# The Effects of Cement Variations on Concrete Workability



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## ABSTRACT

The industrialized production of precast concrete elements requires raw materials with constant quality. The workability variations in daily consignments of a cement supplied from the same factory were studied by measuring the spread of a specially designed mortar on a flow table. The reactivity of the cement was measured with a semiadiabatic calorimeter. The observed workability variations were strongly pronounced when superplastizicers was used. The strongest correlation was found between workability and the time position where the heat evolution had its maximum value.


## 1. INTRODUCTION

Recent studies have shown that the cement variations have a greater effect on the workability and on the early reactions of concrete than is generally thought of. These variations are greater with superplasticized mixes but problems can exist also with normal concrete mixes.

The unexpected variations may lead to serious disturbances in production in the form of poor compaction, too low early strength and strand slippages. This is causing increased waste in production and considerable economical losses particularly at hollow core slab factories.

Cement variation is difficult to measure or control at a precast plant. The quality information presently available from the cement supplier is not detailed enough to predict the behaviour of cement in a concrete mix. The aim of this study was to clarify the role of daily cement variations on concrete workability and to develop methods for cement quality control at precast concrete factories.

### 1.1 Variation in cement

Cement has several varying properties. These are for example:

1. Composition of clinker minerals
2. Microstructure of clinker minerals
3. Amount and form of calcium sulphate
4. Amount and form of alkalies
5. Material temperature
6. Particle size gradation (fineness)
7. Particle shape

Until now, the most observed single property of cement has been the fineness that is expressed in specific surface according to the Blaine method. Several tests and long time monitoring, however, have shown that Blaine fineness is not a sufficient parameter for explaining the variations in the properties of fresh concrete mix or early age properties of hardened concrete. This seems to be the case especially with superplasticized mixes where superplasticizer and cement compatibility reportedly can cause problems or at least differing workability with various combinations [1,2].

## 2. TEST METHODS

The cement samples were collected once a day from ordinary concrete production by stopping the weighing of cement at the mixer and taking 30 kg out from the weighing container. A simple and often used flow table test (ASTM C 230) was selected as the basic test [3]. A mix of industrially produced lab sands was mixed with the daily CEM I 52.5 R type cement samples using w/c of 0.420 and 0.465 for plain cement mortars and 0.320 and 0.335 for superplasticized mortar mixes. The aggregate/cement ratio was 1.9 in all tests. The used sand fractions were 0 - 0.6, 0.5 - 1.2 and 1.0 - 2.0 mm. The combined gradation of the sand is presented in Table 1. Mixing was done with a small lab mixer at room temperature. The superplasticizers were a typical melamine plasticizer (SP) Peramin F supplied by SEMTU OY and a polycarboxylate plasticizer (SSP) Glenium 51 supplied by Master Builders OY. Peramin F was dosed 2.14 % of cement weight and Glenium 51 was dosed 0.77 % .

*Table 1. Mortar sand gradation*

| Sieve mm | 0.125 | 0.25 | 0.5 | 1 | 2 | 4 |
|---|---|---|---|---|---|---|
| Passing [ % ] | 2.3 | 16.0 | 44.1 | 68.7 | 95 | 0 |

The chemical composition of the cement used is in Table 2 and 3.

*Table 2. Approximate chemical composition of the cement used in the tests.*

| | CaO [%] | $SiO_2$ [%] | $Al_2O_3$ [%] | $Fe_2O_3$ [%] | MgO [%] | $K_2O+Na_2O$ [%] | Others [%] | Total [%] |
|---|---|---|---|---|---|---|---|---|
| Chemical composition of clinker | 64.0 | 20.0 | 4.6 | 2.9 | 3.1 | 1.6 | 3.8 | 100.0 |

*Table 3. The Bogue clinker minerals of the clinker.*

| | $C_3S$ [%] | $C_2S$ [%] | $C_3A$ [%] | $C_4AF$ [%] |
|---|---|---|---|---|
| Clinker minerals according to Bogue | 70 | 4 | 7 | 9 |

## 3. SEMIADIABATIC CALORIMETER METHOD

The chemical heat of reaction, which is released during the hydration of cement, can for practical purposes be measured with a simple semiadiabatic calorimeter as described in Nordtest NT BUILD 388. The system consists of a 250x250x250 mm box of a suitable insulation material (e.g. expanded polystyrene) with a cavity for the concrete or mortar sample. The temperature of the sample and the surrounding temperature are measured with a thermocouple transducer that was connected to a PC. As the reaction proceeds, the temperature will rise, but a part of the heat is dissipated to the surrounding.

The heat loss can be calibrated with a preheated old sample that does not react any more. The results have to be transformed to a equivalent time scale at a reference temperature. Several models have been proposed for this transformation, but we have used the Arrhenius model proposed by Freiesleben Hansen [4], because of good correlation with results from tests carried out at different temperatures.

