

Early-age behaviour of cement-based self-leveling flooring compounds

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Abstract. The article deals with the cement-based flooring compounds, especially with the behaviour during the early solidification process. A touch-less laser sensor and a cone-shaped mould were used for the measurement of the plastic settlement/shrinkage. The process of solidification and the strength development were determined using the ultrasonic pulse velocity measurement. Both test devices were equipped with the thermocouple to measure the real-time internal temperature evolution during solidification of the flooring compounds. The measurements presented in this paper proved to be useful for the clarification of the technological problems which arose during the manufacturing of the test specimens.

1. Introduction

The self-leveling flooring compounds are usually dry ready-mixed composite materials used mainly in indoor applications for constructing new or renovating existing floors. The demands posed to today's flooring compounds are quite high, which forces the manufacturers and implementing companies to continuously develop and improve the compounds' composition and laying procedure during its implementation. The basic requirements posed to these products are usually rapid setting time, which has to be adequate for finishing the application, early strength development, good adhesion to the existing subfloor-layer, low shrinkage deformations and high resistance to abrasion [1].

One of the factors, which takes a notable role in the characteristics of the final flooring compound, is the quality and characteristics of the raw materials themselves [2]. Another factor is the composition design which consists in the appropriate combination of the raw materials to obtain the product of high quality [3]. The sustainable development of building materials emphasizes also the eco-friendly approach, which motivates to the usage of industrial by-products as a component of the final product [4].

The most frequently discussed issue of the flooring compounds is still the shrinkage and high risk of cracking after pouring/laying the fresh mixture. Consequently, the enhanced effort of the producers is still aimed at the development and testing of appropriate binders with a low potential to shrinkage [5-9]. Note that the curing conditions often do not comply with the requirements stated in the technical sheets of the flooring products, which can be the main source of cracking in the finished floors.

The authors of the paper focused on the behavior of the cement-based flooring compounds during its early solidification process, especially on the measurement of the plastic settlement/shrinkage and on the strength development expressed by the development of ultrasonic pulse velocity.

2. Experiment

Three different self-leveling cement-based flooring compounds (FC), identified as FC 1, FC 2 and FC 3, were selected for the experiment. The main motivation to perform the measurements was the



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technological problems which arose during manufacturing and demoulding process of the test specimens, which were intended for the shrinkage and strengths' parameters measurement.

One of the problem was the excessive plastic settlement of the FC 1 resulting in a decrease in the top surface of the test specimens from the edges towards the center. Subtle test specimens showed uneven cavities in the top surface (see figure 1). Another problem was the demoulding of the test specimens made of FC 3 compound. The specimens were not hardened enough at the required time for demoulding (after 24 hours) which led to the spalling of the material and to the rupture of the subtle test specimens (see figure 2). The last problem was observed in the case of FC 2 which showed high sensitivity to the changes in the ambient relative humidity which led to cracking of the test specimens.

