Mæling á stöðugleika sjálfútleggjandi steinsteypu með Rheometer-4SCC

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Abstract: Self-compacting concrete (SCC), also named self-consolidating concrete, has been defined as a concrete that is able to flow and compact under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction. SCC differs from conventional vibrated concrete in that its fresh properties are critical to its ability to be placed satisfactorily. Three key aspects of workability need to be controlled carefully to enable satisfactorily performance of the SCC during its fresh state, namely filling ability, passing ability, and resistance to segregation. The theme of the current work is resistance to segregation. More precisely, the use of the ConTec Rheometer-4SCC to determine the stability of SCC. In this device, the resistance to segregation is measured in terms of a so called RSI value (or Rheological Segregation Index).

1. Introduction

The theme of this work is the determination of stability for SCC (or more precisely its *resistance to segregation*) and the use of the **ConTec Rheometer-4SCC** for that purpose. This rheometer is shown in Figure 1 and as will be clear later, the stability of the SCC is given in terms of a RSI value (or Rheological Segregation Index).

Figure 1: The ConTec Rheometer-4SCC device.

The ConTec Rheometer-4SCC is a portable rheometer for SCC. It is capable of determining the yield stress τ_0 and plastic viscosity μ of concrete mixtures with yield stresses ranging from 5 to 120 Pa, plastic viscosities ranging from 5 to 120 Pa·s, and maximum aggregate sizes of up to 22 mm. The Rheometer-4SCC consists of control box and measurement units that are connected when rheological tests are performed. The control box and measurement unit are each less than 25 kg, which makes the device suitable for quality control measurements at both building sites and in laboratories. To perform the test, concrete is placed in the sample bucket and the impeller (shown in the right illustration of Figure 2) is inserted. In this illustration, two different impeller systems are shown. The larger impeller (the most right one) is the standard unit and is used in measuring the rheological properties of SCC as a whole. The smaller impeller (slightly to the left) is used to measure the RSI value (i.e. the stability of the SCC). The former mentioned impeller is not used in this work.

Figure 2: To the left is the ConTec Rheometer-4SCC. To the right are the two impeller systems. The larger impeller (the most right one) is the standard unit, while the smaller (on the left) is used to measure the RSI value.

2. Measuring procedure

The measuring procedure now explained only applies for stability measurements (i.e. resistance to segregation). That is, a different measuring procedure is used when measuring the rheological properties of SCC as a whole. As the latter concept is not a subject in the current work, it will not be explained here.

The ConTec Rheometer-4SCC measures torque $T = T(t)$ at different rotational frequency $f = f(t)$. It is the rotating impeller system that registers the torque (the smaller impeller in the right illustration of Figure 2). During a single test, the impeller starts to rotate at constant speed f = 1.00 rps for the duration of 60 seconds. Thereafter, the rotation is decreased in steps down to 0.40, 0.33, 0.27, 0.20, 0.13 and 0.07 rps. The duration of each such step is 5 seconds. This means that a single test has the duration of 60 + 30 = 90 seconds.

