ALKALI-ACTIVATED SLAG WITH LOW WATER/BINDER-RATIO

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Introduction

Alkali activated materials (AAM) consist of alumino-silicate precursors and alkaline solutions as activators.[1] Based on the principle of ultra-high performance concrete (UHPC) an alkali-activated slag was optimised. A low water/binder-ratio was realised by using silica fume and nanosilica as additives. The use of silica fume has been reported elsewere[2-3], but no positive impact on the rheology was described. Although no macroscopic cracks could be observed the measured shrinkage in this system was very high. With the motivation of reducing the shrinkage two strategies were followed. a) Several superplasticisers were tested in order to reduce the water content further and to reduce the drying shrinkage and b) shrinkage reducing admixtures were tested on standard prisms. The slump flow was measured and additionally the viscosity was estimated by the rotor energy of the mixing tool.

Experimental procedure

Raw materials

The AAM used in these investigations are based on ground granulated blast furnace slag (Table 1). Additionally, silica fume is used as precursor leading to a decrease of the viscosity. It was found that a mix of potassium waterglass and potassium hydroxide (10 molar) leads to the best rheological behaviour in fresh state and to the best mechanical characteristics in hardened state.

Chemical Admixtures

The water/binder ratio was kept on 0.20 in these investigations to study the influence of superplasticisers and shrinkage admixtures. For the superplasticisers, a MPEG type polycarboxylate ether, as it is used for systems based on Portland Cement was compared to an APEG type superplasticiser. It has been reported[2] that the APEG type superplasticiser is effective in a slag-based system. Because these systems[2] differ in the concentration of the alkaline solution and no silica fume is used as additional precursor, further measurements on the rheology were conducted by increasing the silica content and the concentration of the alkaline solution. Four different shrinkage

reduction agents have been tested, while the first 3 (SRA 1- SRA 3) are based on polyether and SR4 is based on neopentylglycol. All chemical admixtures were dosed by weight of binder (slag and silica fume).

Table 1: Raw materials

precursor	• ground granulated blast furnace slag • silica fume
aggregate	• quartz sand • quartz powder
activator	• potassium silicate solution (ratio of weight SiO_2:K_2O 2.5, solid content: 28.5%) • potassium hydroxide (2-10 molar) • ratio of hydroxide to waterglass of 60:40
admixture	• superplasticiser (SP) • shrinkage reducing admixture (SRA)

After dry mixing, the hydroxide solution was added first, followed by addition of the water glass. Finally, the sand was added. While keeping a constant rotation speed for the mixing tool, the rotor energy was monitored. An increase of the rotor energy indicates an increase of the viscosity. Additionally, slump tests were conducted, which show the same indication. Shrinkage was measured on standard prisms (4 x 4 x 16 cm^3), which were demoulded after 24 hours and stored in standard climatic conditions (20°C, 65% rel. hum.).

Results

Shrinkage

The measured shrinkage after 28 days is about 3 mm/m in case of the reference without any shrinkage reduction agent. All tested SRA (0.5%) showed a reduction of the shrinkage, while SRA 1 and 3 showed the best results slightly above 2 mm/m (Figure 1). Some SRA showed an improvement by increasing the content from 0.5% up to 1 or 2%, but no better improvement than a reduction to 2 mm/m as shown in Figure 2 was achieved.

The addition of SRA leads to a decrease in compressive strength. The reference showed a compressive strength of about 125 MPa after 7 days and the use of 0.5% of SRA or SP lead to a decrease of about 10 MPa to 115 MPa in minimum. The optimum of shrinkage reduction and minimum decrease in compressive strength (10 MPa) was found for of SRA 1 and 3 with a dosage of 0.5%.

Flowability and workability

At the end of the mixing procedure after 900 s, a slight decrease of the rotor energy and therefore an indication of a slight decrease of the viscosity (Figure 2) could be recognised for the mixture containing 0.5% of one of the superplasticisers (bwob - by weight of binder) compared to the reference.

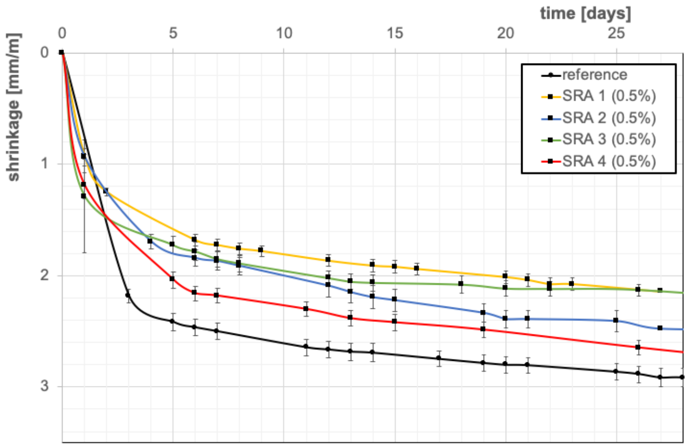

Figure 1: Shrinkage of AAM based on slag and silica fume using different shrinkage reducing agents (SRA)

The slump flow (DIN EN 1015-3) for these mixtures were in the range of 200 mm, but the values varied only in a small amount as well as the results of the rotor energy. All other used superplasticisers showed even less improvement of the flowability.

