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New method for testing the sedimentation stability of modern concretes at construction sites

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Abstract. Modern concretes are characterised not only by rising demands on properties but also by increasingly complex compositions. With sophisticated formworks and dense reinforcements, the trend in concrete technology continues towards to self-compacting and easily-compacting concretes. The use of highly effective superplasticizers makes these concretes not only more efficient but also more susceptible to environmental factors and influences. Compliance with desirable fresh and hardened concrete properties is becoming increasingly problematic. In this case, there are no methods for testing today's concretes, especially the easily-compacting and self-compacting concretes, which are suitable for construction sites. Because of their sensitivity, however, these should be examined separately for their tendency to segregation and, in this context, for their sedimentation stability. For this reason, a test method is currently being developed at the Institute of Construction Materials at the University of Stuttgart, which is intended to examine concretes in particular for this problem. First preliminary test in a simplified procedure have already confirmed the basic idea of testing.

1. Introduction

The development of self-compacting concretes has increased in recent years in accordance with the trend in concrete technology. Many advantages, such as independent venting and levelling as well as cavity-filling behaviour, have proven themselves particularly useful in the case of extremely complex formwork and delicate structural elements. This eliminates the need for time-consuming and usually very extensive/time-intensive vibration on the construction site [1]. Easily-compacting concretes and SCC (self-compacting concrete) are only problematic if a sedimentation test suitable for construction sites has to be carried out. For the standardised test, an approx. 30-minute procedure according to DIN EN 12350-11, ensuring concrete quality is extremely time-consuming and unsuitable due to the long waiting time. In most cases, actual statements about the sedimentation stability can only be made if the sedimentation is determined concretely by the deposition of the coarse aggregate in a precise sectional view.

In contrast to SCC, easily-compacting concrete is characterised by a lower consistency class (F5 - F6) and thus corresponds with spreading dimensions of 560 - 700 mm. This concrete only needs to be mechanically compacted to a small extent. As the concretes become more flowable, the risk of segregation and the associated lower sedimentation stability increases. During sedimentation, the coarse aggregates settle at the bottom and the concrete has significantly more cement paste on the surface. Such a segregation process has a negative effect on strength, deformation and durability properties. This effect is intensified by compaction in case of easily compacting concrete and must therefore be taken into account both during concrete formulation development and when setting the correct compaction energy.

The decisive parameters that affect the sample are the duration of vibration and the centrifugal force.

While the parameters of the duration of vibrating action can be easily determined, the centrifugal force depends on the frequency of vibration, the mass to be moved and the range of vibration. On the construction site, it is usually very difficult to manipulate this effect due to the complex interrelationships within the concrete mix. If, for example, the flowability is too low, a superplasticizer is often added, mostly without adjusting the amount of water. Even small amounts have a high influence on sedimentation stability. While there are various test methods according to DIN for fresh concrete properties such as consistency and flow behaviour, there are so far only a few test methods for analysing the sedimentation stability of SCC. For this reason, the German Committee for Structural Concrete issued an SCC guideline based on the so-called three-cylinder test method. A cylindrical form is filled with fresh concrete and left to stand for a defined period of time (approx. 30 minutes) until the concrete apparently stiffens. The cylinder is then divided into three cylinder segments and the concrete mass is washed out under a sieve. The mass differences within the segments provide information about sedimentation tendencies. This experiment can only be carried out to a limited extent on construction sites due to being time-consuming and elaborate.

2. State of art

Based on this circumstance Lohaus et al. [2] has already developed a measuring method, which analyses sedimentation of normal concretes. It combines the three-cylinder test and a dielectric measuring to obtain results. The three-cylinder test is located on a vibrating table and is to examine vibrated concretes in terms of segregation. A radar-based moisture measurement system is used to detect the moisture differences between the individual segments. The water content differences within the three segments are interpreted as a consequence of possible sedimentation of the coarse aggregate. The behaviour of coarse aggregate to measured water content profile is described by reciprocal proportionality (figure 1) [2]. Not only vibrated concretes but also easily compacting concretes could be investigated. With the electronic procedure, the measurement is substantially faster than washing out partial areas according to the German Committee for Structural Concrete.

