Effect of Alite Content in Sulphate-resistant Cement on Heat Release in Massive Hydraulic Engineering Structures

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INTRODUCTION

The heat release of cement affects the quality and speed of concrete works, the implementation of the construction project management, and the durability of concrete structures, especially for massive hydraulic structures, in a construction of which sulfate-resistant cement is often used [1].

The greatest amount of heat is released during hydration of tricalcium aluminate C_3A and tricalcium silicate - alite C_3S. At the same time, the Interstate Standard GOST 22266-2013 on sulfate-resistant cement normalizes only the limit value of C_3A content (<3.5%) in mineralogical composition, when there are no special requirements to C_3S content.

Some thermo mechanical and thermo physical concrete properties depending on the ambient temperature, the amount of heat generated, and the mineralogical composition of sulfate-resistant cement coming from cement plants for the Rogun HPP construction are presented.

RESULTS

Sulphate-resistant Portland cement of two different batches, with different mineralogical compositions, coming to the construction site of Rogun HPP from Dushanbe plant "Tajikcement" was investigated. According to GOST 22266-2013, mineralogical composition both of them (Table 1) corresponds to norms.

Table 1. Cements mineral composition by Bogue.

	C_3S	**C_2S**	**C_3A**	**C_4AF**
B1	52,7	18,3	2,76	16,10
B2	70,4	4,76	3,49	16,26

The heat release of the studied cement batches was determined, with a simultaneous assessment of their activity. The test results are shown in Table 2 and in Figure 1.

The Building Code SP 41.13330.2010 [2] gives the norms for the allowable amount of cement heat hydration emitted in hardening time, according to which the studied cement from batch No. 2 does not meet the heat release criterion. An analysis of the results from Tables 1 and 2 allows to conclude that the reason for exceeding the allowable heat release of cement from batch No. 2 is the increased content of the tricalcium silicate C_3S (alite) in its composition.

Table 2. Cements heat of hydration and strenght.

	C_3S content, %	Heat of hydration, kJ/kg (requirement according to SP 41)			Compressive strength, MPa (% grade strength)	
		3 days	7 days	28 days	2 days	28 days
B1	52,7	208,6 (<250)	232,2 (<295)	311,1 (<345)	25,1 (63%)	42,1 (105%)
B2	70,4	290,1 (<250)	358,1 (<295)	409,6 (<345)	26,6 (67%)	37,9 (94%)