The most interesting feature of the reaction profile is the rate of heat release, which can be called the ”fingerprint” of cement. The very complicated interactions of cement and admixture chemistry will become visible in the curve. The method seems to be very sensitive to cement quality changes as well as to water/cement ratio and admixtures. Other advantages of the method are that it includes all mix (mortar or concrete) properties such as impurities and influence of fine particles in the test and that it has a temperature profile similar to precast production.

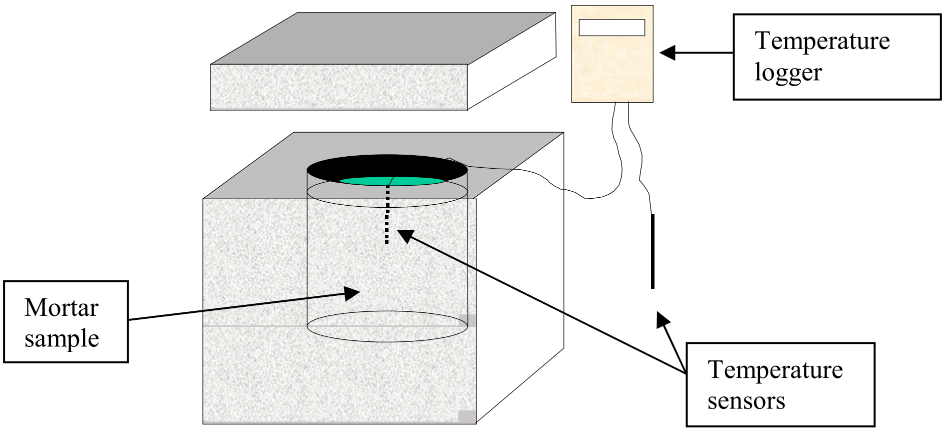


*Figure 1. A schematic presentation of the semiadiabatic calorimeter*

## 4. TEST RESULTS

Mortar tests with a flow table were made with samples from 50 daily collected cement samples. The range of variation in spread measurements in mixes without superplasticizer was 24.5 mm. With a SP superplasticizer the variation was 111.5 mm. With SSP the variation was somewhat less than with SP.

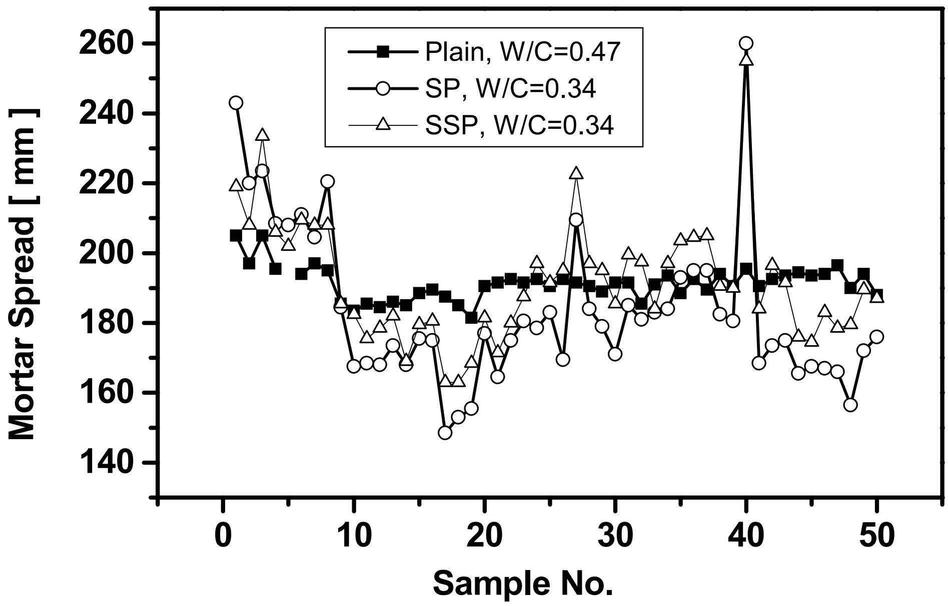


*Figure 2. Flow table test results with SP mortar mix.*

The semiadiabatic calorimeter test showed that the heat release is affected by the cement and superplasticizer interaction. While the maximum temperature of 57 degrees was obtained with plain mix at 9 hours, with SP the maximum temperature was 63 degrees also at 9 hours. SSP seemed to cause retardation as the maximum temperature of 60 degree was reached after 12 hours.

