficient form filling.

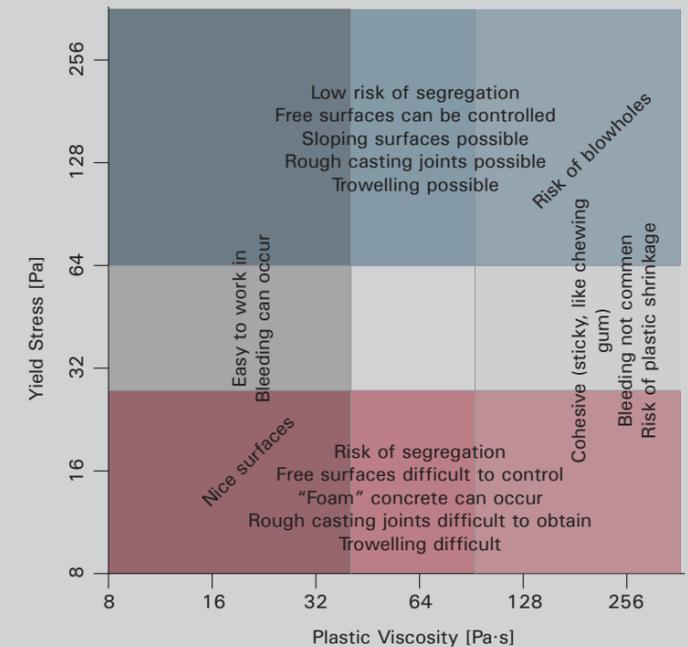
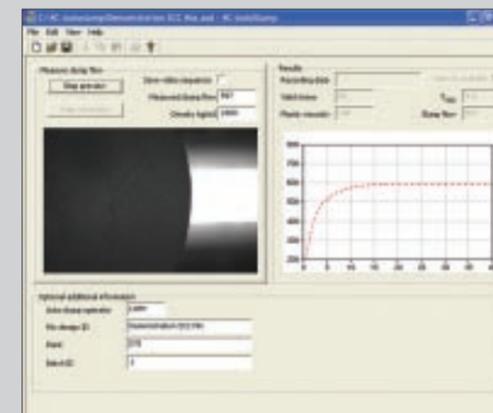
With the 4C-Rheometer it is now possible to measure the yield stress and plastic viscosity of SCC in an easy way both in the laboratory and at the job site. It opens for establishing databases comparing experiences from full scale castings with knowledge about the fundamental rheological behaviour of the SCC used (see figure on the next page). As a result improved acceptance criteria for SCC can be set leading to a higher success rate for SCC castings.

As an example, the 4C-Rheometer was used for acceptance testing at a full-scale highway bridge deck casting in October 2006, where it proved a valuable tool in testing the concrete rheology onsite in order to avoid dynamic segregation, to control the moving front of the concrete, and to assure that the concrete could be finished with a slope of 3%.

### Mix Design Development

Designing SCC mixtures with specific rheological parameters is often a challenge. The 4C-Rheometer can be used in the process of mix design development as the primary tool for measuring the rheology of the test mixtures. With information about the yield stress and plastic viscosity it becomes easier to differentiate between different SCC mixtures, thus making it possible to develop mixtures with rheological parameters targeted at particular types of castings e.g. slabs, walls, bridge decks, etc.

The system is easy to transport and can therefore potentially be shared between different laboratories or productions sites each taking advantage of the equipment in shorter periods of time.



Rheology-chart: illustrates the effect of different rheological parameters on the qualitative behaviour of SCC. The chart is based on more than 150 Danish SCC mixtures measured with the 4C RHEOMETER ( $D_{max} \approx 16$  mm).

User interface: The “Start recording” button activates the lifting of the cone and the subsequent analysis. In less than 2 minutes the yield stress, plastic viscosity, slump flow, and  $t_{500}$  are listed and saved to the harddisk.

