Figure 1 Viscometer for Fresh State Properties of Concrete (Concrete Rheometer)

DESCRIPTION

Concrete rheological properties need to be properly measured and predicted in order to characterize the workability of fresh concrete, including special concretes such as self-consolidating concrete (SCC). The Concrete Rheometer is capable to characterize the static yield stress, the dynamic yield stress and plastic viscosity of the concrete. A high static yield stress is desirable because it reduces formwork pressure and increases the resistance to segregation. But for ease of pumping, placement and self-consolidation, a low dynamic yield stress is necessary. The dynamic viscosity provides cohesiveness and reduces segregation when concrete is flowing. Thus, by determining the dynamic flow curves of concretes mixtures and optimum balance between ease of flow and resistance to segregation can be realized. These types of determinations cannot be done using conventional slump-based tests.

The Concrete Rheometer is composed of a container to hold the fresh concrete, a driver head supported on a frame with an electric motor and torque meter, a four-blade vane and a laptop computer to operate, record the torque and calculate the flow curve parameters. The size of the container and vane are selected based on the nominal maximum size of the aggregate. A multiple blade "Carrousel" vane is also available for a container for maximum aggregate size of 13 mm for more accurate and stable measurements on materials like high flow self-consolidating concrete (e.g. slump flow > 600 mm), flowable mortars or grouts (e.g. self-leveling), mortars for 3D printing, etc.

Two types of tests can be performed: stress growth test at a constant slow speed where the maximum torque measured is used to calculate the static yield stress; and the flow curve test to determine the dynamic yield stress and the plastic viscosity (Bingham parameters).

TESTING AND MEASURING CAPABILITIES

- Research and development:
    - to characterize the influence of new materials on concrete rheology

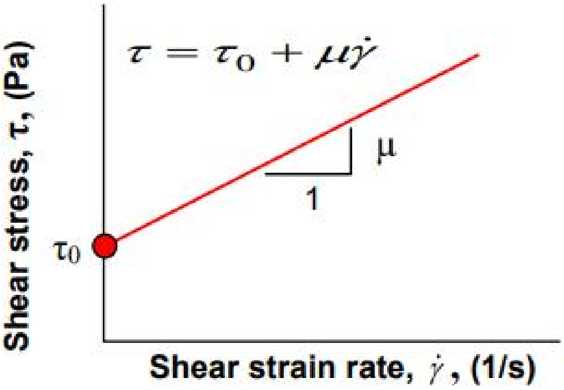
- Optimizing mixture proportions so that the resulting concrete flows readily but is resistant to segregation (especially important for self-consolidating concrete or pumped concrete)

- On-site quality control of mixtures.

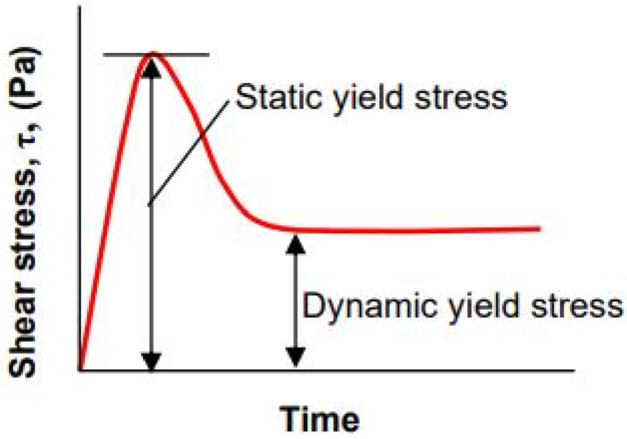
Principle:

Fresh concrete can be considered as a fluid, which means that it will flow under the action of shear stresses. The flow behavior of concrete can be represented by the following twoparameter relationship:

