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Effect of a Naphthalenesulfonic Acid–Formaldehyde Superplasticizer on the Thermal and Physico-Mechanical Properties of Cement Composites

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ABSTRACT

This study examines the thermal and functional properties of a superplasticizer based on a naphthalene sulfonate–formaldehyde condensate in cement systems. Differential thermal analysis (DTA) revealed endothermic effects in the range of 50.23–782.49 °C; the mass loss was 11.568% at 19.49–154.31 °C and 37.834% at 681.44–951.50 °C. The addition of 0.2–1.0% superplasticizer increased the flow of the cement paste by a factor of 1.5–2.5 and the 14-day compressive strength by 4–12%. The results confirm the effectiveness of the admixture for modifying cement compositions.

Keywords: Superplasticizer, naphthalenesulfonic acid–formaldehyde, thermal analysis, DTA, DTG, cement paste, plasticization, flow, compressive strength, Portland cement, physico-mechanical properties.

INTRODUCTION

Thermogravimetric analysis (TGA) and differential thermal analysis (DTA) are widely used to assess the thermal stability and structural transformations of cement compositions. TGA characterizes the change in sample mass as a function of temperature and identifies moisture removal, thermal decomposition and high-temperature degradation. DTA records the endothermic and exothermic effects accompanying these processes and determines the corresponding temperature ranges. Together, these methods make it possible to evaluate the thermal behaviour of a superplasticizer based on a naphthalene sulfonate–formaldehyde condensate and its stability in a cement system.

The superplasticizer obtained from naphthalenesulfonic acid and formaldehyde was subjected to DTA. The results of the analysis are shown in Fig. 1.

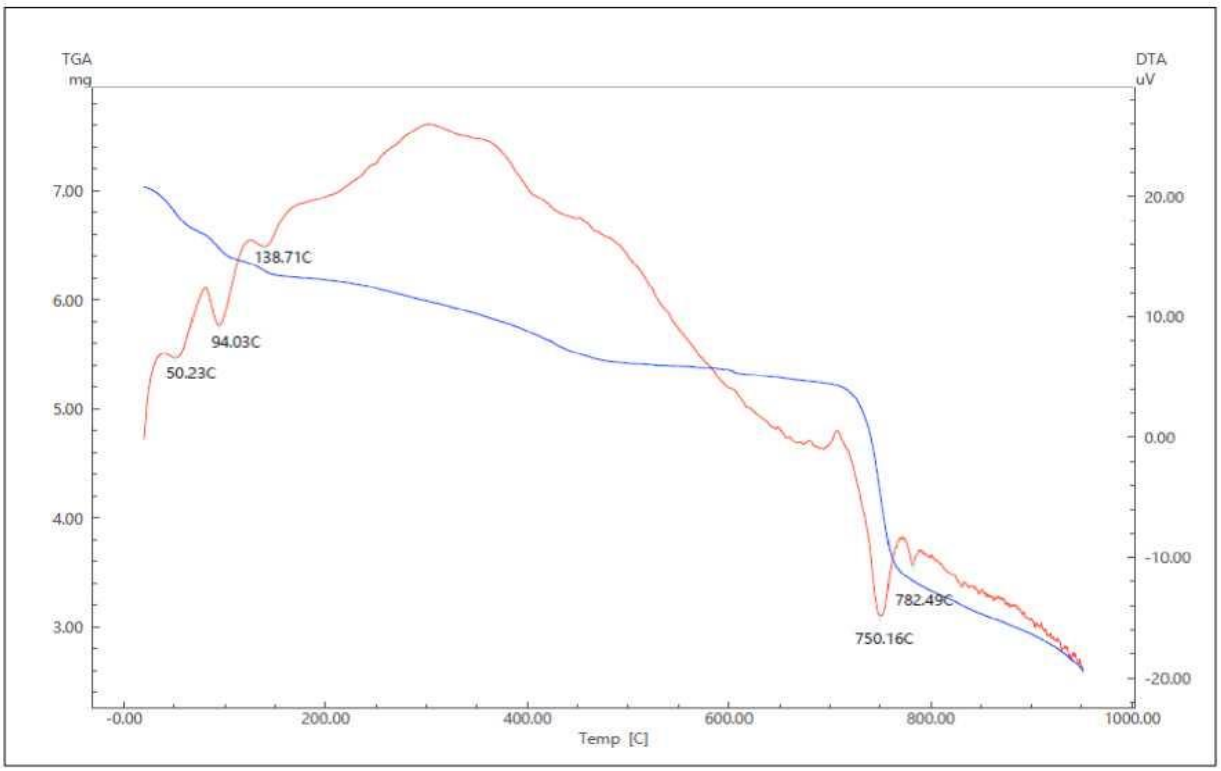


Fig. 1.

