ICAR Rheometer

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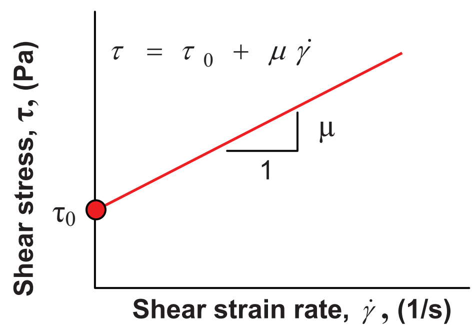
Purpose

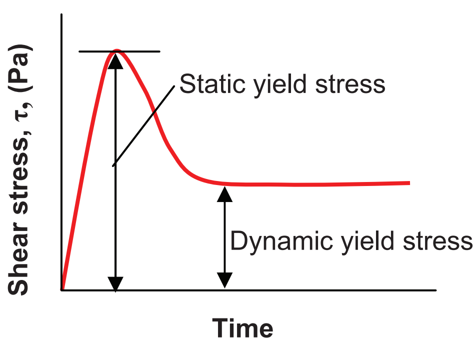
The **ICAR Rheometer** is a rugged, portable instrument for measuring fundamental flow (rheological) properties of fresh concrete. The instrument was developed at the International Center for Aggregate Research (ICAR) located at The University of Texas at Austin to fill the need for a method to characterize the true flow behavior of concrete mixtures. The traditional methods of measuring slump or slump flow are not capable of characterizing the fundamental rheological properties of concrete during the processes of mixing, transporting, and placement. As a result, the true performance of innovative concrete mixtures cannot be measured with these traditional slump-based methods. The **ICAR Rheometer** provides, for the first time, a low-cost and simple to operate instrument that can be used for:

- 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)
- On-site quality control

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 two-parameter relationship $\tau = \tau_0 + \mu \dot{\gamma}$, which is known as the **Bingham model**: The parameter τ_0 is the **yield stress,** and it 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 concrete mixture.





Concrete, however, is not a simple fluid because it displays **thixotropic** behavior, which means that the shear stress required to initiate flow is high when 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 **slowly** applied shear strain. 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 is removed 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."

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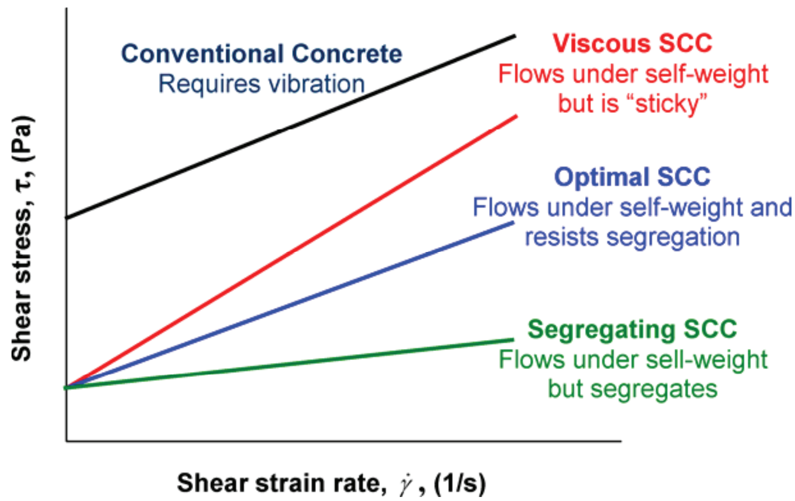
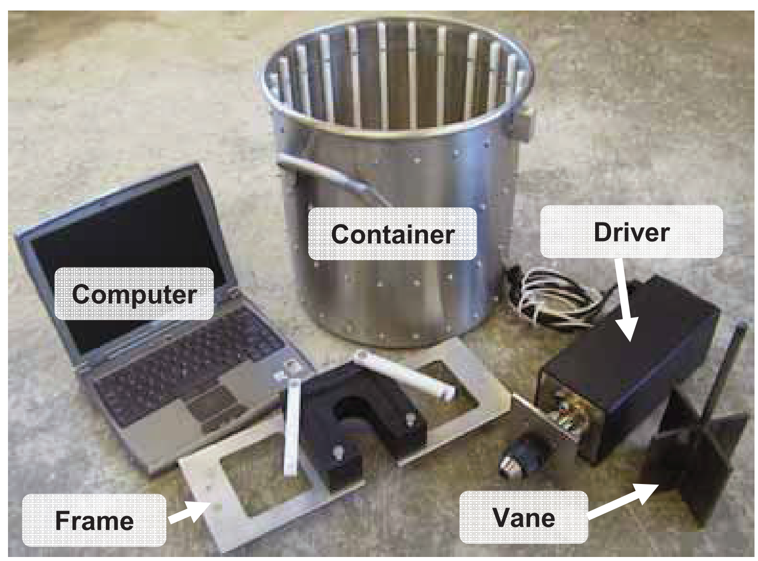


The **ICAR Rheometer** is designed to characterize the **static yield stress**, **the dynamic yield stress** and **plastic viscosity** of the concrete. A high static yield stress is desirable because it reduces formwork pressure and increases the resistance to segregation. But for ease of pumping, placement, 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 for consolidation after the concrete 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 finish. 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.

