# Workability & Rheological Parameter of Concrete

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## Abstract

The present methods available for determining these properties of fresh concrete are operator sensitive and thus, the properties for same mix of concrete made under same conditions will vary depending upon the workmanship. Even the IS code suggesting different methods for different workability and different placing condition. Thus, more judicious methods for determining the physical properties of fresh concrete are required. This seminar consists of such methods for determining the physical properties of concrete viz. shear stress and viscosity. In addition to this the research carried out by various researchers in the field of rheology of concrete has been studied such as the comparison of various types of rheometers, the use of rheometers and workability boxes, rheological properties of self-compacting concrete, rheological properties of ultra-high performance concrete and the various types of rheogarphs has been studied.

**Keywords- Concrete, Shear Stress, Rheology, Rheogarph, Rheometer, Workability**

## I. INTRODUCTION

Technical literature abounds with variations of the definition of workability and consistency but they are qualitative in nature and more reflections of a personal viewpoint rather than scientific precision. The same applies to the plethora of terms such as flow ability, mobility and pump ability. These terms do have a specific meaning but only under a set of given circumstances. Also, the definition of workability defers from person to person and is solely the function of workmanship.

Workability of concrete is defined as the ease by which the concrete can be mixed, transported, placed, compacted and finished. But to say merely that workability determines the ease of placement and the resistance to segregation is too loose to a description of this vital property of concrete. Furthermore, the desired workability in any particular case would depend on the means of compaction suitable; likewise, workability suitable for mass concrete is not necessarily sufficient for thin, inaccessible or heavily reinforced section. For these reasons, workability should be defined as a physical property of concrete alone without reference to the circumstances of a particular type of construction.

For all these reasons, Tattersall has repeatedly criticized all the existing workability tests on the ground that they measure only one parameter. He argued that the flow of concrete is more complex phenomenon and can be modeled as Bingham fluid. He explained that the concrete in order to flow, must overcome the yield stress. These properties of fluid flow are explained as rheology and were first coined by Professor Bingham of Lafayette College, Indiana. He gave the equation for the flow of viscous plastic fluid or in General Bingham fluid as:

$$\tau = \vartheta + \mu.\gamma$$

Where,
$\tau$ = Shear stress,
$\vartheta$ = Yield stress,
$\gamma$ = Rate of shear and
$\mu$ = Viscosity of fluid

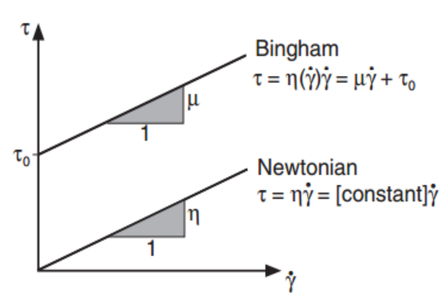


Fig. 1: Modelling of concrete as Bingham Fluid

These parameters of concrete are termed as rheological parameters. Rheology is thus defined as the science of the deformation of and the flow of matter and the emphasis on the flow means that it is concerned with the relationships of stress, strain, rate of strain and time.

However, concrete can be modeled as Bingham fluid only when it is vibration compacted concrete, in case of self-compacted concrete, the concrete has to be modeled considering it to be Herschel-Buckley model defined as the equation as below:

$$\tau = \vartheta + \delta\gamma^{n}$$

Where,

$\tau$ = Shear stress,

$\vartheta$ = Yield stress,

$\gamma$ = Rate of shear,

$\delta$ = Flow coefficient and

n = Power Law exponent.

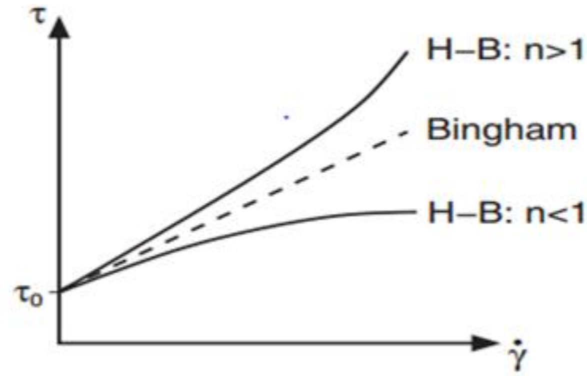


Fig. 2: Modelling of concrete as Herschel-Buckley fluid

### A. *Application of Rheology*

One can use it as a guide during mixture proportioning (mix designing), for raw material evaluation or for quality control at building site. In many countries the plastic viscosity of conventional vibrated concrete (CVC) (having slump value between 50 and 170 mm) is relatively low or between 20 to 40Pa·s. In this case the empirical slump test might be an adequate to evaluate the workability of the fresh concrete. But with higher plastic viscosity values, more information is in most cases needed, available by other and more sophisticated measuring devices like the Mk system, Con Tec-, or the BTRHEOM viscometer. Then it is important to retrieve the rheological properties in terms of fundamental physical quantity to evaluate the workability.

