SETTING BEHAVIOUR OF ALKALINE ACTIVATED FACE CONCRETE FOR PAVING SLABS

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Introduction

In the field of garden and landscape architecture, the demand for dirt resistant surfaces increases. In order to avoid efflorescence on surfaces, cement based paving slabs are produced with the addition of hydrophobising agents in a two-layered paving slab process and, in addition, coatings based on polymer compounds are applied. However, these coatings are not durable and/or scratch-sensitive over an extended period of time.

Alkali activated binders using ground granulated blast furnace slag, hereinafter called as AAM, represent a CO_2-saving alternative to Portland cement-based systems. Furthermore, these AAMs are highly insensitive to mechanical stress and have a low tendency to subsequent efflorescence through calcium carbonate formation.[1-3] It has been shown that soluble aluminosilicate raw materials react with an alkaline activator and finally harden; for example: this activator is often a combination of an alkali hydroxide and an alkali waterglass.

Experimental procedure

Characterisation of the raw materials

As a basic mixture for the face concrete, an AAM-composition with a high compressive strength of 170 MPa after 28 days but quite low open time of 10 minutes was chosen.[4] The components are shown in Table 1.

Table 1: Raw materials (wt%)

binder	aggregate	activator
• ground granulated blast furnace slag [32 – 37]	• quartz sand [50]	• sodium silicate solution (SiO_2:Na_2O = 3.4) • sodium hydroxide
• silica fume [5 – 10]	• quartz powder [8]	• KOH/K_2SiO_3 = 1.5

This mixture is based on the principles of packing-density-optimised concrete.[4] Previous research has shown that the combination of waterglass and alkali hydroxide improves the durability. In addition, the use of silica fume improves the rheology thereby reducing the water/binder value.[5] Therefore, sodium hydroxide and sodium water glass were taken into account with the water content of the respective solution in equal parts in the water/binder value.

Two-layered concrete paving slab process

The production of the paving slabs can be done in a two layered concrete paving slab process, where a water-rich facing concrete is pressed together with a relatively dry core concrete under pressure. The seven steps of the process are shown in Figure 1a.[6] The excess water from the facing concrete is pressed into the core concrete, resulting in a facing layer with a low capillary porosity. As a result, the surface has a dense structure.

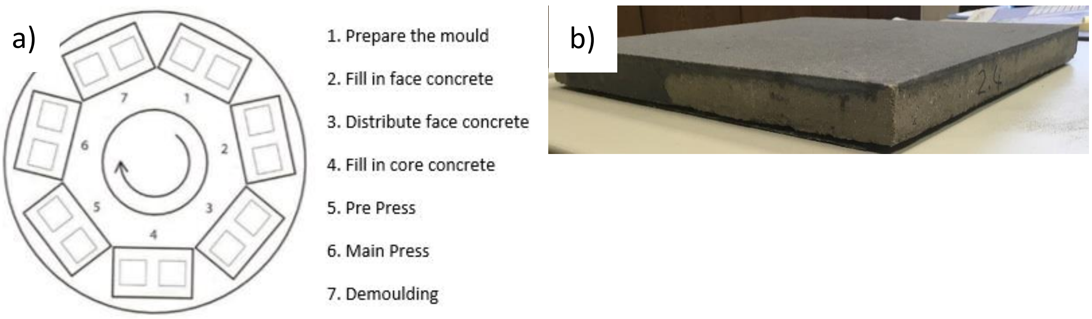

Figure 1: Two layered concrete paving slab process, with a) seven steps of the process and b) picture of the AAM-paving slab

Experiments on laboratory scale

The following requirements for the face concrete had to be maintained according to the manufacturer. Thus, an economical production process could be ensured:

- start of setting progress > 90 minutes
- compressive strength ≥ 40 MPa
- constant flow consistency around 15 cm for one hour

Therefore, the composition of the activator in the mixture was varied. Based on an activator combination of 60% sodium waterglass and 40% sodium hydroxide, only the molarity of the sodium hydroxide was changed to adjust the requirements. The determination of the setting time of the fresh concrete was carried out by means of a Vicat-test in accordance with DIN EN 196-3 and by ultrasonic test. The used system was IP-8 ultrasonic measuring system from the company ULTRATEST and had a resolution of 0.05 µs. The flow consistency was measured by means of flow table according DIN EN 1015-3.