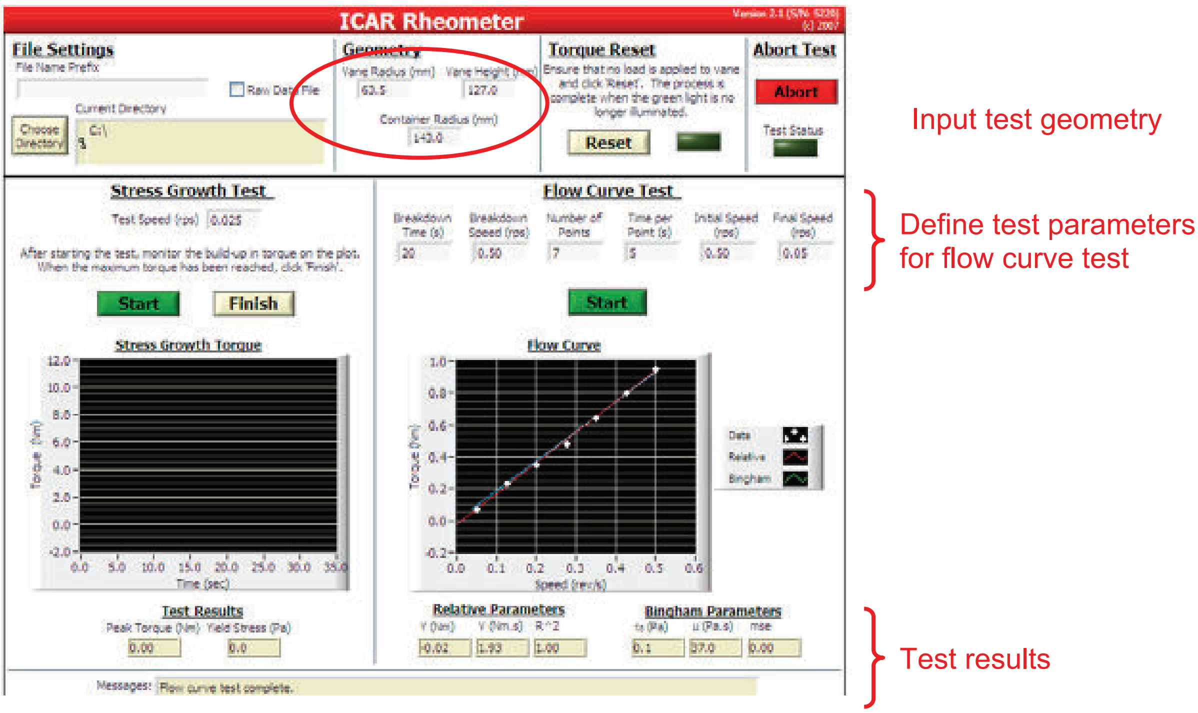
Method of operation



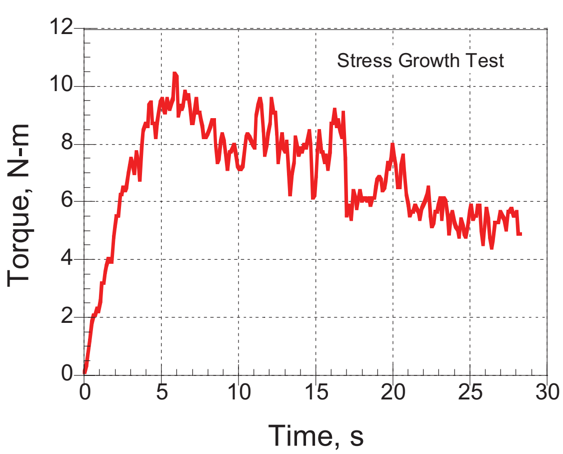
The **ICAR Rheometer** is composed of a container to hold the fresh concrete, a driver head that includes an electric motor and torque meter; a four-blade vane that is held by the chuck on the driver; a frame to attach the driver/vane assembly to the top of the container; and a laptop computer to operate the driver, record the torque during the test, and calculate the flow parameters. The container contains a series of vertical rods around the perimeter to prevent slipping of the concrete along the container wall during the test. The size of the container and length of the vane shaft are selected based on the nominal maximum size of the aggregate. The vane has a diameter and a height of 127 mm.