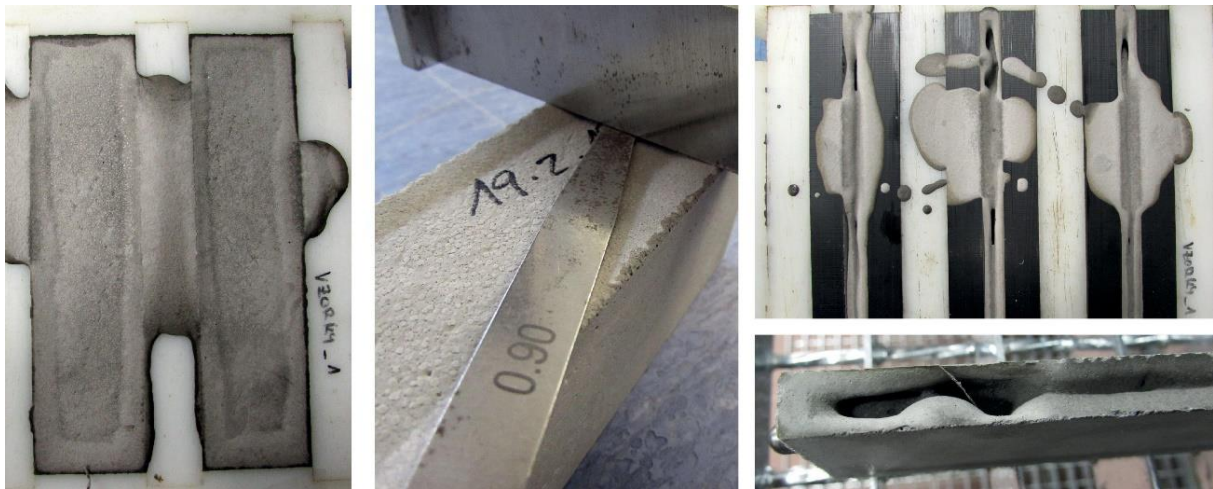


Figure 1. FC 1: Test specimen with dimensions of 40×40×160 mm (left) and 10×40×160 mm.

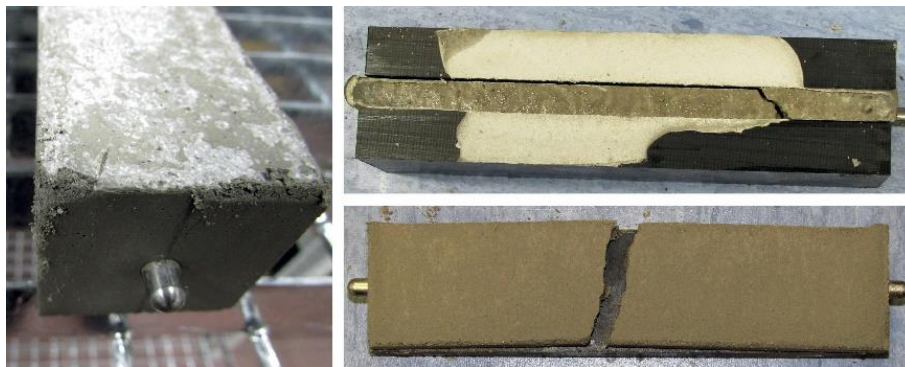


Figure 2. FC 2: Test specimen with dimensions of 40×40×160 mm (left) and 10×40×160 mm.

2.1. Materials

The composition of the tested products cannot be listed in the article because of the pilot tests of the floor compounds, which are currently under development. Generally speaking, the FC 1 is primarily intended for the thin-layer floors (approx. 10mm), while the FC 2 and FC 3 can be applied in layers up to 40 mm. All tested materials are described by the strength characteristics, shrinkage values and mass losses values determined on the prismatic test specimens with dimensions of 40×40×160 mm at the age of 3, 7 and 28 days (see figure 3 and 4) [10].