Results

The binders for the face concrete have been adapted according to the requirements of the industrial partner in order to enable the manufacturing process, see above. The used waterglass content was kept constant and thus the setting time and strength was controlled by the molarity (solid content in the solution) of the sodium hydroxide solution. Thus, a molarity of the sodium hydroxide solution of 2 mol/l - 2.5 mol/l comply with the necessary requirements (see grey area in Figure 2a). In addition, the slump of the fresh concrete could be held constant for 60 minutes (Figure 2b, tested for two replicates). Finally, a 2.5 molar sodium hydroxide was used for further experiments.

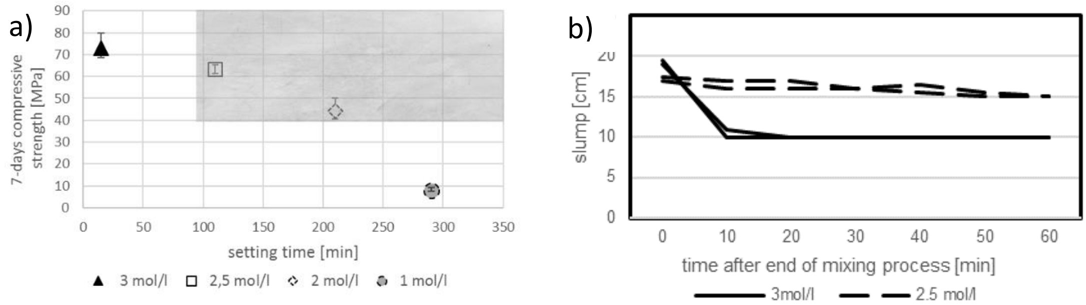

Figure 2: Concrete properties of the face concrete depending on the molarity of the activator, with a) 7-days compressive strength depending on the setting time and b) slump of the fresh concrete at different times

Furthermore, the ultrasonic test method was used to control the setting process. When using a molarity of 1 mol/l, after 1 day (1440 min) the material is still in the hardening process near 750 m/s. The mixtures with a sodium hydroxide molarity of ≥ 2 mol/l are already hardened and reach values about 2300 m/s, Figure 3). Thereby, a connection between the results from the Vicat-test and the velocity could be figured out. The setting time of the AAM was reached at a velocity of 250 - 500 m/s.

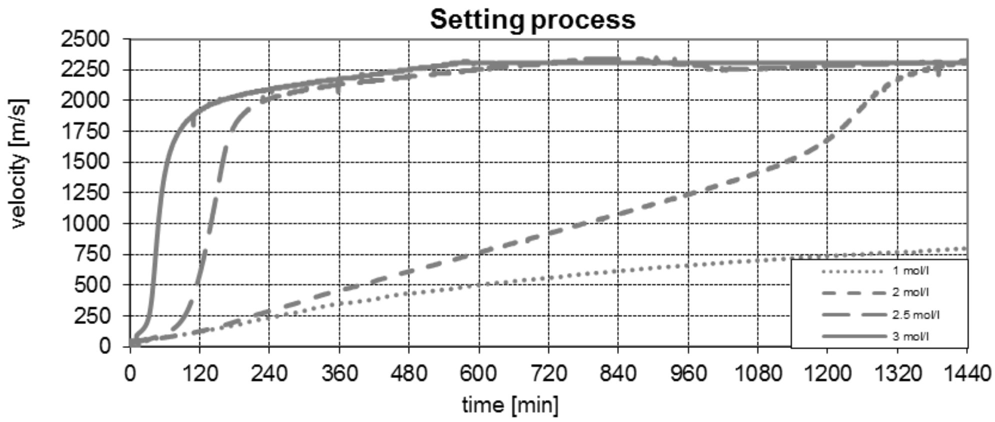

Figure 3: Ultrasonic test of the face concrete with different molarities of the activator

In the literature there are no results that compare the initial setting time measured by the Vicat-test and the ultrasonic velocity of slag-based AAMs with a similar composition. In tests with Ordinary Portland Cement (OPC) based systems the initial setting time is compared to the ultrasonic measurement. The point of the beginning of the initial setting time measured by ultrasonic test that can be compared to the setting time measured by Vicat-test variates in a wide range; for example, it is defined where the sound velocity starts to increase or at the turning point of the function.[7,8]

Summary and Outlook

The production of a permanent face concrete layer of AAM is possible and the strength and the beginning of solidification can be adapted according to the requirements. In addition, the thickness of the facing layer could be reduced to < 10 mm by using a permanent facing concrete layer of AAM, see Figure 1b). The requirements for hardened concrete according to DIN EN 1339 were complied with. The ultrasonic test is an effective method to monitor the setting process by in-situ measurement and as a result, a velocity was found to forecast the initial setting begin.

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