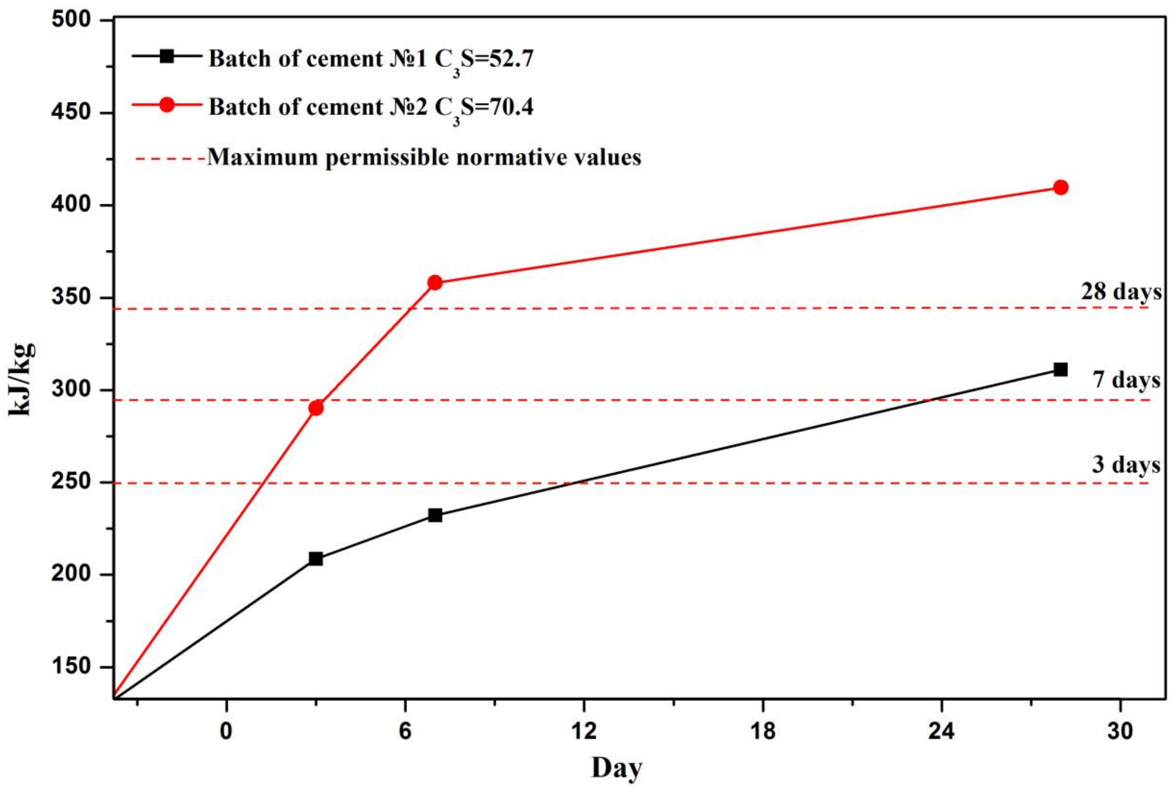

Figure 1. Heat release of two cement batches

Consequently, in order to study a behavior of these batches of cement in massive reinforced concrete hydraulic structures, production (in-process) tests were carried out to determine the heat release, when industrial concrete mixes are used. Monitoring was carried out using thermocouple sensors installed in the epicenter of the concrete block (T1), on the surface of the reinforcement protective layer (T2) and outside the concrete space (T3). The test results are shown in Table 3.

Normative document VSN 31-83 [3] establishes that during concrete works the temperature difference between the core and the side surfaces of the array in hydraulic structures is allowed no more than 16-18°C. When cement No. 1 (C_3S = 52.7%) used, the maximum temperature of the concrete structure core reached 63.1 °C, and the temperature of concrete surface at the same time was 46.2 °C. So, the temperature difference between the core and the surface was 16.9 °C, which meets the requirements of Building Codes SP 41.13330.2010 and VSN 31-83 according to the heat dissipation criterion (Figure 2).

Table 3. Temperature difference between core and surface of structure.

	C_3S content, %	Temperature, °C				
		T_3 Outside	T_1 Core of structure	T_2 Concrete surface	$\Delta T = T_1 - T_2$	VSN 31-83 requirements ΔT
B1	52,7	20-30	63,1	46,2	16,9	Not more than 16-18 °C
B2	70,4	20-30	78,5	50,6	27,9	