### B. *Need for Study*

Workability accounts for most important factor in case of fresh concrete. But present methods available for determining these properties of fresh concrete are operator sensitive and thus, the properties for same mix of concrete made under same conditions will vary depending upon the workmanship. There are various Tests and methods for determining such properties and their values differ from each other. Even the IS code suggesting different methods for different workability and different placing condition. Thus, more judicious methods for determining the physical properties of fresh concrete are required. So the use of rheometer for determining fresh properties will give us a single trustworthy test which will be applicable for all range of workability

## II. METHODOLOGY

### A. *Rheometer*

The word Rheometer comes from the Greek, and means a device for measuring flow. In the 19th century it was commonly used for devices to measure electric current, until the word was supplanted by galvanometer and ammeter. It was also used for the measurement of flow of liquids, in medical practice (flow of blood) and in civil engineering (flow of water). A Rheometer is a laboratory device used to measure the way in which a liquid, suspension or slurry flows in response to applied forces. It is used for those fluids which cannot be defined by a single value of viscosity and therefore require more parameters to be set and measured than is the case for a viscometer. It measures the rheology of the fluid. There are two distinctively different types of rheometer. Rheometers that control the applied shear stress or shear strain are called rotational or shear rheometers, whereas rheometers that apply extensional stress or extensional strain are extensional rheometers. Rotational or shear type rheometers are usually designed as either a native strain controlled instrument (control and apply a user defined shear strain which can then measure the resulting shear stress) or a native stress controlled instrument (control and apply a user defined shear stress and measure the resulting shear strain). The various types of rheometers that are used for determining the rheological parameters of the concrete are:

1) Tattersall two point rheometers,
2) Rheometers with impellers.

### *B. Tattersall Two Point Rheometer*

The Tattersall two-point device was reportedly the first rheometer to measure concrete as a Bingham fluid. The device was developed after other researchers had made unsuccessful attempts to measure concrete workability using coaxial cylinders' rheometers. The original version of the two-point device, the Mk I apparatus, was first presented in 1971 and consisted of a Hobart food mixer with a hook-shaped impeller moving in a planetary motion. The intent of the design was to use an impeller that would move in planetary motion and continuously come into contact with fresh concrete. Speedways altered by changing the gear settings while torque measurements were made indirectly with a wattmeter. The three speed settings were 95, 170, and 310revolutions per minute. The measured flow curves, when used on mixes with water-to-cement ratios from 0.40 to 0.70, were generally linear. This is the oldest and most widely used apparatus for measuring the flow characteristics of the concrete. The instrument as shown in figure consists of a bucket in which the concrete is poured and the special vane as shown in figure is lowered in the sample and the vane is rotated and the resistance set up in the material is measured in the form of torque. As the speed of rotation is increased, a graph is obtained for the torque versus speed.

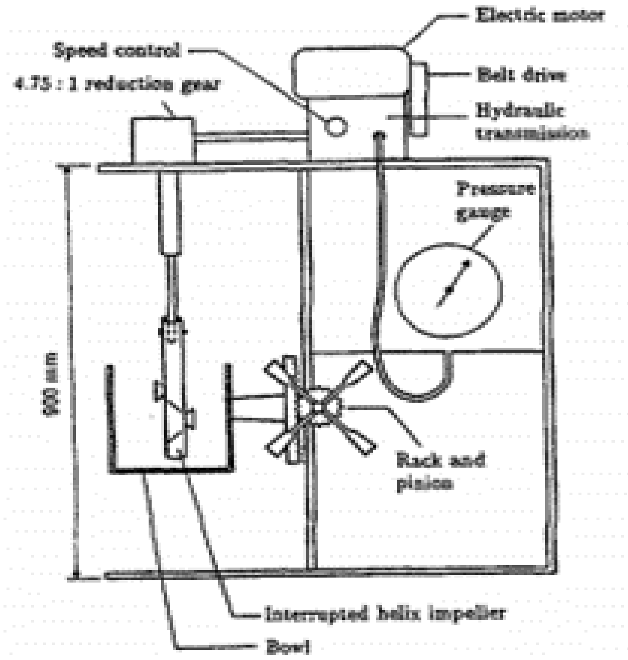


Fig. 3: Tattersall two-point test

### *C. Rheometers with Impellers*

These type of rheometers are most commonly used because they are portable, easy to handle and give fairly accurate results. The apparatus consists of a series of vanes that is lowered in the bucket containing concrete, then the vane rotates at a certain speed and the torque is measured. Such readings are carried out for a number of series and then the graph is plotted for torque versus speed. This type of Rheometer comes with various types of impeller sections.

Although several different Rheometer impellers have been developed, it is clear that the statement of Tattersall and Banfill (1983) that "an improved form may yet be developed" remains true. If possible, the impeller should move in an axial motion, thereby avoiding the cost and complication of a planetary gearbox. The impeller should be of minimal size, while meeting a gap size to aggregate size ratio of 3 to 5 for 1-inch aggregate. The movement of the concrete generated by the impeller should not result in either segregation or trapping of aggregate. In order to select an impeller, it was necessary to test experimentally several impeller geometries in concrete. The evaluation of nine potential impellers, developed based on the information in this section, is described in Chapter 4. The final impeller selected was a four-bladed vane intended to act as the inner cylinder of a coaxial cylinders Rheometer.

