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Rheology as a tool in concrete science: The use of rheographs and workability boxes

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ABSTRACT

Rheology can supply valuable and practical information regarding the properties of fresh concrete, how to reach an optimization of the product and how to attain it by the use of rheograph. Otherwise, the optimization is largely based on feeling. The rheograph reveals in a systematical way the effects of diverse changes on the rheological behavior of the cement based suspension and thus is a convenient and essential tool to compare different concrete types and examine the behavior relative to changed quantities of constituents. Effects of many admixtures as well as the basic constituents of fresh concrete have been revealed in rheographs. In principle the effect of two or more constituents can be added in a rheograph to estimate the combined effect, which constitutes a so-called vectorized-rheograph approach.
Different applications and types of concrete like slipform, underwater, and high strength, are described by workability boxes. New rheograph with boxes for various types of self compacting concrete is proposed.

1. Introduction

1.1. Rheological terminologies

Since civilizations first started to build, the human race has sought materials that bind stones into solid formed mass. After the discovery of Portland cement in 1824 (year of patent), concrete has become the most commonly used structural material in modern civilizations. The quality of the concrete structure is of course dependent on the quality of each constituent used in the concrete mix. However, this is not the only controlling factor. The quality also depends very much on the rheological properties of the fresh concrete during placement into the formwork [1]. That is, the concrete must be able to properly flow into all corners of the mold or formwork to fill it completely, with or without external consolidation (depending on workability class). This is a process that might be hampered by the presence of awkward sections or congested reinforcement [1]. Tragic events may sometimes be traced back to concrete of unsuitable consistency resulting in, for example, coldjoint and honeycombing. Therefore, one of the primary criteria for a good concrete structure is that the fresh concrete has satisfactory rheological properties during casting.

Older terms like workability, consistency, flowability, mobility and pumpability have been used to describe the rheological behavior of the fresh concrete. It is well-known that these terms rather reflect personal beliefs than scientific precision [1,2]. For example, an interesting discussion about the subjectiveness of the term "workability" is given in a textbook by Tattersall and Banfill [1]. Other similar terms are also discussed there. The primary problem is that there is no guarantee that such terminology means the same thing to different people. In fact, there has been a disagreement between different workers about the exact meaning of the term "workability" [3].

1.2. Empirical test methods

During the course of time, empirical test methods of different types and quality have been developed and used to give some kind of rheological description (or indication) of the fresh concrete. The most famous, oldest and currently most used empirical test is the so-called slump test. It gives only a single value, namely the slump value *S*. The test was developed in the USA about one century ago, or around 1910 [4]. The test apparatus is generally associated with Abrams [4,5] and it is believed that its use was first reported by Chapman [6]. After this, other different empirical rheological tests have been developed like the flow/spread table test, which was developed in Germany in 1933 by Graf [7]. Other empirical test methods, like the L-box and the V-funnel (which are intended for highly flowable concrete), have followed since then.

In Refs. [1,8,9] it is stated that the empirical tests are very often operator-sensitive, in the sense that minor variations in the execution of the test, gives a different result. The same literature discusses the need for describing the rheological properties of fresh concrete in terms of fundamental physical quantities, not depending on the details of the apparatus with which they are measured. For this purpose a different class of test apparatus named *viscometers* has been developed in the community of concrete science.

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