Cold water concreting technology using thermoactive formwork

Dmitriy Imaykin, Ruslan Ibragimov

Kazan State University of Architecture and Engineering, Kazan, 420043, Russia
E-mail: rusmag007@yandex.ru

Abstract. The paper presents the study results of temperature and strength indices of structures while performing isothermal warming in thermoactive formwork. The effectiveness analysis of thermoactive formwork panels warming in the freezer with complex additive was also carried out. Thermoactive formwork is a box-shaped structure consisting of 20 mm thick panels of laminated plywood with built-in wires. The total size of the thermoactive formwork for concrete construction was 200x200x200 mm. Concrete mixture was laid in thermoactive formwork in layers and caked by rodding. Then concrete mixture was warmed up using heating wires. Samples were placed in the freezer at a temperature of 18 °C for 1, 3, 7, 28 days. However, the samples were kept in a positive temperature of about 16 °C during the first ten hours while the concrete mixture was stored in the freezer. According to the experiment results it was established that the lowest temperature was in the center of a formwork, which proved that this formwork could be used at an ambient negative temperature. It was revealed that heavy weight concrete with complex additive had a compressive strength higher by 57 % compared to the control sample.

Keywords: cold-weather concreting, technology, heaters, additive.

1 Introduction

Today, many programs have been launched to provide citizens of Russia with housing, so the construction industry is entrusted with a serious task that is to increase house-building [1-4]. Technological processes of the construction industry are influenced by many factors, namely: change of temperature and weather conditions, technical characteristics of materials and mechanisms, change of requirements to structures quality [5-8].

Monolithic construction being the most advanced construction technology holds a leading position both in industrial and civil construction, and in road and bridge construction [9-12]. And therefore, widespread use of monolithic house-building in housing construction is one of the ways out of the current situation [13-16].

In order to reduce the construction time in monolithic construction, it is necessary to accelerate the strength development time of a concrete installed and to speed up the aging period before a formwork has to be removed [17-20]. For this purpose, the heating methods with complex additives and electrical heating methods using heating wires are very effective. For example, according to [21-24] such usage reduces electricity consumption by 10-25 % compared to other methods of concrete electrical heating at negative temperatures.

That is why we have designed a thermoactive formwork panel. For greater efficiency, a heating experiment with a complex type 2 CRIOPLAST P25 additive was carried out. The test sample was heated in a heating formwork without using additives [25-27].

2 Materials and methods

The type 2 CRIOPLAST P25 additive is a mixture of thiosulfate and sodium rhodanide, polymethylene naphthalene sulfonates and antifreezing inorganic sodium salts [28].

The main benefits of this additive are described as follows:

1. The additive ensures cement hydration flow processes at a concrete hardening temperature not lower than minus 30 °C.
2. The additive contributes to critical strength development using concrete and mortar mix at the age of 28 days at the design hardening temperature not lower than minus 30°C.

3. The additive increases the concrete-mix consistency from P1 to P5, increases mortar mix consistency from Pk1 to Pk4 (no strength loss during all hardening periods).

4. The additive reduces water demand by 20 -25 % while gauging.

5. The additive increases frost resistance and reduces permeability.

6. The additive does not contribute for efflorescence to build up on the structure surface and does not cause corrosion in a concrete reinforcement.

The type 2 CRIOPLAST P25 additive is especially effective when used at an increased temperature of the concrete mixture:

1. The additive contributes to preserving properties of concrete and mortar mix prior to the beginning of active heat treatment while erecting concrete and reinforced concrete structures.

2. The additive lowers the temperature of ice formation in the mixture and provides for cement hydration during enforced periods of heat treatment absence, significantly intensifies strength development while subsequently exposed to positive temperatures.

3. The additive can effectively be used in transporting concrete mixture at a temperature not lower than -30 °C. It is a frost additive for “hot weather” and “cold weather” concretes at an ambient temperature up to minus 30 °C in accordance with the Russian Federation standard 24211-08.

4. The additive provides for reducing the concrete heat treatment time in comparison with monocomponent antifreeze additives.