Thermal analysis of the synthesized superplasticizer (TGA curve, mg – blue; DTA curve, mV – red)

The thermal behaviour of the newly synthesized plasticizer (naphthalenesulfonic acid–formaldehyde) was studied in the temperature range of 20–1000 °C. The derivatogram, shown in Fig. 1, consists of two curves. Five endothermic effects are observed in the derivatogram at 50.23, 94.03, 138.71, 750.16 and 782.49 °C. The first mass-loss zone occurs between 19.49 and 154.31 °C, during which the sample mass decreases by 11.568% (0.813 mg). Endothermic effects 1 and 2 correspond to the evaporation of hygroscopic water from the plasticizer, and endothermic effect 3 corresponds to the softening temperature of the plasticizer. The mass loss was 11.227% (0.789 mg) between 154.31 and 483.82 °C and 2.561% (0.180 mg) between 483.82 and 681.44 °C; no thermal effects or mass-loss peaks were observed in these ranges. Between 681.44 and 951.50 °C the mass loss was 37.834% (2.659 mg), and two endothermic effects were recorded on the DTA curve at 750.16 °C and 782.49 °C. The main endothermic effect at 750.16 °C corresponds to the decomposition of the plasticizer, i.e. the breaking of bonds in the composition. Most naphthalenesulfonic acid–formaldehyde admixtures reduce the strength of hardened cement paste as the dosage increases. The study of the physico-mechanical properties of cement compositions containing the obtained superplasticizer is therefore essential for its introduction into the concrete industry. The tables below show selected physico-mechanical properties of cement compositions containing the superplasticizer at a constant water-to-cement (w/c) ratio.

No.	Cement, g	Admixture, % by mass of cement	W/C ratio	Flow, cm	14-day strength, MPa
1	100	–	0.43	7	16
2	100	0.2	0.43	9	16.5
3	100	0.4	0.43	13	17
4	100	0.6	0.43	15	17.5
5	100	0.8	0.43	17	18
6	100	1	0.43	17.5	18

Table 1. Test results of cement pastes with the synthesized superplasticizer

The cement pastes were prepared with PC400 D20 Portland cement produced by the Kyzylkumcement plant.

No.	Cement, g	Admixture, % by mass of cement	W/C ratio	Flow, cm	14-day strength, MPa
1	100		0.43	6	12
2	100	0.2	0.43	6	12
3	100	0.4	0.43	7	12.5
4	100	0.6	0.43	9	12.5
5	100	0.8	0.43	13	13
6	100	1	0.43	14	13

Table 2. Test results of cement pastes with the synthesized superplasticizer

The cement pastes were prepared with PC400 D0 Portland cement produced by the Kyzylkumcement plant.

No.	Cement, g	Admixture, % by mass of cement	W/C ratio	Flow, cm	14-day strength, MPa
1	100		0.43	11	11.5
2	100	0.2	0.43	14	11
3	100	0.4	0.43	14	11
4	100	0.6	0.43	16	11.5
5	100	0.8	0.43	17	11.5
6	100	1	0.43	18	12

Table 3. Test results of cement pastes with the synthesized superplasticizer

The cement pastes were prepared with PC500 D0 Portland cement produced by the Kyzylkumcement plant.

As Tables 1–3 show, the obtained superplasticizer has a good plasticizing effect even at dosages of 0.2–1%. Adding more than 1% of the plasticizer makes the hardened cement paste brittle. The best flow results are shown in Table 1: the flow of the cement paste increased by a factor of 2.5, and the 14-day strength of the hardened cement paste increased by 12%. Table 2 shows that the flow of the cement paste increased up to twofold, while the 14-day strength increased by 4–8%. Table 3 shows a 1.5-fold increase in flow and a 4% increase in the 14-day strength.

Conclusion

The thermal and physico-mechanical studies showed that the superplasticizer synthesized from naphthalenesulfonic acid and formaldehyde can be used as an effective plasticizing admixture in cement systems. The DTA/DTG results revealed moisture release at low temperatures, softening at about 138.71 °C and high-temperature thermal decomposition in the range of 750.16–782.49 °C. The addition of 0.2–1.0% superplasticizer to cement considerably improved the workability of the paste at a water-to-cement ratio of 0.43. The best results were obtained with PC400 D20 cement: the flow increased from 7 cm to 17.5 cm, i.e. approximately 2.5-fold, and the 14-day strength increased from 16 to 18 MPa. With PC400 D0 cement, the flow increased from 6 to 14 cm and the strength from 12 to 13 MPa; with PC500 D0 cement, the flow increased from 11 to 18 cm.

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