Optimization of concrete works technological process in the winter period

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Abstract. The goal of this study was to optimize the technological process of works related to concreting in the winter period to ensure a high-quality overhaul process. Demonstrate by laboratory research the effect of using various methods of concreting on the quality of work performed. To study thermodynamic processes, a stand is used that monitors the temperature fields in the volume of the concrete mixture, as well as heating elements with a positive coefficient of thermal resistance. The distribution of temperature fields in the volume of concrete mixture was studied depending on applied methods of concreting. Studies have shown that in order to reduce the time of repair work in the winter period, it is necessary to heat up the base of structures, and apply additional heating for critical structures. The experiments have shown that the use of heating elements with a positive coefficient of resistance when carrying out concrete work in the winter period of time will provide a high-quality performance of repair and construction work.

1. Introduction
Achievement of the required quality of concrete products manufactured in the low temperature range is possible only if a favorable concrete hardening regime is observed in the initial period of time. Optimization of the production process of concreting in the winter overhaul is a difficult and complex task. The choice of the optimal parameters of the concreting process depending on the composition of the concrete mixture, the thickness of the structures, their location depends on the time of work and the quality of provided services. When carrying out work related to major overhaul in the winter period, it is necessary to maintain a given temperature throughout the volume of the concrete mixture, taking into account the technological process of concreting and climatic factors [1-5].

The different behavior of concrete mixes during hardening in summer and winter time is explained by the fact that at low temperatures all hydration reactions slow down and when the temperature reaches the lower limit of +5°C the strength gain in concrete mixes sharply decreases. At temperatures below 0°C, chemically unbound water turns into ice and increases in volume by about 9%. The structure of the hardened mixture does not withstand the resulting stresses. The strength of the frozen concrete is due only to the bonds of frozen water. With an increase in the temperature regime, the process of hydration of the concrete mixture continues, but the destroyed structure does not restore. As a result, the expected strength parameters of the concreted product are not achieved, and it is no longer possible to correct this [6-10].
2. Methods
The required quality of concrete products manufactured in the low temperature range is possible only if a favorable concrete hardening regime is maintained in the initial period of time. Depending on the phase of concrete hardening, the parameters of the heat capacity and thermal conductivity of the concrete mix change and the uniformity of the distribution of temperature parameters in the concrete volume changes, which leads to a temporary change in the hardening and strength development processes. The resulting stresses create microdefects, reducing not only the quality of work, but also reducing the service life of the structures concreted at low temperatures. When carrying out overhaul works, especially in winter, the scale of concrete work usually does not have large volumes, but the quality of the work performed significantly affects the terms of the further operation of the building [11, 12].

To study thermodynamic processes and optimize the technological process, and in fact optimize the temperature regimes, we used a laboratory complex created on the basis of a TPM138 "OWEN" brand device with a set of thermocouples. For the implementation of additional heating, heating elements of the "EFSH" brand were used, the temperature parameters of which change depending on changes in external meteorological conditions.

Heating elements of the "EFSH" brand, which are shown in figure 1, are manufactured by the Thermostat LLC, which is part of the Technopark organization of INRTU.

![Heating elements of the "EFSH" brand.](image)

The percentage change in resistance of the heating element versus temperature is shown in figure 2.

![Percentage change in the resistance of the "EFSH" heating element depending on the temperature.](image)
The parameters of the heating elements were monitored with an "OWEN" device of the "IMC-PH1.SH1" brand. This device simultaneously controls the parameters of voltage, current consumption and power.

From the above graph it follows that the "EFSH" heating elements have a positive coefficient of resistance and change their resistance in a given temperature range. This property allows them to be used for positional regulation of heating in the case of a decrease in the temperature of the concrete mixture without external control devices [13, 14].

3. Results and discussion

We have carried out experiments to investigate the thermodynamic processes that occur in the hardening concrete mixture during concreting at an ambient temperature of −15°C. The thickness of the concrete mixture was 200 mm, the temperature of the concrete mixture was controlled with a step of 50 mm.

In the first experiment, with an ambient temperature of −12°C, a prototype was made from a concrete mixture with a temperature of +15°C. The temperature of the concrete mixture corresponded to the technical regulations TR 147-03 for the production of structures from cast concrete mixtures at temperatures ranging from −10°C to −15°C. Figure 3 shows a graph of temperature field changes in the process of concrete hardening with an initial temperature of the concrete mixture of +15°C: the graphs correspond to the temperature: 1 - on the surface of the concrete base; 2 - at a depth of 150 mm from the surface; 3 - at a depth of 100 mm; 4 - at a depth of 50 mm; 5 - on the surface of the concrete mix.

![Figure 3. Experiment №1. Change in the temperature field with the initial temperature of the concrete mix 15 °C.](image)

It can be seen from the graphs that it is impossible to carry out concrete work in this way, within one hour the temperature of the entire volume of the concrete mixture dropped below zero.

In the second experiment, a similar process was carried out at a concrete surface temperature of + 60 °C, the results of the experiment are shown in figure 4.
Figure 4. Experiment №2. Change in the temperature field with the initial temperature of the concrete mixture +60°C.

The graphs show that, despite the fact that directly on the surface of the concrete mix, the temperature dropped to zero within 28 hours, the average temperature of the entire volume approached zero after 48 hours. When providing additional insulation, it is possible to increase the residence time of the concrete mixture at positive temperatures, but this method is not suitable for critical structures that must have the design hardness necessary for the safe operation of the building.

Figure 5 shows the results of the third experiment, when, in addition to the preliminary heating of the concrete surface, a "EFSH" heating element was installed on the concrete prototype.

Figure 5. Experiment №3. Change in the temperature field with the additional use of a "EFSH" heating element.

It can be seen from the graphs that on the third day the concrete mixture reached a stationary mode, in which the temperature is positive and evenly distributed over the entire volume of concrete. The study of thermodynamic processes shows that this method can provide a high quality of concrete work performed in the winter period.
4. Conclusions
The experiments carried out showed that it is impossible to carry out work related to the concreting process in the winter period without preliminary heating of the structures. The preliminary heating of massive structures on which concrete work is carried out allows to ensure positive temperatures of the concrete mixture for up to several days. To carry out important work on major overhaul, where the designed strength is required, it is necessary not only to additionally heat the base of the structure on which the concrete work is carried out, but also to use additional heating of the concrete mixture. The best option for this are heating elements with a positive coefficient of resistance. Using these heating elements, it is possible to manufacture mobile, portable structures allowing to ensure high quality concrete work and reduce the cost of work.

Studies [15, 16] have shown that if you use electronic control devices, it is possible to improve the heating characteristics, but this will increase the cost and reduce the reliability, as well as require qualified personnel. From the presented graphs it can be seen that heating elements with a positive coefficient of resistance provide positional control of the heating layer, thereby ensuring the maintenance of the concrete mixture in a given temperature range until the maximum strength is achieved.

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