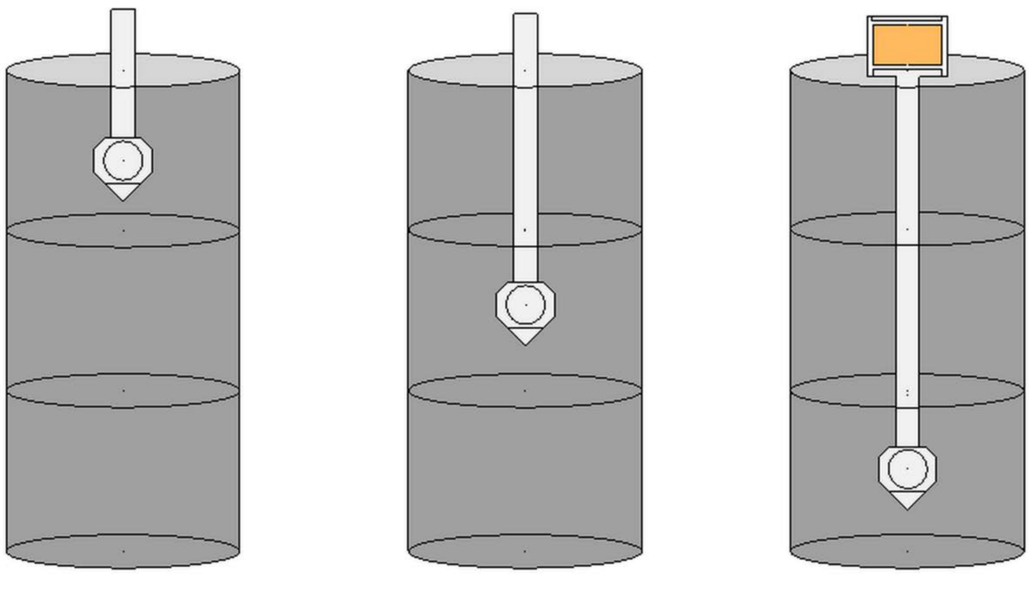

Figure 1. Radar sensor combined with the self-compacting concrete guideline.

The correlation of the radar-based measurement results with the wash-out test has already been shown, but the measurement results still fluctuate considerably. The position of the hand-held probe in the sample must be changed because the existing measuring instruments only have a single measuring window. This, however, disturbs the sample again after resting, which can influence the measurement result. In addition, only a single measurement is possible in each of the three segments. The determination of a temporal development of the sedimentation is not possible. In fact, the radar method used in concrete has only a relatively small range, so that only a small part of the sample can be examined. Hence, it is not possible to determine a value over a larger volume. Consequently, to date there is no feasible measuring system for the rapid characterisation of mixture stability on the construction site.

3. Test method

For this reason, a test method is currently being developed at the Institute of Construction Materials of the University of Stuttgart that will allow the description of the sedimentation process in individual segments by a dielectric measurement method in combination with an independent and coherent method. The sedimentation-measuring device is going to be a wireless test prototype, which will be ideally used on construction sites. The control and the evaluation software are to be transmitted wirelessly. Inside the sedimentation cylinder a stirring unit as well as a transportable electronic independent frequency and amplitude adjustable vibrating table will be placed.

3.1. Procedure of the test method and the technical structure

Based on the three-cylinder test, which is described in the SCC guideline [3], the testing should be considerably faster and also more user-friendly in contrast to known procedures. With the help of this method, not only SCC but also easily compactible concretes are to be tested for their sedimentation tendency. As in the SCC guideline, the fresh concrete, which should be tested, is filled into a cylindrical mould (figure 2).