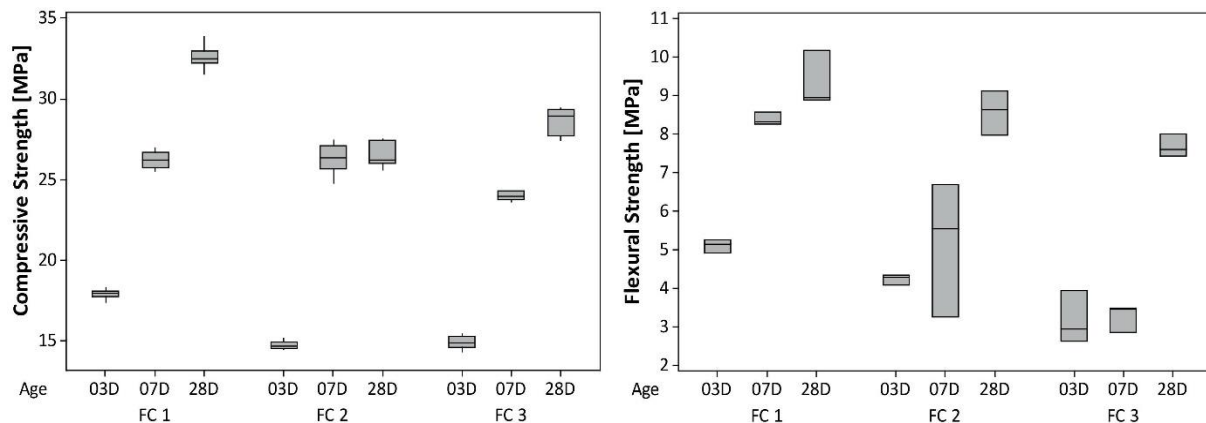


Figure 3. Compressive strength (left) and flexural strength of tested floor compounds.

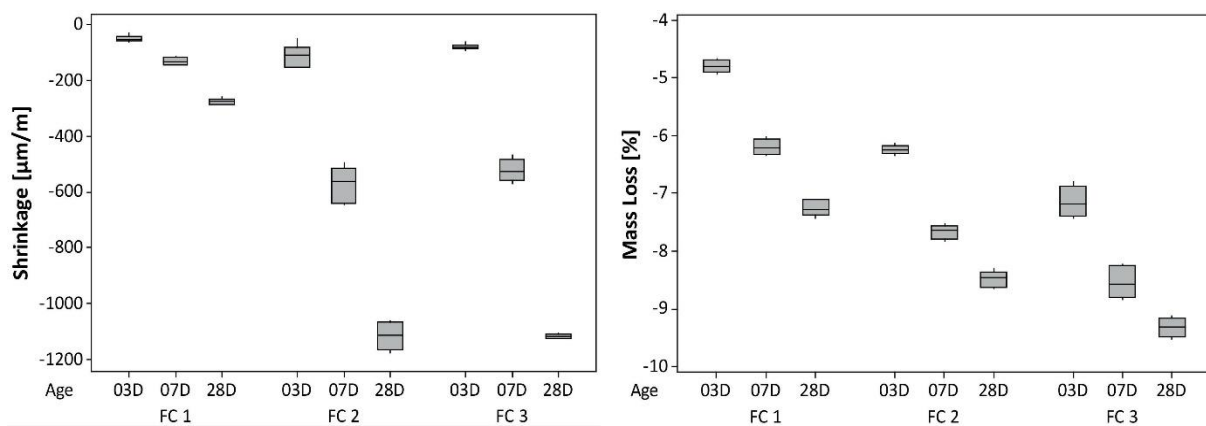


Figure 4. Shrinkage (left) and mass loss of tested floor compounds.

2.2. Test specimens and test methods

All mixtures were prepared from the dry-mixture mixed with the prescribed amount of water. The Hobart mixer was used for preparation of the fresh mixtures, whereas the mixing and manufacturing process followed the instructions stated in the technical sheet of each product. The Shrinkage-cone and Vikasonic apparatus were used for the determination of the plastic settlement and solidification process of selected flooring compounds.

The Shrinkage-cone was used especially for measurement of the plastic settlement. It is a test device equipped with a touchless laser sensor which enables to measure the changes in height (Δh) of the test specimen poured into the cone-shaped mould with height of 125 mm and volume of 682 cm³ (diameter approx. 144 mm). The evolution of the internal temperature during the maturation process was continuously measured by the embedded thermocouple. The measurement in the Shrinkage-cone started immediately after filling the mould with the fresh mixture. The data were continuously recorded into the data-logger. In the experiment, the PTFE foil was placed into the mould before its filling to avoid the friction between the mould and poured material. The upper surface of the test specimens was not protected from drying during the whole time of measurement.