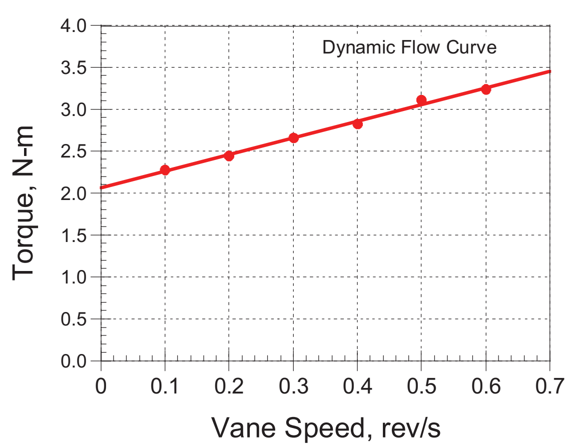
Two types of tests can be performed. The first is a **stress growth test** in which the vane is rotated at a constant slow speed of 0.025 rev/s. The initial increase of torque is measured as a function of time. The maximum torque measured during the test is used to calculate the **static yield stress**. The other type of test is a **flow curve test** to determine the **dynamic yield stress** and the **plastic viscosity**. The flow curve test begins with a "breakdown" period in which the vane is rotated at maximum speed. This is done to breakdown any thixotropic structure that may exist and to provide a consistent shearing history before measuring the Bingham parameters. The vane speed is then decreased in a specified number of steps, which is selected by the user but at least six steps are recommended. During each step the speed is held constant and the average speed and torque are recorded. The plot of torque versus speed of vane rotation is the **flow curve**.

The **ICAR Rheometer** software performs all the necessary functions: operates the driver, records the torque, computes test results, and stores data. For simplicity, the entire program is operated from a single screen as shown below. The user defines the test geometry and provides the test parameters to run the flow curve test. A simple press of the "Start" button initiates the tests, which takes less than 1 minute to complete.



Example results
The figure on the left shows the results of a stress growth test. The peak torque and test geometry are used to calculate the static yield stress, which is displayed at the bottom of the computer display. The figure on the right shows the plot of the average torque and average vane rotation measured during six steps of decreasing vane speed. The software computes a best-fit line to the data and reports the intercept and slope as relative parameters. The software also computes the Bingham parameters: dynamic yield stress and plastic viscosity.





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ICAR Rheometer Specifications

- Requires that concrete have slump greater than 50 to 75 mm, otherwise the concrete is too stiff for testing by the apparatus
- Nominal maximum size of aggregate: 32 mm for largest available container
- Vane rotation speed: 0.001 to 0.6 rev/s
- Performs static stress growth test and dynamic flow curve tests
- Software control tests and computes static yield stress, dynamic yield stress, and plastic viscosity in fundamental units
- Test time: 1 minute

ICAR Rheometer Kit Ordering Numbers

Item	Order #
Motor drive/torque meter unit	RHM-3001
Power cord for motor drive/torque meter unit	RHM-3002
Base plate for attaching motor drive/torque meter unit to container	RHM-3003
Container for 19 mm NMSA aggregate – standard (see below for other sizes)	RHM-3005
Four-blade vane for 19 mm NMSA aggregate Vane is 127 mm in height and diameter Overall length depends on NMSA (see below for other sizes)	RHM-3009
USB cable to connect motor drive/torque meter unit to computer	RHM-3012
Laptop computer with installed software	RHM-3013
Software on CD-ROM	RHM-3014
User manual	RHM-3015
Carrying case for laptop computer	RHM-3016
Carrying case for Rheometer and accessories Container does not ship with case Weight of case and Rheometer kit – 19 kg	RHM-3017

Ordering numbers for container and vane for different nominal maximum size of aggregate (NMSA)

	Nominal Maximum Size of Aggregate			
	12.5 mm	**19.0 mm**	**25.0 mm**	**32 mm**
Container Diameter/Height	RHM-3004 280 mm/280 mm	RHM-3005* 305 mm/312 mm	RHM-3006 355 mm/380 mm	RHM-3007 405 mm/460 mm
Vane Overall length	RHM-3008 235 mm	RHM-3009* 240 mm	RHM-3010 290 mm	RHM-3011 330 mm

*Size provided if another size is not specified.

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Test smart - Build right