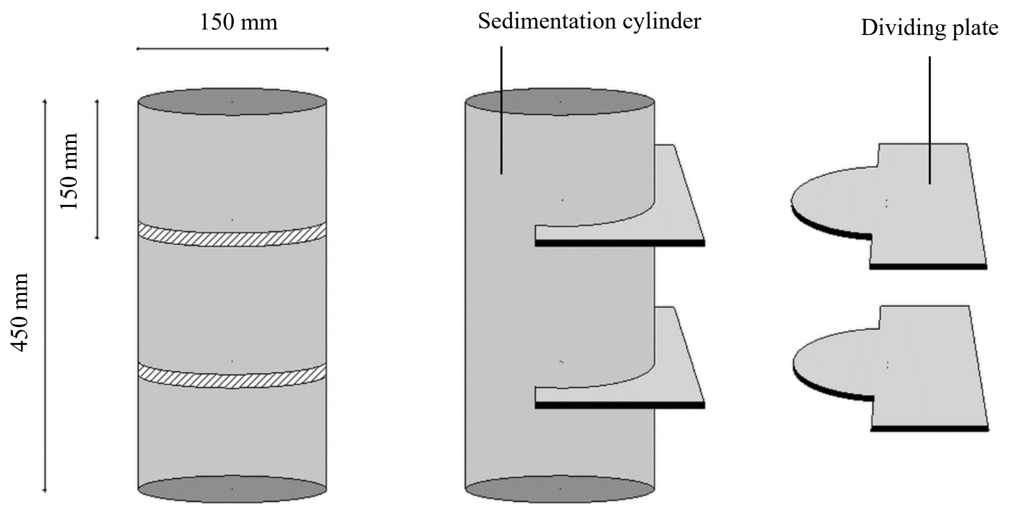

Figure 2. Three-cylinder test according to the SCC guideline, while using a cylinder that can be separated in three section in combination with the wash- out test in DIN EN 12350-11.

The washing out of the three sectors is replaced by a sensor array in the middle of the cylinder (figure 2). The sensor array will be used to record the sedimentation behaviour electronically. The sensor array is to consist of a stainless steel rod, which has to integrate three sensors along its entire length. The sensors will work with electromagnetic waves, which means they operate according to the microwave method. The dielectric method should detect the amount of water/flour grain that is too coarse in the respective measuring volume. The sensors should be centred at the height of the three cylinders sections so that differences within the areas can be measured. A comparison of sensor values should provide information about the sedimentation tendencies of fresh concrete.

The sensor array should be able to cover a larger measuring volume through a rotary movement. Thus, several measurements in the fresh concrete are possible without the sample being mixed or remixed by the introduction of a foreign body (probe). This also has the advantage that the values can be recorded almost simultaneously at three different height points (distances = as in the three-cylinder test method). It should also be possible to detect, record and describe time-dependent sedimentation. An extrapolation of the temporal development of the initial measured values and hence a meaningful characterization of the sedimentation behaviour of SCC within a few minutes should be possible.

In addition to self-compacting concretes, it should also be possible to investigate concretes that are easily compacted. For this purpose, the cylinder will be equipped with a transportable, electronically independent frequency and amplitude-controlled vibrating table. This is to be connected to the control and evaluation software, which makes it possible for vibration parameters to be included in the evaluation. It is to be expected that both the vibration frequency and the choice of the vibration amplitude have a different impact on the segregation of the fresh concrete formulations. For further investigations in the laboratory, the long-term sedimentation behaviour of SCC (after a certain rest period) will be investigated. For this purpose, a stirring unit is to be developed as an alternative to the sensor array, which is to be introduced into the sedimentation cylinder in order to stir the fresh concrete again after a resting period. Only in this way, the sedimentation behaviour can be determined at a certain time interval after the individual components have been mixed.