The Vikasonic apparatus is an ultrasonic (US) device which consists of measuring cell equipped with two transducers and a Vicat ring, and a control unit which enables to setup the measurement and also serves as a data storage device. The measurement principle is based on the measurement of the transit time of ultrasonic wave which pass through the solidifying material from the transmitter to the receiver. Based on the measured US transit time and the distance between transducers, the US pulse velocity can be calculated. The Vikasonic apparatus is also equipped with the thermocouple to record the internal temperature evolution during the solidification process of the compounds. Both

measurement devices are shown in figure 5. During the measurement, all of test equipment were placed in a climate chamber with an ambient temperature of $(22 \pm 2) ^\circ\text{C}$ and relative humidity $\text{RH} = (50 \pm 5) \%$. More details about Shrinkage-cone and Vikasonic see in [11].

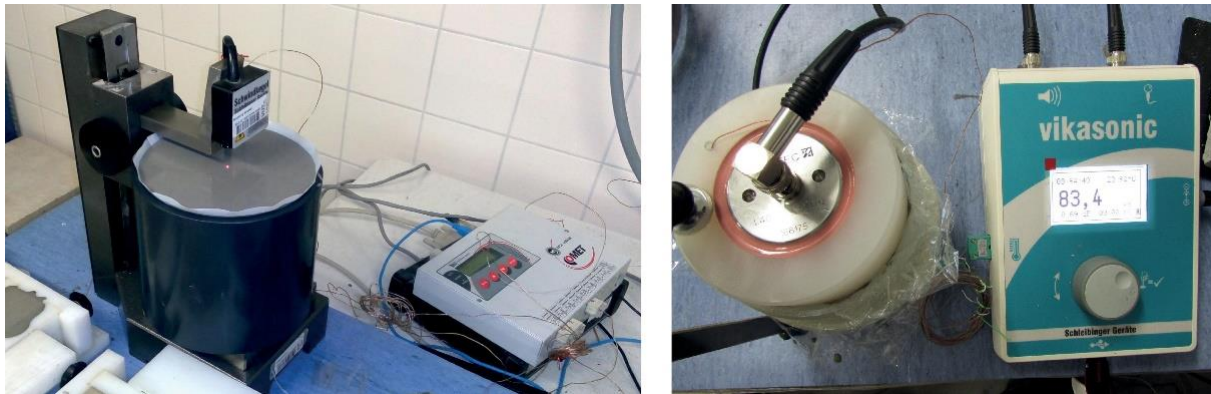


Figure 5. Shrinkage-cone (left); Vikasonic apparatus.

3. Results and discussion

The results of performed measurements are shown in figures 6 – 8. The outputs from the Shrinkage-cone are shown in the left column. The data obtained from the measurement performed by Vikasonic apparatus were processed and they are shown in the right column. The results show differences in the solidification process of particular flooring compounds.

In the case of FC 1, the initial plastic settlement is three to four times higher than in the case of FC 2 and FC 3. There is also a visible delay in the evolution of the internal temperature of the test specimen. The steep growth of the temperature occurred approx. 7 hours after the start of the measurement. In this time, the growth of plastic settlement/shrinkage had stopped and the vertical deformation stabilized (see figure 6 left). The above mentioned findings clarified the technological problems during the manufacturing of the test specimens using FC 1. It can be suggested that the process, magnitude and final impact of the plastic settlement on the quality of upper surface depends on the shape and area of this surface (see figure 1). The results obtained from the measurement of the US transit time for FC 1 correspond well to the measurements performed by Shrinkage-cone. The delay in the internal temperature evolution, which led to the delay in the setting time, was also detected. This delay is very well expressed by the progress of the US pulse velocity. The steep growth of the US pulse velocity occurred within the interval of temperature growth. Shortly after the temperature reached its peak, the US pulse velocity had stabilized (see figure 6 right). This process indicates rapid strength development.

The slight differences between the magnitude and evolution of the internal temperature recorded in the cone-shaped mould and Vicat ring-mould are supposedly caused by the different volume of test specimens and technical parameters of the moulds.

