INFLUENCE OF DEMOULDING OIL ON THE RHEOLOGICAL PROPERTIES OF FRESH SCC

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INTRODUCTION

In concrete research centers, the determination of the rheological properties of concrete is becoming a daily business, easy to perform when the proper apparatus (and staff) are available. On the building site, rheometers are still absent, although some portable rheometers have been developed (1)(2). Instead, the slump (flow) test is the only one performed to characterize the “workability” of the concrete. On the other hand, the rheological properties are very important on site, especially in case of self compacting concrete (SCC), in order to know whether the concrete can provide proper filling of the formwork, which pumping pressures will be needed (3), how long the concrete can wait before placement (4), …

The difference between laboratories and building sites is not only noticeable by the test equipment, there is also another mentality and way of thinking. In a laboratory, the scientist tries to eliminate every disturbing factor as much as possible. On site, workmen prefer to work more easily, and if necessary, they apply some “tools” to ease their jobs, sometimes not being aware of the negative consequences.

Specifically in the domain of rheological characterization of concrete and its application, there is a large difference between lab and building site. In the lab, thorough cleaning of the testing material is obtained by washing with water, but on site, as the water availability is restricted, releasing agents are applied so that the concrete does not stick to the equipment. Although these releasing agents are applied daily, very few scientific reports have been made on their influence on the rheological properties.

This paper describes the influence of one type of demoulding oil on the rheological properties of SCC. No research has been performed on the causes of the differences between SCC with or without oil, so the only purpose of this paper is to show the resulting differences. Secondly, the results have been obtained in steady state, thixotropy and loss of workability have not been investigated explicitly.
MATERIALS AND METHODS

Concrete Mixes
In total, 9 concrete batches have been produced, of which the composition of 4 of them is shown in table 1. Remark that the composition of SCC 1, 2 and 3 is equal, apart from the amount of superplasticizer (SP) applied. SCC 6 is, due to the application of SP 2 and the high content of cement and filler, a largely shear thickening SCC (5). Both SP used (SP 1 and SP 2) are polycarboxylether-based, but SP 1 has a longer workability retention than SP 2. As a result, concrete with SP 1 is able to maintain the workability during minimally 1 hour, while SCC with SP 2 loses workability already after 30 minutes (6).

<table>
<thead>
<tr>
<th></th>
<th>SCC 1</th>
<th>SCC 2</th>
<th>SCC 3</th>
<th>SCC 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>sand 0/4 (kg/m³)</td>
<td>853</td>
<td>853</td>
<td>853</td>
<td>805</td>
</tr>
<tr>
<td>gravel 2/8 (kg/m³)</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>248</td>
</tr>
<tr>
<td>gravel 8/16 (kg/m³)</td>
<td>434</td>
<td>434</td>
<td>434</td>
<td>410</td>
</tr>
<tr>
<td>CEM I 52.5 N (kg/m³)</td>
<td>360</td>
<td>360</td>
<td>360</td>
<td>400</td>
</tr>
<tr>
<td>Limestone filler (kg/m³)</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>300</td>
</tr>
<tr>
<td>water (kg/m³)</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
</tr>
<tr>
<td>SP 1 (l/m³)</td>
<td>26.36</td>
<td>25.45</td>
<td>25.45</td>
<td></td>
</tr>
<tr>
<td>SP 2 (l/m³)</td>
<td></td>
<td></td>
<td></td>
<td>5.82</td>
</tr>
<tr>
<td>Oil added part 1 (ml/19l concrete)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oil added part 2 (ml/19l concrete)</td>
<td>50</td>
<td>20</td>
<td>300</td>
<td>50</td>
</tr>
<tr>
<td>Slump flow (without oil) (mm)</td>
<td>705</td>
<td>715</td>
<td>655</td>
<td>765</td>
</tr>
</tbody>
</table>

Table 1: Composition of concrete mixes.

Testing procedure
The mixing of the SCC occurred in a forced pan mixer, in batches of 55 l. First, all dry components were mixed for 15 seconds. After water addition, mixing continued for 2 minutes followed by the addition of the SP. Once all SP has been added, the SCC was mixed for 3 more minutes. After mixing, first of all, the slump flow has been measured in order to have an idea of the workability of the concrete, which can be seen in table 1. After the slump flow tests, 4 buckets have been filled consecutively with 9.5 l of concrete each. Buckets 1 and 4 contained the concrete without oil, buckets 2 and 3 are placed back inside the mixer. In this way, an attempt has been made to eliminate variations in composition of both samples of concrete. The remains of the batch have been removed in order to empty the mixer.