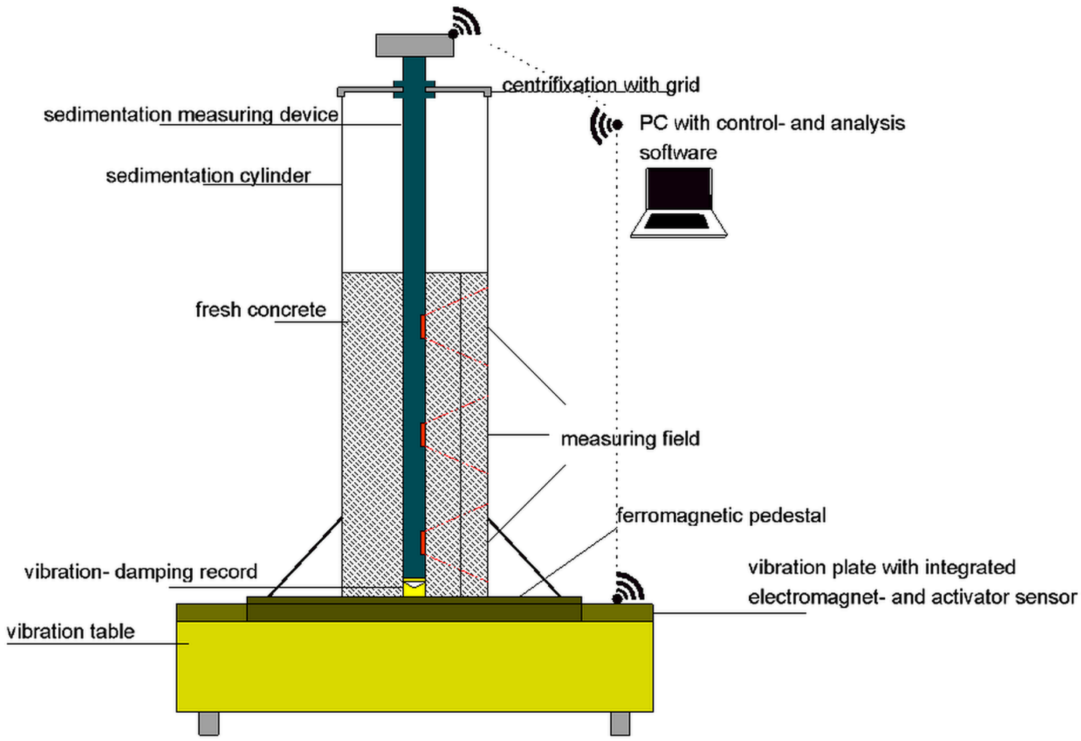

Figure 3. Technical structure of the test device.

First preliminary tests in a sample container (figure 4) have confirmed the expected results for the first time. With this measuring method, a moisture probe was attached to the side of the device. The cement paste was then placed in a container. It was first made flowable by a superplasticizer. Then the water content was measured with the side-mounted probe. The data in figure 4 shows raw values and is therefore only to be interpreted as an allegory for the functional principle.

In section 1, the water content was determined by several measurements. For section 2, a calibration ball according to Bottke was inserted into the cement paste and held directly in front of the sensor. The result is a significant decrease of water content. The sensor only measures air volume in this area and therefore a considerable change in the cement volume can be observed. Hence, the water content must have also decreased rapidly. In section 3, the calibration ball was removed and the water content reaches the same level as in section 1. In section 4, small quantities of aggregates, such as gravel and granules up to a size of 16 mm, were added to the cement paste. This process causes the measuring probe to react sensitively to changes in the cement paste volume and is reflected in the drop of the water content.

