Some effects of silica fume on variations in rheology of mortar due to production date of cement

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ABSTRACT

Rheological properties of cementitious suspensions (such as mortar and concrete) can change severely when a new cement batch/production date[1,2] is used. Particularly mixes containing dispersing admixture can be affected. Such a cement-admixture interaction problem[3] can cause various difficulties on construction sites. Too stiff concrete needs more workforce to be compacted properly and too liquid concrete could segregate. Previous research has shown that silica fume can reduce this effect. This means that silica fume can provide a more stable concrete production.

A study was carried out on mortar mixes to investigate the influence of silica fume on rheology. The objective of this study is twofold. Firstly, to determine if silica fume can reduce the variations in rheology when cement of different production dates is used, thus reducing variations in rheological properties in concrete. Secondly, to quantify the advantageous effect of the silica fume.

INTRODUCTION

Concrete plants and pre-cast factories with high daily consumption of cement sometimes experience differences in rheological parameters of fresh concrete when using a new cement delivery (e.g. a new cement truckload). Nevertheless, the cement is of same type and coming from the same plant and production line. It only differs in production date. Particularly, mixes with high cement content and high admixture dosage (such as Self Compacting Concrete) can be affected by such a cement-admixture interaction case. During a previous study[4] more than ten different production dates of a Portland composite cement[5] were tested on their rheological properties. All cement samples were of same type, a CEM II/A-M 42,5R already blended with 4% of silica fume. Due to the high reactivity of Icelandic aggregates (with respect to alkali silica reaction), all cements produced in Iceland should be blended with silica fume. The cement samples were produced from October 2006 to February 2008, representing more than a one year production period. The cement samples were coming from the same production line. It was found that the yield stress was relatively stable in the blank mixes, whereas the yield stress was fluctuating significantly in the mixes containing polycarboxylate.

MATERIALS AND METHODS

The objective of this study is to investigate the effect of silica fume addition on rheology of mortar produced from one low yield cement and one high yield cement.

In a series of cement deliveries (production dates) those which generate yield stress below the mean minus one standard deviation of that series are named

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low yield cement deliveries, analogously, those which generate yield stress above the mean plus one standard deviation of that series are named high yield cement deliveries.

If a concrete is produced with these cements, the utilization of low yield cement results in a relatively fluid concrete, whereas the utilization of high yield cement can result in a sticky mix with relatively fast workability loss. Note that the high yield and low yield cement are of same type (CEM II/A-M 42,5R) and from same production line.

The low yield cement was produced on 09.11.2007, the high yield cement was produced on 18.10.2007. Two different silica fumes were incorporated in the study, a regular silica fume and a relatively high purity silica fume. The silica fume was added at two dosages, 2,5% and 5% by weight of cement on replacement basis.

Table 1. Mix design of mortars

Constituents	Density (kg/dm³)	Ref. mix	2,5% silica fume	5% silica fume
EN sand	2,62	1350 g	1350 g	1350 g
Water	1,00	265,4 g	264,2 g	263,1 g
Cement	3,05	669,1 g	650,1 g	632,1 g
Silica fume	2,20	0 g	16,3 g	31,6 g
Admixtures	PC = 1,10	3,62 g **(0,20%)**	3,61 g **(0,20%)**	3,60 g **(0,20%)**
w/c-ratio	-	**0,40**	**0,40**	**0,40**
sand/cement		2,02	2,08	2,14

The mortar was mixed under laboratory conditions at a temperature of 20°C in the ConTec Rheomixer. First, sand and cement were dry mixed in the Rheomixer for 20 seconds. Second, the water was added through a funnel followed by the admixture. The delay in admixture addition was approx. 5 seconds. All mixes contained 0,20% of polycarboxylate as dispersing admixture (dry polymer by weight of cement). The mix design for the reference, the 2,5% and 5% silica fume mixes are given in table 1. Note that the cement used contained already ~4% of silica fume added in the factory.

The admixture used was a modified polycarboxylate ether (PC). Some characteristic values of this admixture are given in table 2. Throughout the test series, the same batch of admixture was used.

Table 2. Characteristics of admixture used

Product name	Glenium 51
Producer	BASF
Based on	Modified polycarboxylate ether
Chloride content	<0,1%
Density	1,10 kg/dm³
Polymer content	36,9%
Recommended dosage by the producer (dry polymer)	0,1 – 0,7%
Workability	120 minutes

Rheological parameters, yield value and plastic viscosity, were measured on the same mix in both ConTec Rheomixer and ConTec Viscometer 6[6]. ConTec Rheomixer measures the G-yield and H-viscosity while ConTec Viscometer 6 measures the corresponding yield stress and plastic viscosity. G-yield and H-viscosity (Rheomixer) was measured after 13 and 15 minutes while yield stress and plastic viscosity (ConTec Viscometer 6) was measured 18 and 22 minutes after water addition.

RESULTS AND DISCUSSION

Results obtained on low and high yield cement are given in table 3.

Effect of silica fume addition on rheology

Two different silica fumes were added at the same dosage to mortar mixes containing 0,20% of polycarboxylate as dispersing admixture. As the variations in rheology (due to production date) are much more significant in mixes with chemical admixtures, the effect of silica fume was only investigated here in mixes containing chemical admixtures. Figures 1 and 2 depict the effect of silica fume on the rheological parameters yield stress and plastic viscosity, respectively.

