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Mechanisms of early shrinkage and expansion of fast setting flooring compounds

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Abstract

Self-leveling flooring compounds are applied in thin layers (< 10 mm). These fast setting mortars set and harden within a couple of hours and subsequent drying of such a thin layer is generally terminated after the first day. In order to investigate the dynamics of early shrinkage and expansion we developed a special set-up of two laser units which are horizontally aligned. This experimental set-up allows to investigate the different formulation parameters and their influences onto the different stages of shrinkage and expansion, namely the plastic shrinkage, setting expansion and drying shrinkage. The shrinkage/expansion behavior is strongly related to both, external (climate) and internal (formulation) factors. With respect to the latter, begin, intensity and duration of setting are key to the overall shrinkage/expansion behavior.

Introduction

Fast setting self-leveling flooring compounds are usually based on a pseudo-ternary mixed-binder system, a mixture of different cement types (/1/ and references therein). Self-leveling compounds are applied in thin layers ranging in thickness from 1 to 10 mm. Shrinkage is one of the major issues because of two reasons: The high surface-volume ratio causes evaporation to be a dominant mechanism for strong and fast physical shrinkage, and the intense hydration reactions can cause a pronounced chemical shrinkage, or in case of ettringite formation a strong expansion.

1. Method

To investigate early shrinkage/expansion mechanisms in fast setting thin mortar layers a special set-up was developed which consists of two commercially available laser units (“Schleibinger cone”, /2/). The two lasers are directed horizontally onto a pair of light-weight reflectors, which are placed on top of the fresh mortar. The change in distance between the reflectors is then registered with an accuracy of 0.1 µm. The non-contact laser device allows to start measurement right after emplacement of the fresh mortar.

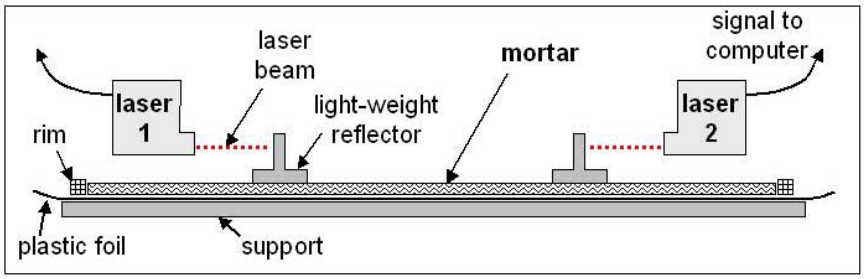

Fig. 1: Experimental set-up to measure free shrinkage of a thin mortar layer. Due to the two mobile laser units there are no limitations to specimen size.

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2. Mechanisms of shrinkage and expansion

Generally, a strong plastic shrinkage (shrinkage before setting) can be measured (Fig. 2). In combination with evaporation rate measurements and thermal analysis we found that evaporation and chemical shrinkage by hydration are two significant mechanisms for plastic shrinkage.
Close to the begin of setting, plastic shrinkage can turn suddenly into expansion. The current working hypothesis is that this is a pure structural effect related to a critical concentration of hydrates, which cause the mineral grains (cement, sand and fine-grained fillers) to become supported by a matrix of hydrates. From this moment on any further hydration causes the mineral grains to be pushed apart (expansion). The ongoing chemical shrinkage (caused by continued hydration), which contributed to plastic shrinkage before, is now producing porosity.
As the hydration rate decelerates, evaporation becomes the dominant mechanism and forces the mortar layer to shrink again. In most cases, this drying shrinkage levels out during the first day and the mortar layer becomes stable in volume (Fig. 2).

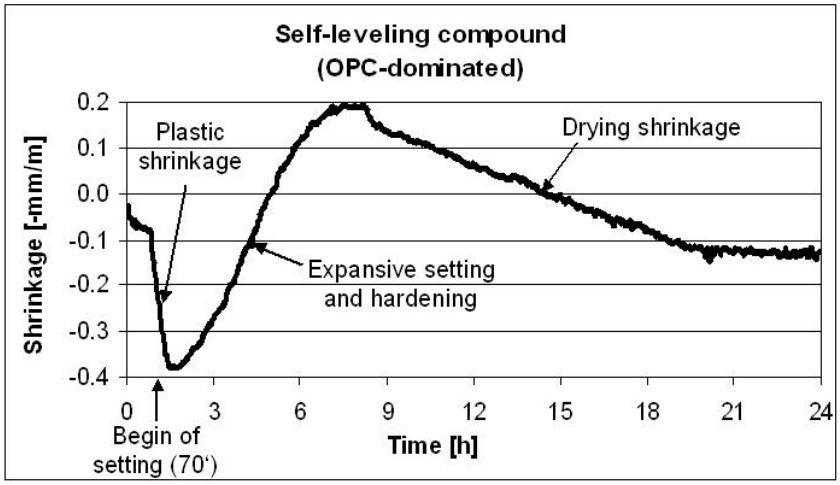

Fig. 2: Typical shrinkage/expansion curve of a freshly applied self-leveling compound (SLC) with a dominant proportion of Ordinary Portland Cement. The layer is about 5 mm thick. Begin of setting was measured according to Vicat test.

3. Conclusions

The three main stages of plastic shrinkage, setting expansion, and drying shrinkage are critically influenced by environmental and formulation parameters. Plastic shrinkage is increased by high evaporation and chemical shrinkage by initial hydration (before setting). Setting terminates plastic shrinkage and often causes a turn into expansion. With begin of setting any expansion or shrinkage becomes relevant in terms of internal stress or relaxation which can weaken or strengthen the hardening mortar layer. As the hydration rate decelerates drying shrinkage becomes the dominant mechanism. Any unbound water at this stage causes the mortar to shrink. Mortars which fail by cracking often show a strong drying shrinkage.

References

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