In order to prepare a concrete mixture, we used M400 cement, enriched sand of the Kamskoye deposit of 2.8 fineness modulus, 5-20 mm fraction gravel produced from the Satkinskoye deposit rocks (Chelyabinsk region). The ratio of all the components amounted to 1:1, 4:3:1 (cement:sand:gravel). The complex additive was introduced into the pre-mixed concrete mixture with the gauged water remaining shortly before the mixing was completed [29-30]. This allowed to obtain a more flexibilizing effect. The additive dosage rate was about 6 % of the cement weight. At the same time, the amount of water was selected so that the consistency of concrete mix would correspond to P2 class according to GOST 7473-94. The water-to-cement ratio of the sample with the additive was W/C = 0.38, and that of the sample without additive was W/C = 0.5.

Concrete mixture was laid in thermoactive formwork (Figure 1) in layers and caked with rodding. Then concrete mixture was warmed up using heating wires. Samples were placed in the freezer at a temperature of 18 °C for 1, 3, 7, 28 days. However, the samples were kept in a positive temperature of about 16 °C during the first ten hours while the concrete mixture was stored in the freezer.

![Figure 1](image)

**Figure 1.** Formwork design: 1-concrete mixture; 2-thermocouple; 3-formwork.

Previously [3], it was established that when concreting monolithic structures, it is most important to
control the temperature of three main areas in a concrete body, namely:
- in the corners of structures where the heat outflow is during concreting in open air at a negative air temperature;
- in the middle of the formwork panels, where the concrete is most intensely warmed by external heating elements;
- in the center of the monolithic structure, with the highest temperature caused by self-heat dissipation of a hardening concrete.

In order to determine the temperature value inside the concrete mixture, we used a Thermochron measuring complex installed in the corner, in the center and in the middle of the heating formwork wall. The results are listed in Table 1.

| Heating time, h | Wall | Centre | Corner |
|----------------|------|--------|--------|
| 1              | 17   | 15.5   | 17     |
| 2              | 17   | 15.5   | 16.5   |
| 3              | 16.5 | 15.5   | 16.5   |
| 4              | 16.5 | 15.0   | 16.5   |
| 5              | 16.5 | 15.0   | 16.5   |
| 6              | 16.5 | 15.0   | 16.0   |
| 7              | 16.5 | 15.0   | 16.0   |
| 8              | 16.5 | 15.0   | 16.0   |
| 9              | 16.0 | 15.0   | 16.0   |
| 10             | 16.5 | 15.0   | 15.5   |

3 Results
Thermoactive formwork is a box-shaped structure consisting of 20 mm thick panels of laminated plywood with built-in PSV-1.2 wires (Figure 2). Overall design size is 200x200 mm, height is 200 mm.

![Figure 2. Design of the formwork panel: 1- formwork; 2-heating element.](image)

The test samples' strength indicators at the hardening age of 1, 3, 7, 28 days were determined under normal conditions (Table 2).

| Name of the additive | Compression strength (MPa) of concrete per days. |
|---------------------|-------------------------------------------------|
|                     | 1       | 3       | 7       | 28      |
No additive & 6.24 & 14.9 & 24.3 & 31.1 & 100 \% & 100 \% & 100 \% & 100 \% \\ \hline type 2 CRIOPLAST P25 & 6.9 & 18.0 & 33.3 & 48.8 & 110 \% & 121 \% & 137 \% & 157 \% 

4 Conclusions

The following conclusions can be drawn from the results of the research.

1. The design of the thermoactive formwork panel allowing to concrete construction structures in cold weather conditions was developed. The concrete body temperature has slight deviations from the average value. Thermoactive formwork is a box-shaped structure consisting of 20 mm thick panels of laminated plywood with built-in PSV-1.2 wires.

2. According to the experiment results, the lowest temperature was observed in the center of a formwork, which proves that this formwork can be used at an ambient negative temperature.

3. A concrete with complex type 2 Cryoplast P-25 additive has a compressive strength higher by 57 \% compared to the control sample when concrete heat treated.

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