

Tittel:  
**Effect of different silica fume on concrete properties**

Comparative testing and analysis

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 silicon products



**Reducing CO<sub>2</sub> emissions related to concrete production**

Concrete, as the world's most widely used construction material, is responsible for approximately 8 percent of global CO<sub>2</sub> emissions. Efforts within the construction industry have been focused on reducing CO<sub>2</sub> emissions associated with cement and concrete production. Significant progress has already been made, but continued efforts are crucial in the ongoing development of sustainable building materials, and the mitigation of detrimental effects associated with current practices. Research on application of waste and by-products from industries in concrete can contribute to lessening the environmental impact caused by the construction industry.

**Microsilica in concrete**

Microsilica, a fine amorphous silica by-product of elemental silicon production or silicon-containing alloys, is a highly reactive pozzolanic material commonly used in concrete. Microsilica in concrete allows for cement reduction while enhancing concrete strength. The material is primarily composed of amorphous SiO<sub>2</sub> which reacts with the calcium hydroxide produced by the hydration of cement and contributes to additional production of CSH. The physical properties of microsilica contribute to "packing" of the concrete due to its small spherical particles which decrease the void spaces in the cement mixture. This effect can give increased durability.

**Research question:**

How do different compositions of microsilica affect the properties and characteristics of concrete?

**Method**

The objective of this study is to explore the impact of incorporating 10 different types of microsilica on the properties and characteristics of concrete. Process development and a preliminary study have been conducted as preparative work before investigating the effect of microsilica on concrete properties. The influence of microsilica on fresh mortar properties, strength development and durability has been investigated by execution of flow tests, temperature logging, total heat value calculation, standard mechanical strength tests, pozzolanic activity index, chloride ion migration tests, and microscopic imaging.



Figure 1. Flow test

Figure 2. Chloride ion migration test specimens

**Testing and comparative analysis**

Analysis of the influence of microsilica on fresh mortar properties was performed by looking for correlations between the flow test results and the physical properties of the microsilica samples.

Table 1. Comparison of flow test results and physical properties of microsilica E1-E10.

	Flowability [mm]	BET SA [m <sup>2</sup> /g]	Bulk density [kg/m <sup>3</sup> ]	Form of microsilica (U/D/S)	Moisture of microsilica [%]
E1	203,03	16,9	348	U	0,63
E2	170,41	27,74	330	U	0,45
E3	182,85	16,65	360	U	0,88
E4	199,10	18,16	167	U	0,46
E5	174,77	24,21	228	U	0,65
E6	177,13	24,62	638	D	0,72
E7	177,755	24,69		S	
E8	183,03	24,57		S	
E9	193,37	17,15	681	D	0,7
E10	191,85	18,94	252	U	0,76

The influence of microsilica E1-E10 on strength development was investigated by analyzing the correlation between test results and the physical and chemical properties of microsilica.

Table 2. Relationship between temperature logging results, PAI, and physical and chemical properties of microsilica E1-E10

	Maximum temp. [°C]	Total heat of hydration [°C*h]	Complete setting time [h]	Average PAI [%]	BET SA [m <sup>2</sup> /g]	Bulk density [kg/m <sup>3</sup> ]	Alkali content [%]	Silicon dioxide content [%]	pH
Ref	34	1184,2	18,0	-	-	-	-	-	-
E1	28,9	1120,6	15,6	126,37	16,9	348	364,9	0,167	8,17
E2	30,4	1154,0	15,3	143,36	27,74	330	357,74	0,169	7,49
E3	31	1166,2	17,4	139,64	16,65	360	376,65	0,354	7,33
E4	30	1133,8	18,0	138,8	18,16	167	185,16	0,355	7,33
E5	30,5	1141,6	16,5	142,3	24,21	228	252,21	0,493	7,14
E6	31,5	1153,3	17,3	138,4	24,62	638	662,62	0,864	6,92
E7	-	-	-	137,8	24,69		24,69	0,499	5,07
E8	-	-	-	139,3	24,57		24,57	0,512	6,06
E9	32,2	1184,6	17,8	128,2	17,15	681	698,15	1,209	6,59
E10	32,7	1193,2	17,9	134,4	18,94	252	270,94	1,573	2,95

Investigation of the influence of microsilica on the durability of concrete was done by executing a chloride ion migration test.

**Conclusions**

As a result of the testing and comparative analysis, several observations about how microsilica influences concrete properties have been obtained. A common denominator in the observations for all tests was that the densification of the microsilica allegedly does not influence the properties of concrete.

The BET specific surface area of the microsilica influence both the flowability of the mortar as well as the pozzolanic activity index of the samples after 28 days of curing. Low BET SA (m<sup>2</sup>/g) gave high flowability and an increase in PAI was observed for mortars containing microsilica with high BET SA (m<sup>2</sup>/g). The pozzolanic activity index of the mortars also showed an increase as the content of silicon dioxide in the microsilica increased. When assessing how the mortars were influenced by the pH of the microsilica samples, complete setting time was investigated and it was concluded that there was no correlation between pH of microsilica and the complete setting time. However, there was a minor correlation between the complete setting time of the mortars and the alkali content of the microsilica samples, where low alkali content gave early complete set. No correlation was observed when investigating the influence of moisture in the microsilica samples on the flowability of the mortars.