High-Quality Concretes for Foundations of the Multifunctional High-Rise Complex (MHC) «Akhmat Tower»

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Abstract. The paper presents results of studies of monolithic concrete mixes and concretes produced with the integrated use of local natural and technogenic raw materials, including waste scrap and crushed bricks. We developed optimal compositions of monolithic concretes and studied their technological and physical-mechanical properties.

Keywords: High-strength concrete · High-quality concrete mix · Filled binder · Technogenic wastes · Mineral technogenic filler · Monolithic concrete

1 Introduction

The modern materials science and construction now deal with an important national economic and engineering problem: development of efficient technologies for producing high-strength monolithic concretes through the integrated use of technogenic raw materials to obtain secondary raw materials for concrete, while eliminating the enormous environmental damage caused by waste “cemeteries” (Bazhenov et al. 2006; Salamanova et al. 2017; Lesovik et al. 2012; Murtazaev et al. 2009; Kaprielov et al. 2018) in Russia and the world and, in particular, for the Chechen Republic, considering construction of 435-m high-rise complex «Akhmat-Tower» in Grozny City (Udodov 2015; Koryanova et al. 2018; Salamanova and Murtazaev 2018).

2 Methods and Materials

Our experimental studies used local additive-free Portland cement of PC 500 D0 grade as a binder. Natural sand from the Chervlensky deposit of the Chechen Republic was used as a fine filler. Local gravel of 5–20 mm fractions from the Argunsky and Ser-novodsky deposits of the Chechen Republic and imported crushed stone of 5–20 mm

fraction from granite-dabase rocks of the Alagirsky deposit of the Republic of North Ossetia-Alania were used as a coarse filler.

As plastifying agents in accordance with GOST 24211-2008 “Additives for concrete. General technical requirements” modern additives of various manufacturers of building chemicals (POLYPLAST, TOKAR, etc.) were used.

The raw materials for the production of dispersed technogenic mineral fillers (DTMF) were local materials, mainly technogenic, namely concrete scrap, crushed ceramic bricks (CCB), ash and slag mixture from the Grozny heat and power plant (HPP) and very small non-conditioned quartz sands ones were used in comparative tests.

All the DTMFs were ground for 5 min in MV-20-EX laboratory vibratory ball mill with a loading volume of 5–6 L to obtain a specific surface of 450–600 m²/kg.

3 Results and Discussion

The Filled Binder (FB) formulation was developed and investigated with activity 60–71 MPa with concrete scrap and CCB fillers with ratio 70:30%. The proportion of the mixture of filler in FB was 25 and 40% by weight of the binder.

Due to the fact that for designing the underground part of the Akhmat Tower multifunctional complex, concrete of different strength classes (B40, B75-B80) was laid, the task was to develop high-quality concrete mixes (HCM), starting from the middle B40-B50 classes and ending with high-strength concrete of B80-B90 classes, with the integrated use of local raw materials, including with technogenic nature.

Fig. 1. Temperature change and stress characteristic in fresh concrete with limited deformation: σ_{CS} - internal compressive stresses; σ_{CST} - the same, tensile; t_N - initial temperature of concrete mixture; t_{max} - the same, maximum; t_{AT} - ambient temperature (air); I, II, ... V - stages (periods) of process of heat dissipation of the concrete mix in time; curve 1 - kinetics of heat dissipation of concrete with PC; curve 2 - the same with FB

In massive building constructions, such as the Akhmat Tower MFC base plate, because of their large dimensions, as a rule, the heat from cement hydration is slowly released into the air or into adjacent structural elements, as a result of which the core of the monolithic element heats up much faster and stronger than the shell. Therefore, we investigated thermophysical processes of the developed compositions.

Figure 1 schematically shows the dependence of temperature and voltage due to external pressure generated by this concreting technology.

The dependence of heat release curves in time is conventionally divided into 5 stages (Table 1).

Table 1. The main stages (periods) of the process of heat dissipation in time of concrete mixes with various binders

Stage №	Duration, h		Description
	With PC	With FB	
1	0–2	0–8	The initial stage without raising the temperature of the concrete mix (dormant period). This period is significantly increased due to the use of surface-active substances (surfactants) in the composition of FB, hardening retarders, etc.
2	2–6	8–15	Temperature increase due to hydration of the binder, no measurable stress, because in the plastic concrete, thermal expansions are converted to relative compression. At the end of this stage, the temperature is referred to as “the first temperature at zero stress” t_{01}
3	6–13	15–24	Further heating of the concrete, the strength of the concrete increases and a compressive stress is formed, partially decreasing because of relaxation. Stage III ends when the maximum temperature t_{max} is reached
4	13–24	24–72	Heat transfer prevails: the temperature of concrete and compressive stress in concrete decrease, a part of compressive stress decreases because of relaxation. The “second temperature at zero stress” t_{02} is reached, which significantly exceeds t_{01} in cooling rate and age of concrete
5	24–72	72–144	Further cooling and increasing tensile stress, which are partially reduced due to relaxation. If the tensile stress reaches the tensile strength of the concrete under tension (at $\Delta T_{крит}$) through cracks are formed

According to calculations (Kapielov et al. 2018), the temperature difference between the upper surface layers of concrete slab and outside air ΔT_1 should be no more than 20 °C, and the difference between the side layers ΔT_2 - no more than 30 °C.

4 Conclusions

Thus, analysis of data confirms the effectiveness of the use of FB with DTMF in high-quality concretes used for concreting massive structures. We established that the peak of the maximum heat release t_{max} from the exotherm of cement in (massive) concrete on HB was reduced by 30–35% in comparison to the concrete with PC (from 70–75 °C to 50–55 °C).

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