$$\tau = \tau_0 + \mu \gamma$$

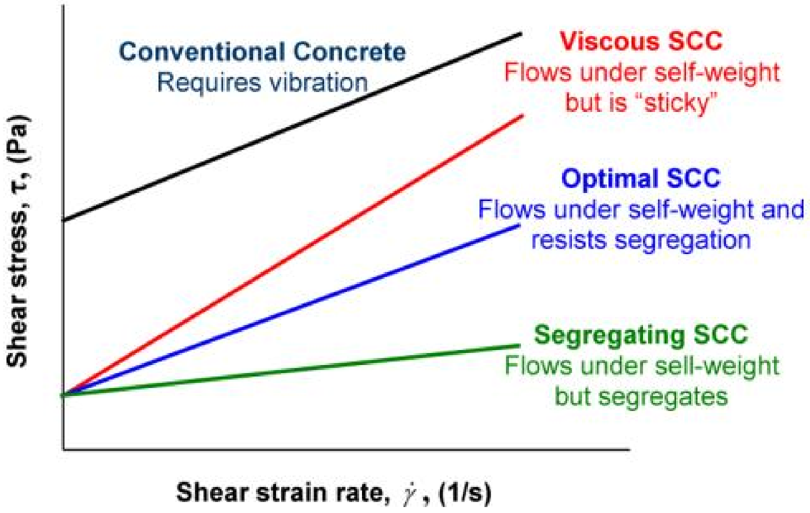


hich is known as the Bingham model: The parameter τ_o is the yield stress and represents the shear stress required to initiate flow. The slope of the line is the plastic viscosity, μ, and it affects the resistance to flow after the yield stress has been surpassed. These two parameters, which define the flow curve, provide a complete description of the flow behavior of a fluid. Concrete, however, is not a simple fluid because it displays thixotropic behavior, which means that the shear stress required to initiate flow is high if the concrete has been in an "at rest" condition, but a lower shear stress is needed to maintain flow once it has begun. This type of behavior is summarized in the schematic plot shown to the left, which shows the variation in shear stress with time for the case of a low applied shear strain rate. At the start, the shear stress increases gradually with time but there is no flow. When the stress reaches the static yield stress, the concrete begins to flow and the stress required to maintain flow is reduced to the dynamic yield stress.



If the applied shear strain rate is reduced to zero and the concrete is allowed to rest, inter-particle forces create a weak framework that restores the static yield stress. With time, the static and dynamic yield stresses increase as the effectiveness of water-reducing admixtures diminish and hydration proceeds, which is commonly referred to as "slump loss."

It is designed to characterize the **static yield stress**, the **dynamic yield stress** and **plastic viscosity of the concrete**. A high static yield stress is desirable because it reduces formwork pressure and increases the resistance to segregation. But for ease of pumping, placement, and self-consolidation, a low dynamic yield stress is necessary. The dynamic viscosity provides cohesiveness and contributes to reducing segregation when concrete is flowing. The schematic plot to the right shows dynamic flow curves for conventional concrete and different types of self-consolidating concrete (SCC) mixtures. The conventional concrete has a high dynamic yield stress and additional energy (vibration) is needed to consolidate the concrete after it is placed in forms.



The self-consolidating mixtures all have low dynamic yield stress and will consolidate due to self-weight, but they have different rheological properties. The SCC with a high plastic viscosity (red line) will be sticky and difficult to place and strike off. On the other hand, the mixture with low plastic viscosity (green line) will be prone to segregation. Thus, by determining the dynamic flow curves of concretes with different mixture proportions and type of admixtures, and optimum balance between ease of flow and resistance to segregation can be realized. These types of determinations cannot be done using conventional slump-based tests.

Features

- **Minimum slump:** The concrete has to have a slump greater than 75 mm, otherwise, the concrete is too stiff for being tested
- **Nominal maximum size of aggregate (NMSA):** up to 32 mm for the largest available container
- **Vane rotation speed:** 0.001 to 0.667 rev/s
- **Motor type:** Integrated Servo Motor.

Specification

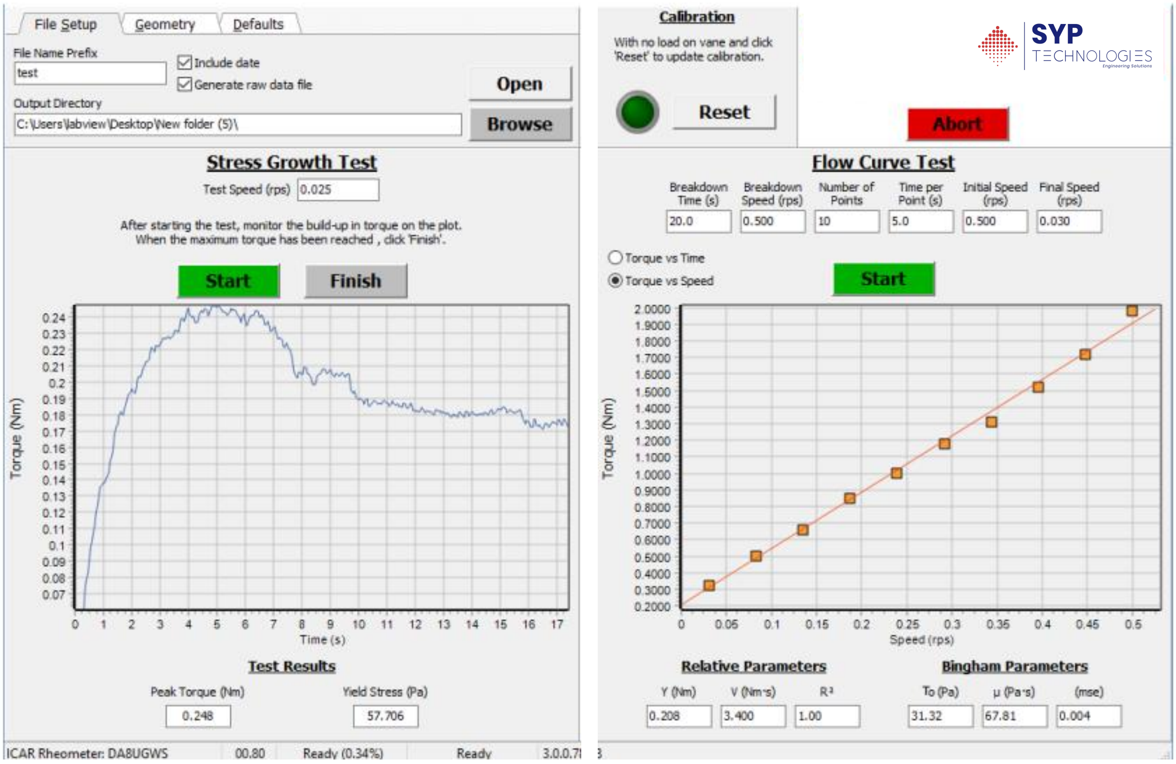
Parts of Rheometer kit involves:

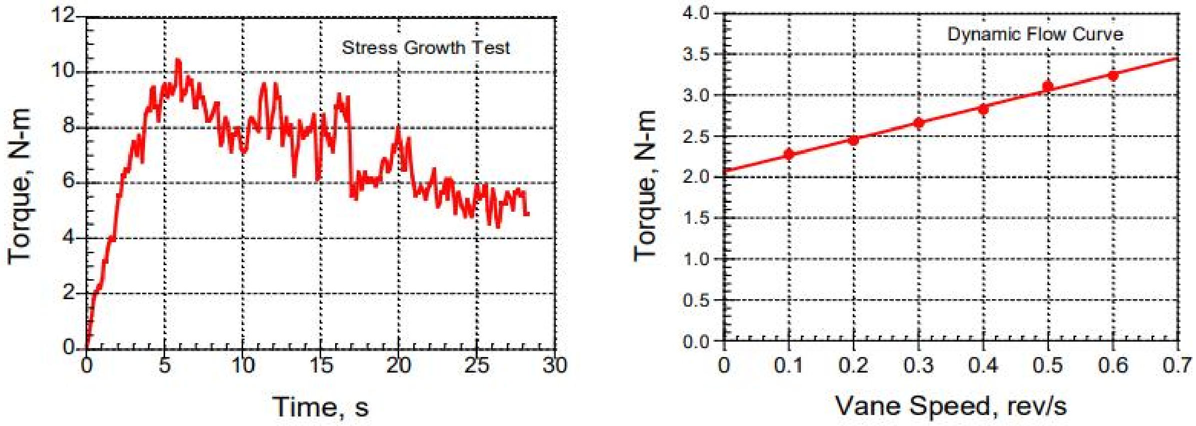
- Motor drive/torque meter unit
- Power cord for motor drive unit
- Base frame
- USB cable RHM-3012
- Laptop computer with software
- Software on CD-ROM
- User manual
- Carrying case for laptop computer
- Carrying case for Rheometer
- Containers and vanes for different NMSA Container, four-blade vanes for Nominal Maximum Size of Aggregate (NMSA) 13 mm 19 mm 25 mm 32 mm

- Carrousel Vane
- 30,000 centistokes silicone oil for verification of instrument (25 L or 19 L pail)
- Motor type: Integrated Servo Motor
- Accuracy: ±0.1 %
- Resolution: 0.001 Nm
- Minimum Torque: 0.01 Nm
- Peak Torque: 90 Nm for not more than 2 seconds
- Continuous Maximum Torque: 32 Nm
- Power Supply: Input of 100-240 VAC 50-60 Hz – 3.5A.
- Digital Calibration can be performed by user at any time
- Performs static stress growth and dynamic flow curve tests
- Software computes static yield stress, dynamic yield
- Stress, and plastic viscosity in fundamental units
- Motor drive dimensions: 11 x 11 x 43 cm
- Motor console weight: 7.5 kg

SOFTWARE

The Concrete Rheometer software operates and calibrates the driver, records the torque, computes test results, and stores data. The entire testing is controlled from a single screen as shown below. A simple press of the "Start" button initiates the stress growth test or the flow curve test. Both tests are completed within 1 minute. The automatic digital calibration allows users to always have a ready to use system. After calibration, the uncertainty torque measurement value is displayed, which is typically less than 0.5%.





The program uses the peak torque and test geometry to calculate the static yield stress, which is displayed at the bottom of the computer display. The figure on the right shows the average torque versus average vane rotation measured during six steps of the flow curve test. The software computes a best-fit line to the data and reports the intercept and slope as relative parameters. Based on the test geometry, the software computes the Bingham parameters: dynamic yield stress and plastic viscosity.

Dimensions & Weights

L x W xH: (0.7 x 0.6 x 0.3) m

Weight: Approx. 50 kg, including motor drive, base frame, vane, power supply and cables