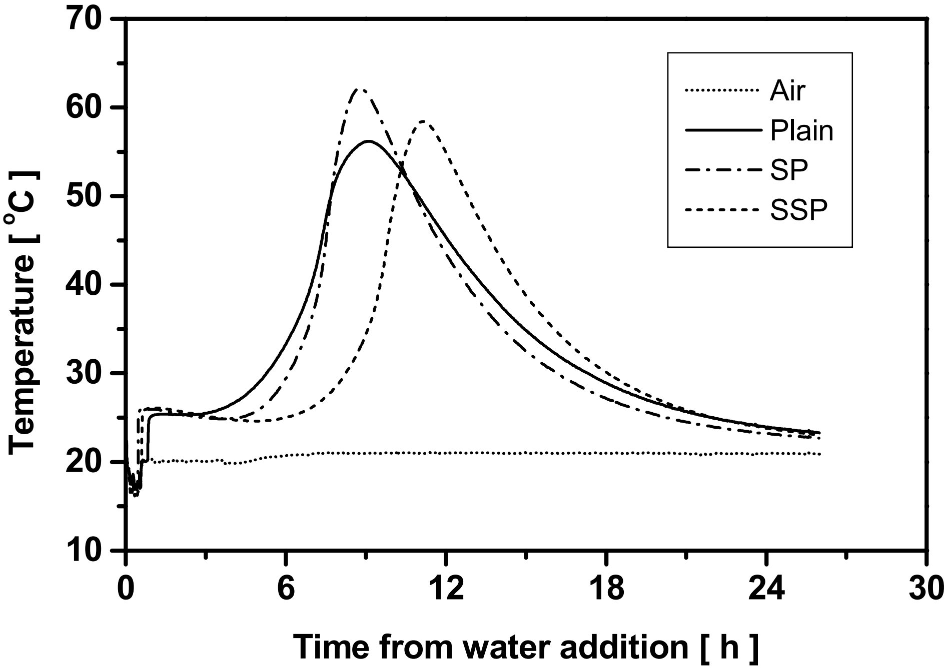


*Figure 3. Effect of SP and SSP on temperature development of a mortar mix*

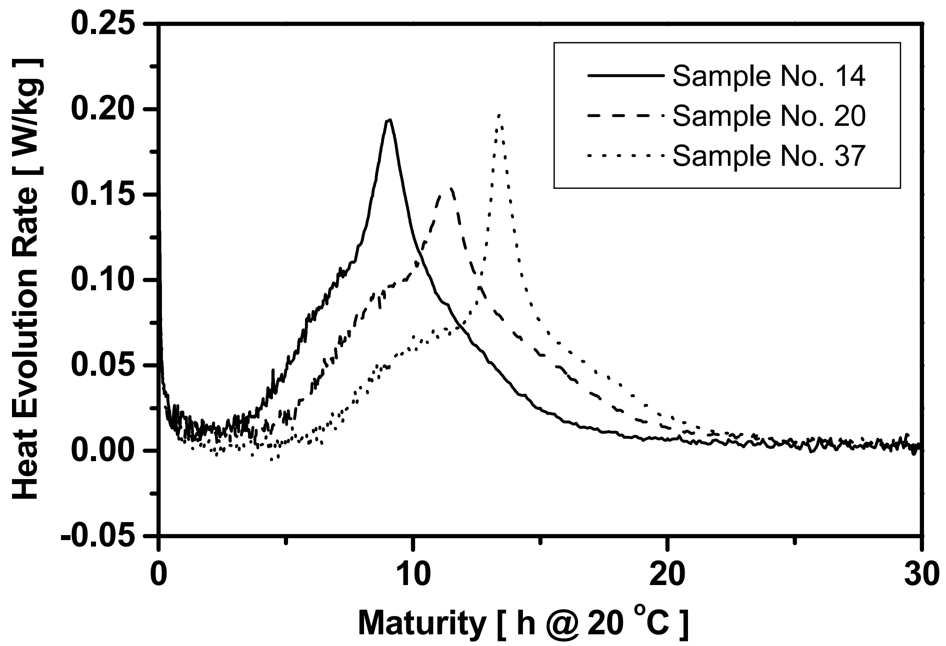


*Figure 4. Examples of cement heat release or 'fingerprints' of three different deliveries of the same cement.*

With the semiadiabatic calorimeter it was possible to generate heat release curves. These curves – or cement fingerprints - showed clear differences between various samples. The peak value is at 9.5 hours for sample No. 14, 11.5 hours for sample No. 20 and 13 hours for sample No. 37. The sample numbers denote the days when tests were carried out. (Fig. 4.)