In the case of FC 2 and FC 3, two temperature peaks were detected during early solidification. The first temperature peak occurred shortly after the start of the measurement (approx. 2 hours for FC 2; 1 hour for FC 3), the second temperature peak was detected approx. 20 hours for FC 2 and 24 hours for FC 3 after the start of temperature measurement (see figures 6 and 7). The magnitude of the internal temperature of FC 2 and FC 3 mixtures was in both cases smaller than the one recorded for FC 1. Concerning the plastic settlement, the initial magnitude was the same for both FC 2 and FC 3. The subsequent process of the vertical deformation was quite different. While in the case of FC 3 the deformation stabilized shortly after the initial settlement, for FC 2 the expansion, which stabilized approximately at the time of second temperature peak, was detected.

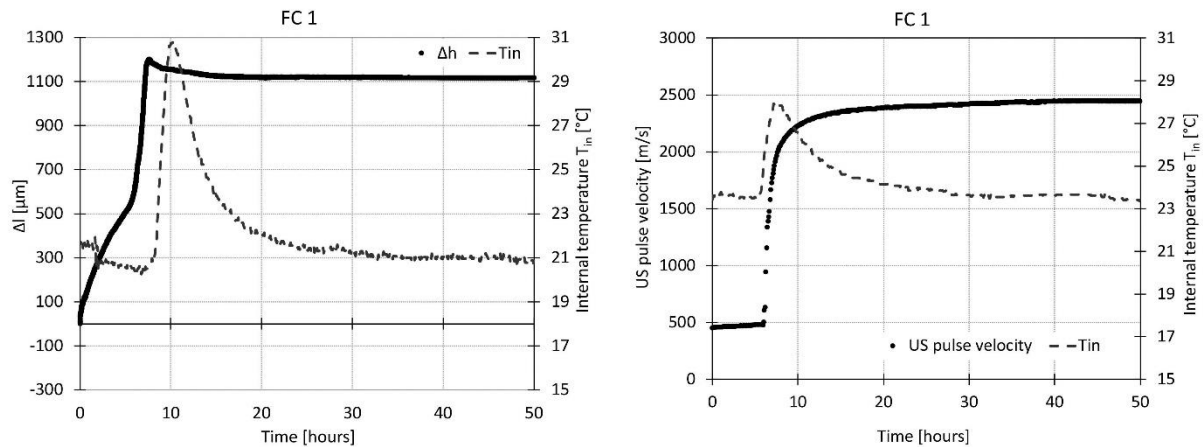


Figure 6. FC 1: Plastic settlement and internal temperature measured in Shrinkage-cone (left); US pulse velocity and internal temperature measured in Vikasonic.