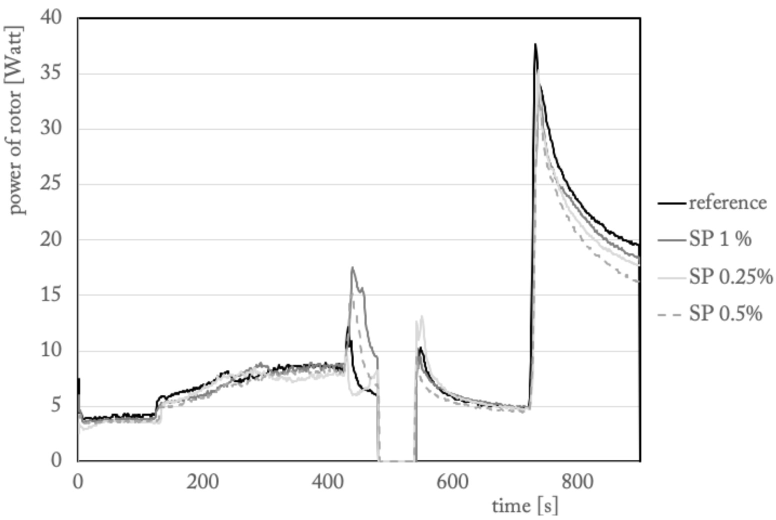

Figure 2: Rotor power during mixing procedure giving an indication of the viscosity; The SP used in these experiments is an APEG-PCE[2]

In contrast to results published by Conte & Plank[2], the change in flowability for the APEG-based superplasticiser is rather low. The results reported by Plank *et al.* used a slag-based system without the use of silica fume and with a lower concentration of

the alkaline solution, thus, a higher w/b ratio resulted. Therefore, some additional tests have been conducted using those reported parameters. Without silica fume and with a low concentration of the alkaline solution (2 mol KOH) the effectivity of the APEG superplasticiser is quite high, while the addition of silica fume results in a very low impact (Figure 3).

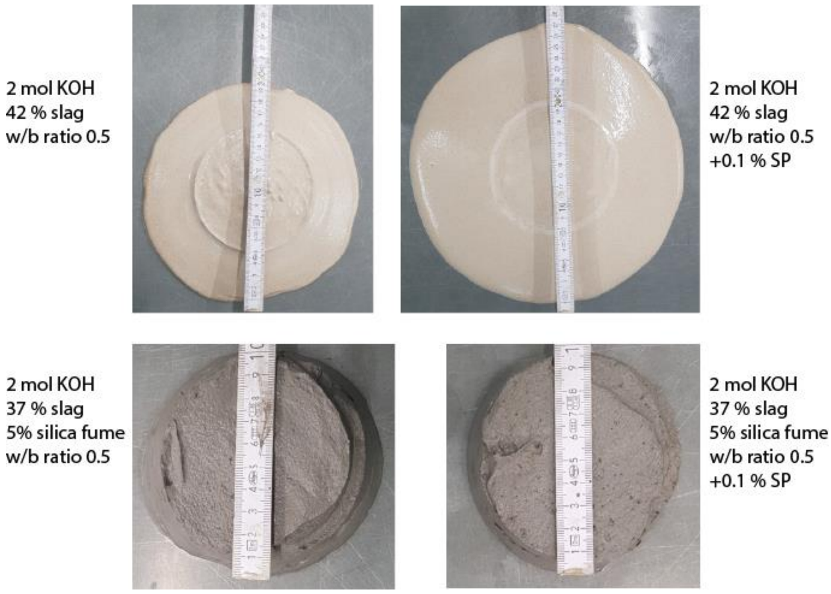

Figure 3: Slump flow of mixtures with and without superplasticisers (SP); The SP used in these experiments is an APEG-PCE[2]

Summary and Outlook

The superplasticiser only showed a small impact on the rheology of the slag based AAM. Best results could be found for the APEG-type PCE with an amount of 0.5 wt%. Anyhow, compared to the results shown in Conte & Plank[2] the APEG type PCE have a lower effectivity due to the presence of silica fume as could be shown in experiments using a lower alkaline concentration. The interaction of silica fume and the APEG-PCE will continue to be the focus in upcoming investigations. The shrinkage of the higher shrinking intensive system could be reduced from about 3 mm/m to about 2 mm/m.

References

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