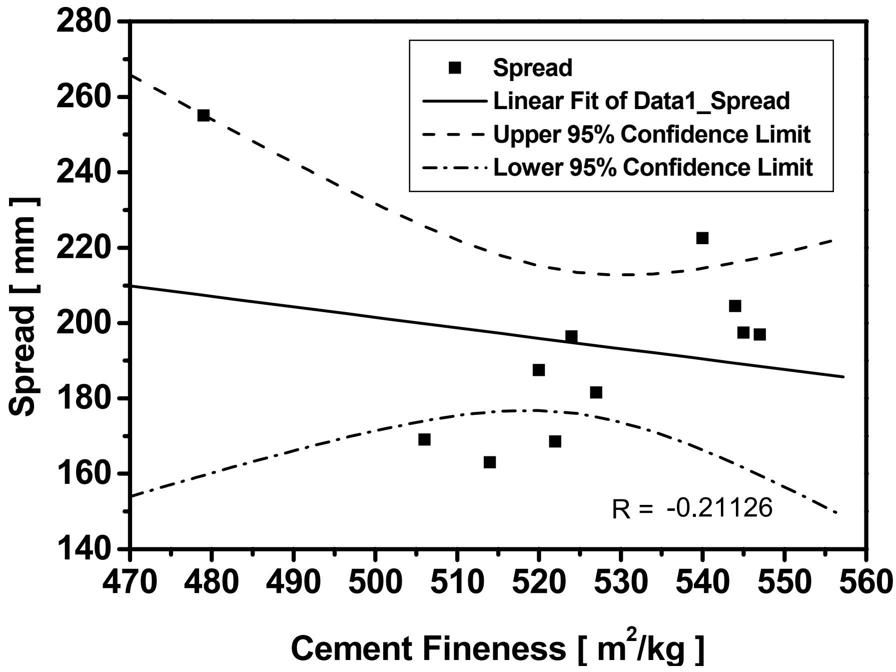


*Figure 5. Influence of cement fineness on spread, SP admixture*

## 5. RESULTS AND DISCUSSION

Based on earlier experience it was expected that the increased fineness of cement would decrease the spread value. In Fig. 5. it can be seen that there is no good correlation between the fineness as it is measured at the cement factory with the Blaine method and the spread value measured at the precast factory. One reason for this may be that the superplasticizer reduces the influence of a larger specific surface and on the other hand the packing properties of the system may improve when smaller cement particles are introduced into the system.

The correlation between the position of the observed peak in heat evolution on a maturity scale and the measured spread is much better, Fig. 6. The reaction behaviour reflects in addition to fineness the variations in the chemical composition of the clinker and possible variations in the solubility rate of gypsum. The better correlation between thermal reaction behaviour and spread value shows that also the chemical variations play an important role in the workability variations observed in this test series.

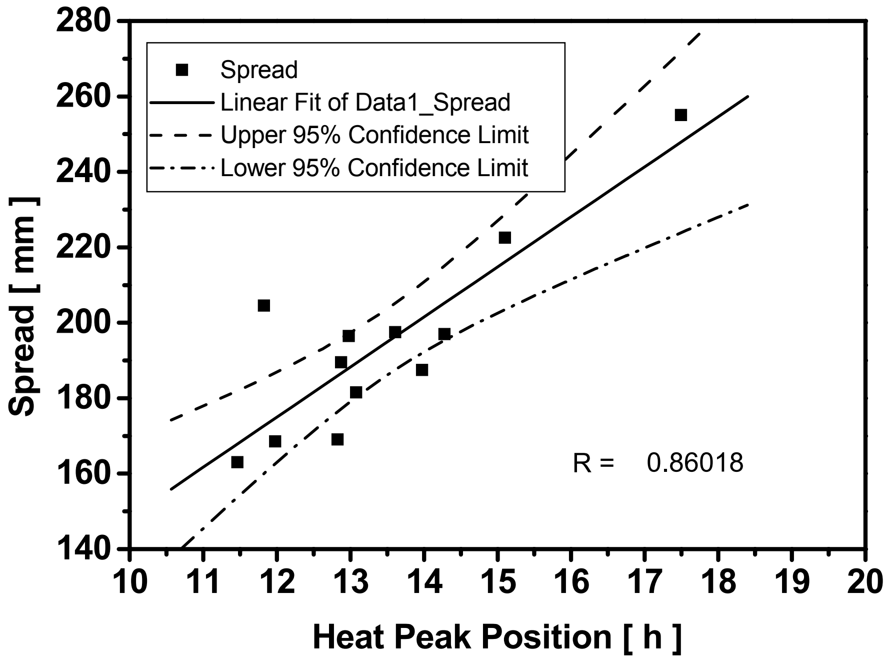


*Figure 6. Correlation between heat evolution and spread, SSP admixture.*

## 6. CONCLUSIONS

1. Variation in the workability of mortar mixes without superplasticizer as measured by the flow table was small. However, the variation in superplasticized mixes is very clear.
2. Variation in heat release is clear between normal and superplasticized mixes and between the two different types of superplasticizers.
3. The variation in heat release between various cement samples was clear.
4. Both the flow table and the semiadiabatic calorimeter can be used at plant conditions to measure the uniformity of cement properties concerning workability and heat release.

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