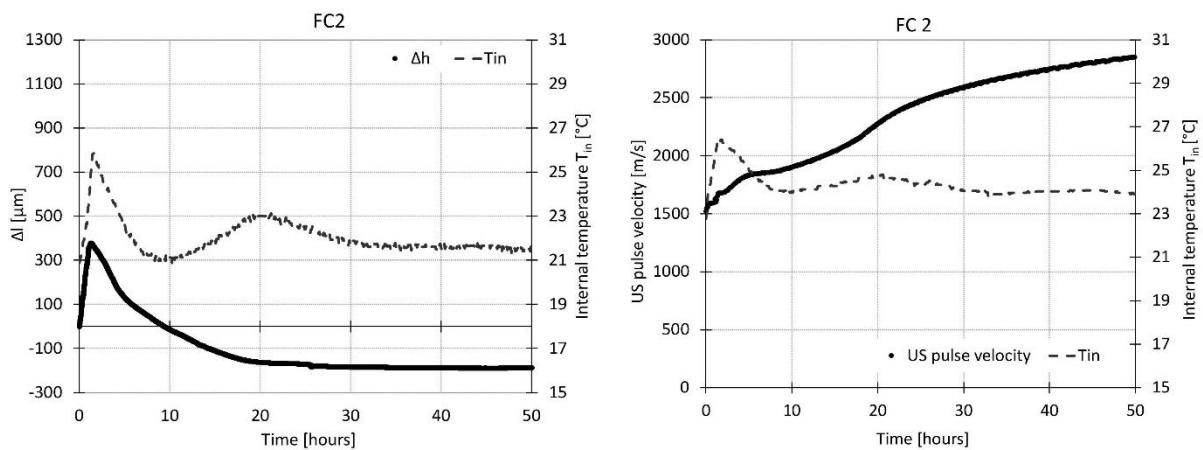


Figure 7. FC 2: Plastic settlement and internal temperature measured in Shrinkage-cone (left); US pulse velocity and internal temperature measured in Vikasonic.

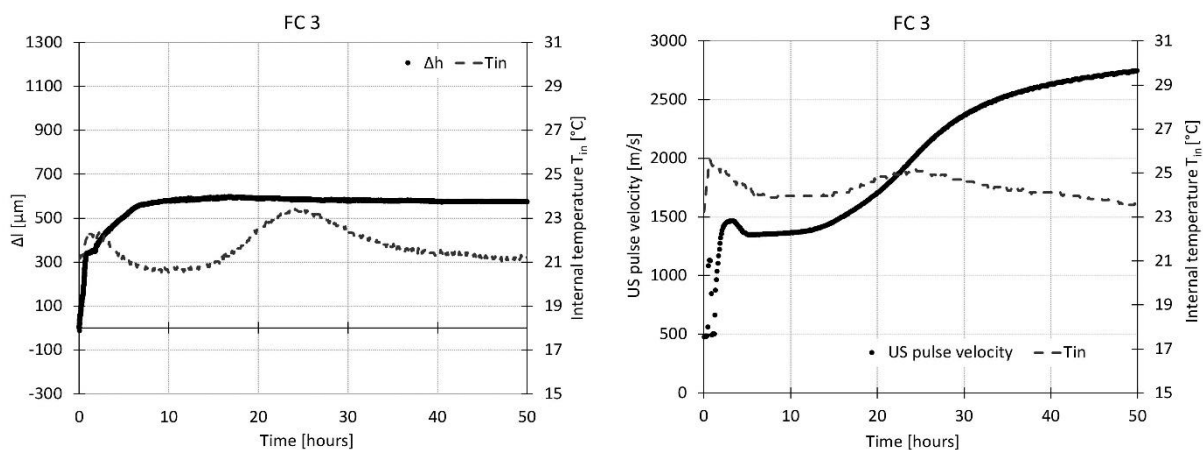


Figure 8. FC 3: Plastic settlement and internal temperature measured in Shrinkage-cone (left); US pulse velocity and internal temperature measured in Vikasonic.

The technological problem with demoulding process of FC 3 is clarified by the results of the US pulse velocity and internal temperature evolution (see figure 8 right). Based on the process of the US pulse velocity and internal temperature, it can be suggested that the strength development of FC 3 was

slower in comparison to the FC 1 and FC 2. The second temperature peak in FC 3 occurred exactly at the time of required demoulding process (see figure 7).

4. Conclusions

The article focuses on the measurement of early age materials' characteristics which take place during the solidification process. The plastic settlement/shrinkage of the flooring compounds was measured by the Shrinkage-cone. The strength development was estimated based on the US pulse velocity development calculated from the US transit time measured by the Vikasonic apparatus. Both test devices were equipped with the thermocouple to measure the real-time internal temperature evolution during solidification of the flooring compounds. The measurements presented in this paper proved to be useful for the clarification of the technological problems which arose during the manufacturing of the test specimens. The Shrinkage-cone measurements proved excessive plastic settlement/shrinkage of the FC 1 mixture which led to the settlement and cavitation of the upper surface of the test specimens. The internal temperature evolution and process of the US pulse velocity determined by the ultrasonic measurements provided information about the strength development of tested products. Based on the results it can be stated, that the FC 3 mixture had not enough strength at the time of demoulding of the test specimens.

Acknowledgement

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