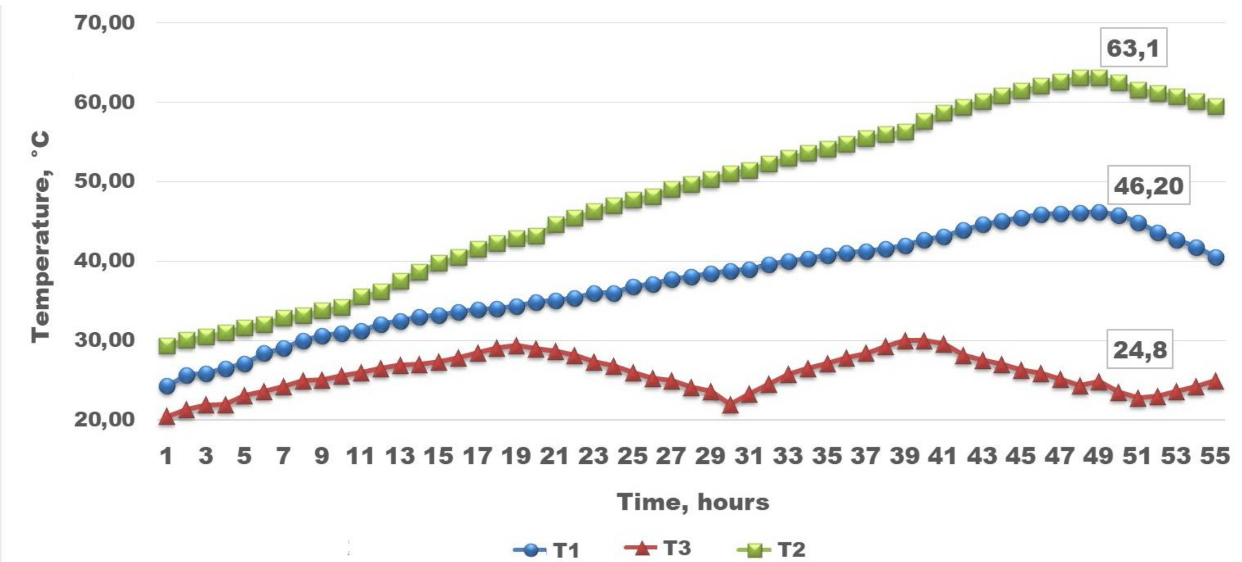

Figure 2. Heat dissipation of concrete produced on cement B1

The maximum temperature of the core of concrete laid with cement No. 2 (C_3S = 70.4%) reached 78.5 °C, with a maximum concrete surface temperature of 50.6 °C. In this case, the temperature difference between the core and the concrete surface was 27.9 °C, which exceeds the permissible norm and does not meet the requirements of the standard (Figure 3).

Sum up: there seem to be necessary to determine the limit content of C_3S, in which the heat release of sulfate-resistant cements will develop within the permissible values of SP 41.13330.2010, and the thermal stress state of massive hydraulic concretes will meet the requirements of VSN 31-83.

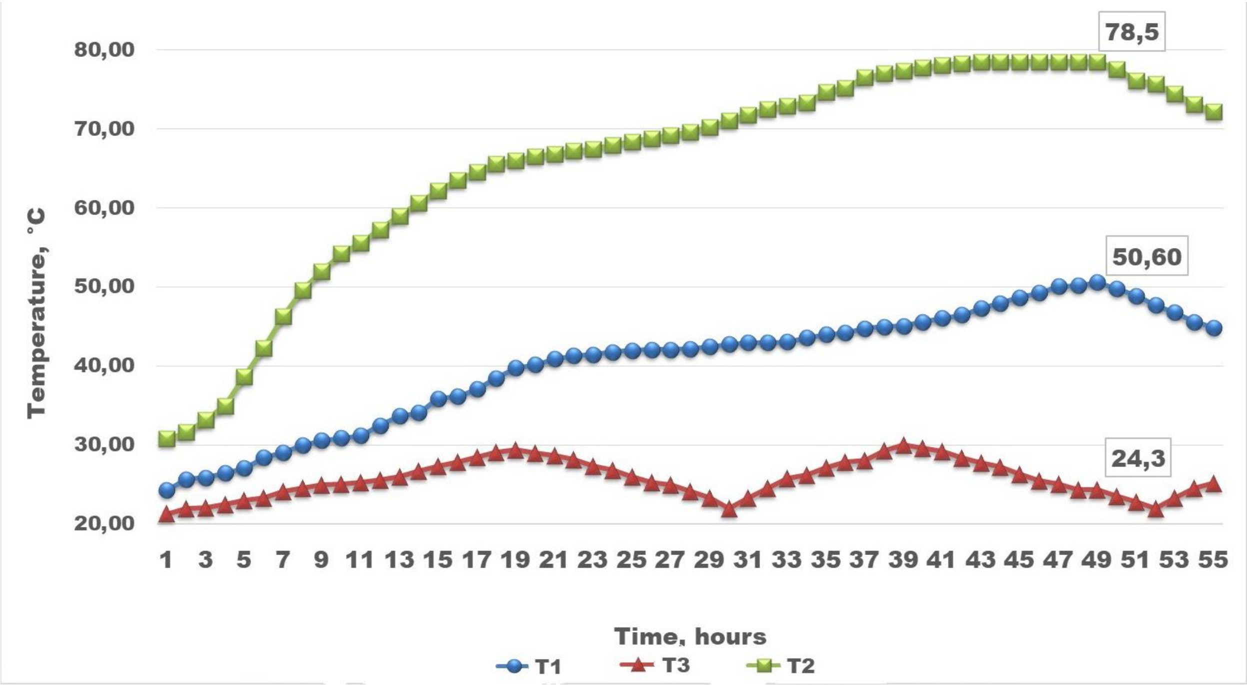

Figure 3. Heat dissipation of concrete produced on cement B2

CONCLUSIONS

It is shown that the alite content in different batches of sulfate-resistant cement can significantly affect the thermo mechanical properties of hardened concrete, which ultimately could lead to cracking and reduce the durability of concrete structures. The experience at construction sites with unstable chemical and mineralogical composition of the delivered cement was considered. With regard to the concreting of massive structures, the norms for sulfate-resistant cement need to be clarified and revised (or updated) in terms of determining the requirements for its mineralogical composition.

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