 

Fig. 4: Impeller type Rheometer

### *D. Rheogarph*

A rheogarph is defined as a plot of changes in the relation between yield stress on y-axis and the plastic viscosity on x-axis as a function of material properties, time, additives, etc. In this article, the author has defined rheogarphs a convenient and essential tool to compare different concrete batches and examine the behavior relative to changed constituents, quantities of constituents, and/or relative to different times from water addition.

Workability box consists of an area. A workability box consists of an area within a rheogarph. More precisely, such a box consists of a certain domain of yield stress and plastic viscosity. A single workability box is associated with particular concrete type. Thus, several workability boxes can be represented in a single rheogarph. It should be clear that a workability box does not have to consist of a perfect square. It can also consist of a two-dimensional polygon, or pointed regions without an exact and clear boundary. Thus, a number of rheogarphs can be plotted as shown;

A single workability box is associated with particular concrete type (like Conventional Vibrated Concrete, CVC) and its corresponding job application. For example, the CVC is often of a relatively stiff consistency (slump 170 mm), which corresponds to yield stress$\tau 0$in the higher range, say above 300 Pa. To maintain a workable CVC, the plastic viscosities are usually in the lower range, or say at and below 40 Pa. A CVC that is located outside this box could indicate a risk of failure at the job site due to unsuitable consistency. A skilled technician would appreciate the importance in keeping the particular mixture close to or in the area defined by a certain workability box of relevance. When the concrete is outside the particular box, a Rheogarphsand aid the technician in putting it back into an optimum state

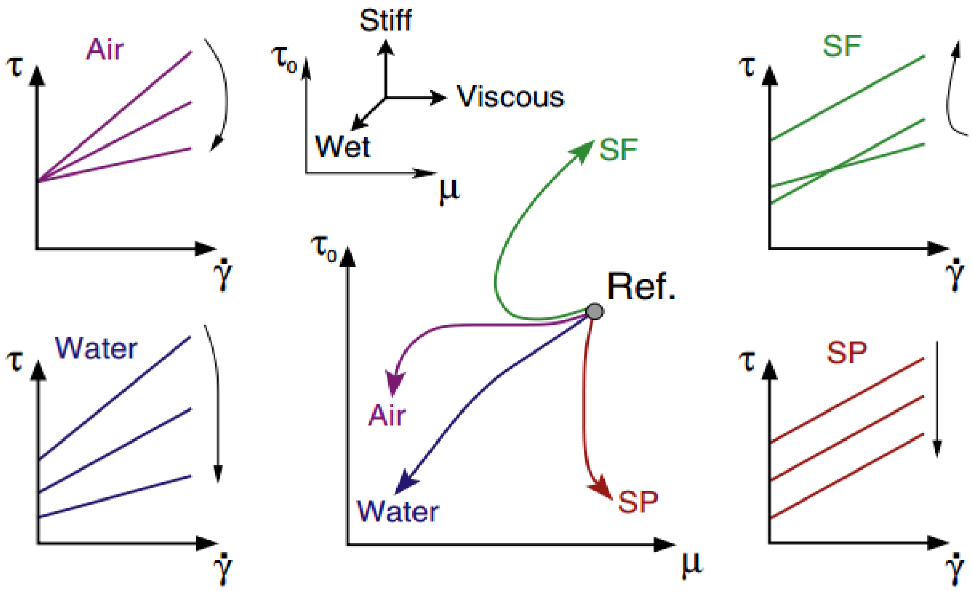


Fig. 5: Rheogarphs and workability boxes for concrete mixes with varying proportion of ingredients

## III. RESULTS

1) The properties of fresh concrete are a complex phenomenon. The present methods available for Even the IS code suggests different methods for different workability and different placing condition. Thus, more judicious methods for determining the physical properties of fresh concrete are required.
2) Determining these properties of fresh concrete are operator sensitive and thus, the properties for same mix of concrete made under same conditions will vary depending upon the workmanship.
3) This report consists of such methods for determining the physical properties of concrete viz. shear stress and viscosity. In addition to this the research carried out by various researchers in the field of rheology of concrete has been studied such as the comparison of various types of rheometers, the use of rheometers and workability boxes, rheological properties of self-compacting concrete, rheological properties of ultra-high performance concrete and the various types of rheogarph has been studied.

## IV. CONCLUSION

The following conclusions can be drawn by the study of rheology of fresh concrete:
Rheology when used along with the correlation charts can be used on RMC plants to achieve desired Strength.
By the application of rheogarphs and workability boxes in the mix design, the desired workability can easily be obtained by reducing the plasticizer content and thereby achieving economy.
Rheology of fresh concrete can provide valuable information regarding the properties of fresh concrete, how to attain optimization by the use of rheogarphs

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