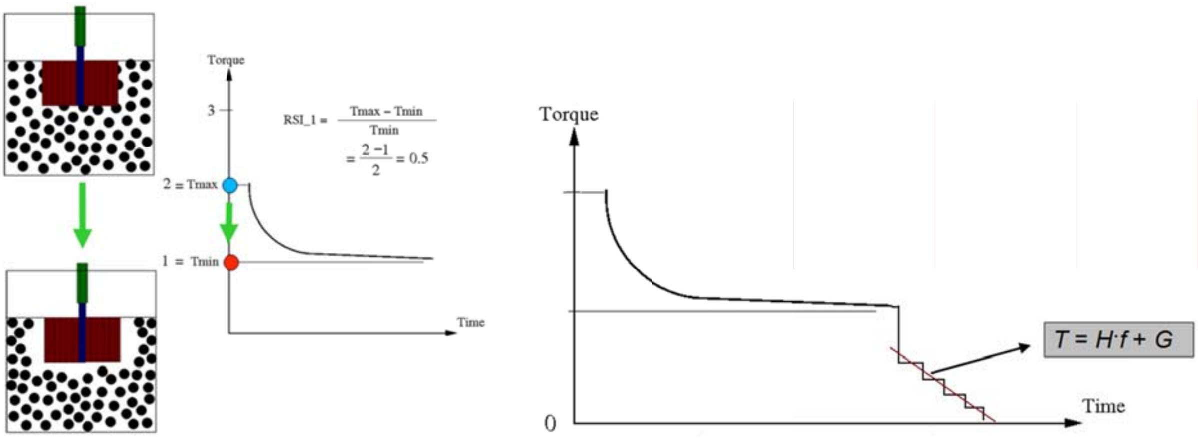

Figure 3: To the left: The proposed mechanism of how the “segregation”-impeller system of Figure 2 works. To the right: In the end of measurement, the *G* and *H* value of the segregated mass is measured.

As soon as the rotation of the impeller f starts at time t = 0 sec, the torque T is registered as a function of time t. In the beginning, when the concrete is in homogeneous state, largest torque value is usually registered. Thereafter, the torque is quickly reduced because of the dynamic segregation process that starts. That is, the torque reduces as a result of reduced quantity of coarse aggregates around the impeller system. This is shown on the left side of Figure 3.

In Figure 3, the term T_max designates the initial torque value at time t = 0 sec. The term T_min designates the torque value at the time t = 60 sec and corresponds to the rheological properties of the segregated mass that remains within the impeller systems. The idea was that the decrease in measured torque would depend on the stability of the SCC (e.g. a very stable SCC would give T_max = T_min). After this process, the rotation is reduced in steps, in which the G and H value are measured of the segregated mass. This is shown in the right illustration of Figure 3.

3. The Rheological Segregation Index – RSI

The range of values that the Rheological Segregation Index (RSI) can hold is shown with Eq. (1). That is, it is defined as such that its value goes from 0 (which means a very stable SCC, or zero segregation), up to 1 (a extremely unstable SCC, or full and complete segregation):

$$RSI \in [0,1] \qquad (1)$$

One should be clear that the value RSI = 1 means a complete segregation, well beyond the minimum accepted criteria for stability. As shown later, it is in fact the RSI = 0.5 which defines the minimum criteria for stability. That is, RSI values from 0 to 0.5 are acceptable, while values from 0.5 to 1 are not. The value at and close to 0.5 are on the threshold of acceptable SCC. The reason for this range (i.e. from 0 to 1), was to have two well defined endpoints that would make judgment of stability and thereafter analysis of results much easier.

3.1 An example of RSI function

In correlation with Eq. (1), it was preferable that the RSI function holds a normalized property. An example of such RSI function is given by the following

$$RSI = (T\_max – T\_min)/T\_max \qquad (2)$$

The above function was in fact the first prototype function for RSI (see the left illustration of Figure 3 for T_max and T_min). Its property is as follows: When RSI = 0, then T_max = T_min. This state was meant to correspond to the largest stability, since the torque was constant as a function of time t. That is, the idea was that because of large stability, the impeller system would not be able to push the coarse aggregates away, which would then correspond to a constant torque value during the first 60 seconds of the measurement. On the other hand, then RSI = 1 would mean T_min = 0. In this case, it would be assumed that the instability of the SCC is such that the impeller system easily manage to push both the coarse aggregates and the sand particles away, and the only thing remaining within the impeller and its surroundings is a very low viscous fluid (i.e. low viscous cement pastes with aggregates fines).

Acknowledgements
Many sponsors and cooperative partners have been involved in this project, among others: NORCEM, RANNÍS, The Housing Financing Fund (HFF), The Icelandic Road Administration and SINTEF.