A MODIFIED PYCNOMETER METHOD TO DETERMINE THE WATER ABSORPTION OF COMBINED CRUSHED CONCRETE AGGREGATE FRACTIONS

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Abstract

Crushed Concrete Aggregates (CCA) as fine and coarse aggregates in new concrete helps achieve closed-loop recycling. Assessment of workability, mechanical properties and durability of concrete demands knowledge of the water absorbed by the CCA. The EN 1097-6 standard method is difficult to execute due to the presence of entrapped air and CCA sedimentation while performing water absorption experiment for fine CCA. Additionally, the assessment of Saturated Surface Dry (SSD) state seems operator specific and non-reproducible; moreover, giving water absorption measurement only at 24 hours. However, findings from this paper show measurements at 15 minutes is influential for concrete workability.

The modified pycnometer method analyses the water absorption of a combined fraction consisting of coarse and fine CCA as proportioned in a given concrete recipe. Furthermore, sedimentation and entrapped air are prevented by pre-soaking the CCA in a solution of distilled water and poly-carboxylate based superplasticizer before commencing the experiment. Ultimately, the combined fraction is drained to SSD condition by vacuum filtration, which is easy to handle by professional operators. In this way, the water absorption development is measured from starting point to 24 hours for the combined fraction to determine the appropriate water amount to saturate CCA during concrete mixing.

Keywords: crushed concrete aggregate, water absorption, pycnometer, SSD, sustainability

1. INTRODUCTION

Crushed Concrete Aggregates (CCA) as fine and coarse aggregates in new structural concrete helps achieve closed-loop recycling. Satisfying the workability requirements of new structural concrete containing CCA demands knowledge of water absorption of the included CCA. Moreover, the cement mortar adhered at the CCA surface causes it to be more porous
than other aggregates [1, 2]; it is even more necessary to determine the water absorbed by the CCA to optimize mixing water added to the concrete.

Practical issues such as sedimentation and air entrapment are encountered when the water absorption of fine CCA is tested using the EN 1097-6 standard pycnometer method. The sedimentation of CCA is also problematic because of the difficulty in removing the CCA specimen from the pycnometer for saturated surface dry state assessment. Also observed, is the fine CCA do not meet the assessment requirements prescribed by the European standard for Saturated Surface Dry (SSD) condition, performed by the sand absorption cone. Earlier research attributed the issues with sedimentation and SSD assessment to the angular shape and presence of excessive fines in the crushed aggregates [3, 4].

2. MATERIALS

To determine the water absorption as it would happen during the concrete mixing, the modified pycnometer method tests a combined fraction CCA consisting of coarse and fine CCA fractions in the same proportions as they occur in the concrete recipe. Combined aggregate fractions are used as specimens for water absorption and particle density investigations in transportation and infrastructure research [5, 6].

This study investigates three CCA fractions namely 0/4 mm, 0.5/4 mm and 8/11.2 mm, which appear in the concrete recipes in the ratio 20, 35 and 45% respectively. The fine CCA fractions 0/4 mm and 0.5/4 mm are used together to satisfy the fines content of the concrete recipe. The combined grading curve for the aggregate fractions are shown in figure 1.

![Figure 1: Combined grading curve of the fine and coarse CCA fractions](image)

The CCA fractions are acquired from prefabricated concrete rejects and are crushed to size by a jaw crusher. The combined fractions as suitable test specimen instead of individual aggregate fractions is verified by comparing the apparent densities of the individual CCA fractions and the combined fraction CCA seen in table 1. The apparent density of the combined fraction lies within the interval of the apparent densities of the 0/4 mm fine fraction and 8/11.2 mm coarse fraction. Thus, the combined fraction is used instead of individual fractions for water absorption investigations.
Table 1: Comparison of the apparent densities of individual and combined CCA fractions

<table>
<thead>
<tr>
<th>CCA Fraction (mm)</th>
<th>Apparent density ( \rho_a (\text{g/cm}^3) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/4</td>
<td>2.94</td>
</tr>
<tr>
<td>0.5/4</td>
<td>2.72</td>
</tr>
<tr>
<td>8/11.2</td>
<td>2.66</td>
</tr>
<tr>
<td>Combined fraction - 0/4, 0.5/4 and 8/11.2 in the ratio 20%, 35%, 45%</td>
<td>2.81</td>
</tr>
</tbody>
</table>

3. METHOD

The modified pycnometer is different from the standard pycnometer methods [7, 8] since it consists of a pre-processing step where the CCA is pre-soaked in a superplasticizer solution which acts like a particle dispersant and prevents sedimentation. The water absorption test is carried out in the same superplasticizer solution instead of distilled water as in the case of the standard method. Finally, the SSD state assessment is performed using a physical device such as the vacuum filtration set up to drain the excess water from the wet aggregates. This is done instead of the oven drying or wiping which are the standard techniques. The flow chart of the modified pycnometer method is shown in figure 2.