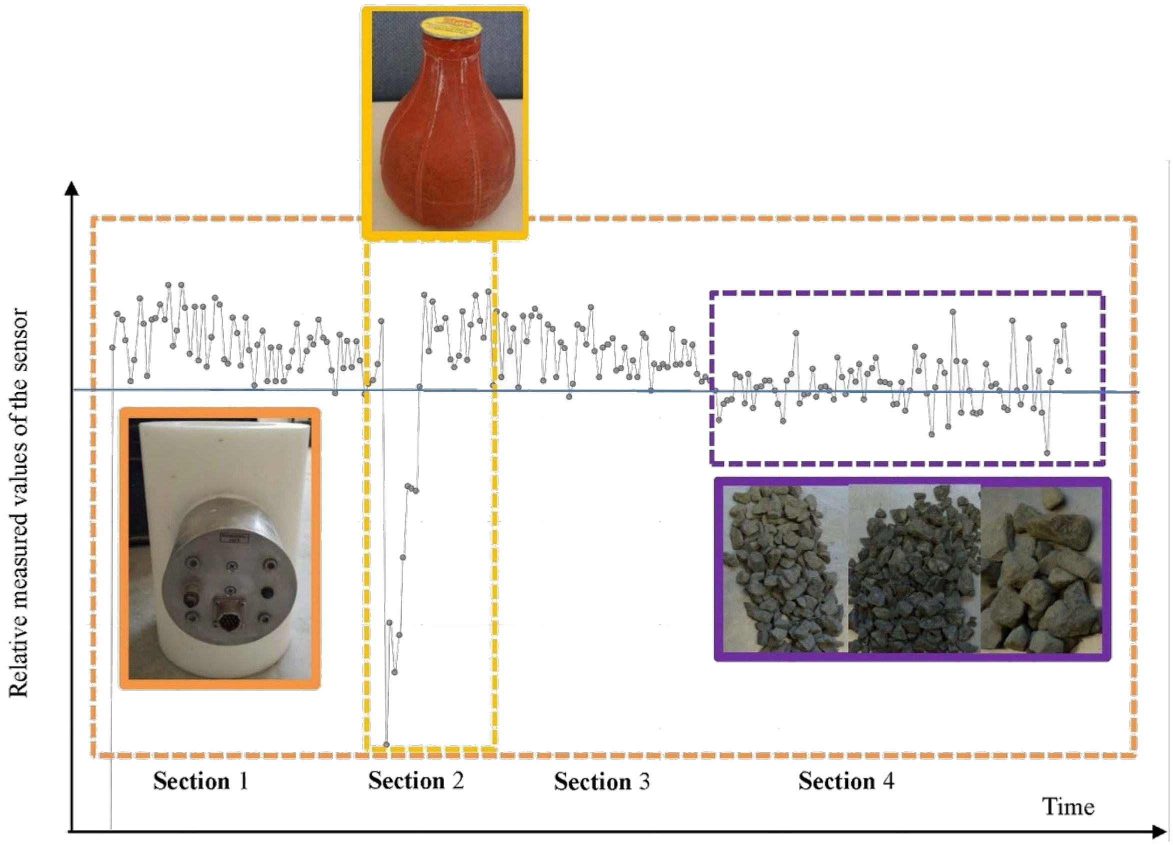

Figure 4. First results from the preliminary investigations, while using a calibration ball (in section 2) and a test container (left side) which include a humidity sensor at the edge of the container.

4. Outlook

With the new measuring method, it will be possible to examine different concrete compositions like e.g. Rhine gravel, basalt aggregates as well as crushed materials for possible sedimentation. In the future, it will be possible to detect dynamic segregation immediately after filling and static segregation during the resting phase as well as to derive possible models to describe the processes. A method suitable for the construction site can facilitate fast and comprehensive testing of the mixture stability in practice. Based on the research at the University of Stuttgart and the resulting material models from the test method, recommendations for compaction (for easily-compacting concrete) will be possible. In order to obtain a sedimentation-stable and highly flowable fresh concrete, recommendations for type and dosage of viscosity modifiers or other concrete additives or admixture (for SCC and easily

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compacting concrete) should also be given. Thus, it should be possible to safely adjust the concrete formulation on site so that the discarding of entire batches or truck mixer loads can be avoided.

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