Table 3. Characteristics and rheological data for mortar samples

Type of silica fume	Cement charac-teristics	SF cont. (%)	Yield stress (Pa)	Plastic visco-sity (Pas)
Regular silica fume	Low yield cement	0	84	5,7
		2,5	113	5,6
		5	133	4,3
	High yield cement	0	226	6,8
		2,5	247	7,9
		5	270	6,2
High purity silica fume	High yield cement	0	226	6,8
		2,5	196	7,6
		5	190	6,5

The utilization of the regular silica fume resulted in an increase in yield stress for both cements investigated. This can be stated for the results obtained by both instruments ConTec Viscometer 6 and ConTec Rheomixer (results from Rheomixer are not reported here).

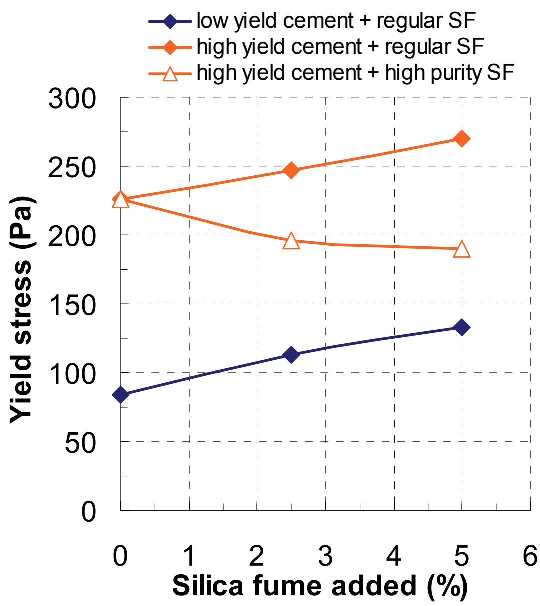

Figure 1. Effect of silica fume addition on yield stress

The yield value increased to some extent when adding the regular silica fume to the mix. To phrase it in simple words, the mortar mixes were getting less fluid and more sticky when the regular silica fume was added (see Figure 1).

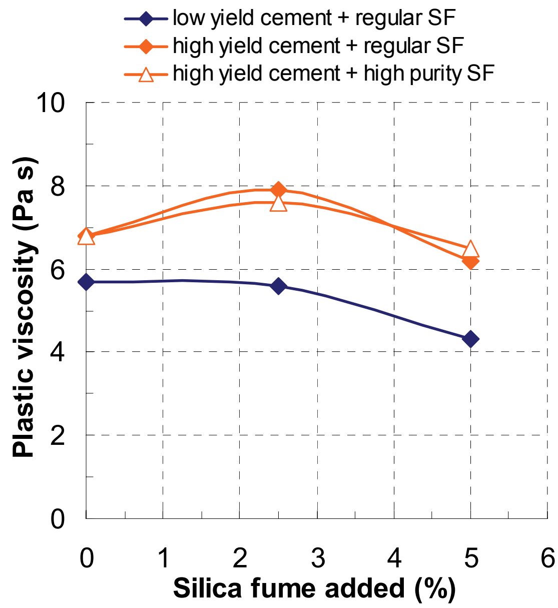

Figure 2. Effect of silica fume addition on plastic viscosity

On the contrary, when high purity silica fume was added, the yield stress of the mortar made with high yield cement decreased (see Figure 1). In simple words, the mortar mixes were getting more fluid and workable when high purity silica fume was added. There seems to be a significant difference between the regular and high purity silica fume in its effect on rheology. According to these results the high purity silica fume is a promising addition to reduce the effect of production date on rheology. It is still under investigation why the different silica fumes showed so unlike results in mortar mixes.

The effect of the two silica fumes on the plastic viscosity can be seen in Figure 2. According to these results there seems to be no significant difference between the regular and the high purity silica fume in terms of its viscosity modifying effect when added to high yield cement. The addition of silica fume of both types resulted in a slightly decreasing viscosity.

FINAL REMARKS

Two cement samples of a CEM II/A-M 42,5R which differed in yield stress in the presence of admixtures were tested in mortar. The cement samples were of same type and only differing in production date. The cement sample from 09.11.2007 represents a low yield cement, the cement sample from 18.10.2007 represents a high yield cement. Two different silica fumes in respect of purity were added on replacement basis to mortar mixes produced with high yield and low yield cement, respectively. The aim of the study was to evaluate if the silica fume can reduce the variations in rheology caused by different production dates of cement. The addition of the regular silica fume resulted in an increasing yield stress, whereas the addition of the high purity silica fume resulted in a decreasing yield stress. From a rheological perspective, the high purity silica fume is the more promising product.

The high purity silica fume reduced the yield stress of the high yield cement by 30% (at a dosage of 5%). The effect of the two silica fumes on plastic viscosity was similar in case of high yield cement. The plastic viscosity of the high yield and low yield cement mixes was slightly reduced, compared to blank mixes, regardless of the purity of the silica fume.

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