![Flowchart of the modified pycnometer method](image)

3.1 Pre-processing the combined fraction CCA

The combined CCA fraction weighing 200g is pre-soaked momentarily in a solution of polycarboxylate-based superplasticizer and distilled water in the concentration 6.35g/l; solution is poured to cover the surface of the aggregates. To drain away the excess solution, the pre-soaked CCA is oven-dried at 110±5°C before it is introduced in the pycnometer containing the same superplasticizer solution. Oven drying the crushed concrete aggregates can be compared to boiling technique performed by Schouenborg et al. [9] where CCA were soaked in boiling water before water absorption test to remove the air obstructing the absorption of water in the CCA pores.

3.2 Water absorption of combined fraction CCA

The pre-processed CCA is poured into a pycnometer containing the superplasticizer solution to measure the water absorption development from starting point to 24 hours. The SSD assessment is performed at three time intervals namely starting point, 15 minutes and 24 hours to receive the water absorption values at the specific duration.

3.3 SSD assessment by vacuum filtration technique

The vacuum filtration technique uses vacuum to drain out the excess water from the wet CCA until they have reached the SSD state. The contents of the pycnometer are directly poured into a Büchner Funnel containing a qualitative filter paper made of cellulose that can retain particles of size less than 10µm. The water from the funnel drains into a flask by vacuum, created by an adjoining tap with flowing water, connected to the flask by a hose.
arrangement as shown in figure 3. An additional moist filter paper is placed on top of the CCA to prevent any possible evaporation. The contents of the funnel are stirred once every two minutes to ensure uniform draining.

Figure 3: SSD assessment by vacuum filtration technique

This technique uses an ocular assessment just as the standard pycnometer method [8] in the case of coarse aggregates which after wiping are considered as SSD when they lose the shiny and wet appearance. In this new technique, during the filtration it is observed that the coarser particles drain faster than the finer ones meaning that the coarse are in SSD state before the fines. Therefore, for the combined fraction to reach SSD state, the majority fraction being the 8/11.2 mm should be in SSD. However, from experiments it is observed that when the coarse appear SSD, the finer fractions are still wet. The fines seem to appear surface dry when the coarse just begin to change colour and appear light grey as shown in figure 4.

Figure 4: SSD assessment by vacuum filtration technique

The effectiveness of the vacuum filtration technique is verified on coarse CCA namely the 8/11.2 mm fraction. The water absorption results performed by the standard pycnometer method [8] followed by the SSD assessments by the standard method and vacuum filtration are compared. The water absorption values shown in figure 5 reveal that both the techniques yield almost similar results for starting point and 15 minutes water absorption. However, there
is a slight difference in the results at 24 hours, which could be due to variations in the composition of the CCA samples investigated.

![Figure 5: Water absorption of coarse CCA- comparison of the standard [8] and vacuum filtration SSD assessments techniques](image)

**4. RESULTS**

The water absorption by the modified pycnometer method has been performed at three different time durations to receive a development as shown in figure 6. It is observed that the water absorption at starting point is at least 90% of the water absorption at 24 hours. The water absorption is almost constant after the first 15 minutes until 24 hours, showing that almost all the water absorption happens within the first 15 minutes.

![Figure 6: Water absorption of combined CCA using modified pycnometer method](image)
The water absorption development is used to determine the amount of water required to pre-soak the crushed concrete aggregates before concrete mixing. Since the CCA are in air-dry condition when they are mixed in the concrete, a water absorption development for such air-dry aggregates is required. The combined fraction CCA is left to air-dry (approx. 72 hours) after pre-processing and the water absorption is determined by the modified pycnometer method. The results in figure 6 show that the water absorption of air-dry CCA is less than the oven-dried CCA over the entire duration. The air-dry CCA at 24 hours is at the same level as the oven dry water absorption value at the starting point. This could mean that air-dry CCA is not reaching the maximum water absorption in 24 hours - a fact, which already reported in earlier research [9, 10]. Alternatively, oven drying the CCA before water absorption can reduce the water absorption duration to receive maximum water absorption in comparatively lesser time.

5. CONCLUSIONS
- The modified pycnometer method with the vacuum filtration technique for SSD assessment is a robust method and can be used for testing in the field.
- The initial condition of the oven drying the CCA is so strict that the development of water absorption with time is considerably even. Whereby, the water absorption at starting point of the oven-dried combined fraction CCA can be assessed as 80% of the 24-hour value and used in practical applications.

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