The following tests have been performed on both parts of the concrete: a rheometer test, with the Tattersall Mk-II rheometer (7), a V-funnel test, and in case of SCC 3 also a sieve stability test. During the rheological characterization of the first part, the second part of the SCC was placed in the mixer and mixed for 2 minutes with the amount of demoulding oil, mentioned in table 1. In this way, the testing of part 2 was 5 minutes later than the testing of part 1. As a result, as SP 1 is capable of maintaining workability a long time, the influence of the loss of workability is eliminated. Only in case of SCC 6, made with SP 2, it is not sure whether loss of workability has influenced the results. On the other hand, the main parameter tested with SCC 6 was shear thickening, and shear thickening does not show a large variation in time (6).

The measurements in the Tattersall Mk-II rheometer have been performed by stepwise decreasing the rotational velocity after a period of pre-shearing at the highest rotational velocity. The test continues until the material reaches a constant shear thickening behavior.
velocity in order to eliminate thixotropy (8). The only difference of thixotropical level could be caused by the different times between mixing and testing. For part 1 of the concrete, the time between the end of mixing and the beginning of the rheometer test has been 10 minutes, for the second part only 3 minutes. This can influence the results (4)(8), and it will be stated further in the paper when thixotropy is thought to have an influence.

Demoulding oil
The demoulding oil which has been used is a standard available oil, produced with highly refined paraffin mineral oils, having a dynamic viscosity of 3.45 mPa s and a density = 822 kg/m³.

RESULTS AND DISCUSSION

Rheological properties
Figure 1 shows the influence of the addition of oil on the rheological properties of SCC 1 and SCC 3. For SCC 1, a rather small amount of oil has been added (50 ml, 0.26 vol %), but for SCC 3, a large amount of oil has been added (300 ml, 1.58 vol %). This large amount of oil causes an increase in both the yield stress and the plastic viscosity, and makes the shear thickening disappear. On the contrary, shear thinning seems to appear, but this can be due to the difference in thixotropy at the start of the test: SCC 3 with 300 ml of oil did not show any stress overshoot during the pre-shearing period. For SCC 1, the same conclusions are valid, but the increase in yield stress and viscosity are lower, and the amount of shear thickening decreases, but does not disappear.

![Figure 1: An addition of oil (50 ml/0.26 vol % for SCC 1, black – 300 ml/1.58 vol % for SCC 3, grey) causes an increase in yield stress and plastic viscosity and a decrease in shear thickening. The larger the amount of oil, the larger its influence.](image-url)
From the black lines in figure 2 (SCC 2), it can be seen that a low amount of oil (20 ml, 0.11 vol %) does not increase yield stress and viscosity but it causes shear thickening to decrease. This result is not affected by thixotropy, because the SCC 2 with oil showed a decrease in shear stress during pre-shearing.

The results of SCC 6, shown as the grey curves in figure 2, confirm the results obtained with SCC 1, 2 and 3. Although the increase in yield stress and plastic viscosity due to the oil addition is very difficult to distinguish from the loss of workability, due to the application of SP 2, the decrease in shear thickening is striking. And as shear thickening is not really affected by the loss of workability, and as also in this case, thixotropy did not influence the results, the decrease in shear thickening is due to the addition of oil only. An amount of 0.26 volumetric percent of oil in concrete is sufficient to make shear thickening (almost) disappear.

**Stability of the SCC**
For SCC 3, sieve stability tests have been performed on the SCC with and without oil. The results indicate that oil has a kind of stabilizing effect, which is confirmed by the increase in yield stress and viscosity.
**V-funnel flow time**

The oil additions to SCC 1 and 3 did not cause any significant change in V-funnel flow times: for SCC 1, the difference was 0.01s (6.55s – 6.54s), for SCC 3, there was a decrease of 0.67s (7.83s – 7.16s). For SCC 2 and 6, a decrease in V-funnel flow time has been observed in case the oil has been added. The decrease was small in case of SCC 2 (7.63s – 6.20s), but it was quite large for SCC 6 (15.64s – 11.33s). These results indicate that the increase in viscosity is compensated by the decrease in shear thickening.

**CONCLUSIONS**

In this paper, the influence of different amounts of demoulding oil on the rheological properties of fresh self compacting concrete have been investigated. Addition of oil to the SCC causes the yield stress and plastic viscosity to increase, although these effects are not significantly visible for very small oil additions (0.1 vol %). Shear thickening decreases significantly on the other hand, in spite of the amount of oil added, or the original amount of shear thickening of the SCC. Oil additions do not seem to provoke an extra danger for segregation, within the limits tested in this project.

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**REFERENCES**