TATIANA KUGAEVSKA
e-mail: strelanebo@yandex.ua

Thermal processing of concrete and ferroconcrete products designed to accelerate the solidification them. This process is energy intensive, so it makes sense to expand ways search to decrease energy consumption in the mentioned process.

One of the areas of energy efficiency in the manufacture of concrete and ferroconcrete products are the way they thermal treatment using only the heat released by the interaction of cement with water [1]. Loss of heat camera with this method should be minimized. The application of special heat insulating design that covers these products.

When heat treatment concrete and ferroconcrete products using only the heat released during the hydration of cement, concrete terms set required compressive strength decreased compared with hardening products in natural conditions but increased compared to their thermal or steam treatment with the use of coolant.

To analyze the factors that provide application feasibility of thermal treatment of concrete products using only the heat released during the hydration of cement necessary to have methodology for forecasting the intensity solidification of concrete products in the studied conditions.

Another direction of decrease the cost of concrete and ferroconcrete products is the use of solar energy for acceleration of hardening. Thus, in the patent [2], the method of heat treatment of concrete and concrete products using air heated in the solar collector. In the patent [3] for similar purposes is proposed to use heated in the collector solar water. Implementation of these production of heat treatment of concrete and concrete products requires a number of experimental and theoretical studies.

DEVELOPMENT OF METHODOLOGY FORECASTING OF INTENSITY SOLIDIFICATION CONCRETE PRODUCTS IN THE ALTERNATIVE METHODS OF HEAT TREATMENT

Chapter 1. The method of forecasting intensity solidification of concrete products for their thermal treatment using only the heat released during cement hydration. Research intensity of heat release during hydration of cement devoted a number of works. Thus, in the books [4], [5] analyzed the factors that influence this process.

In the source [6], in particular, the relationship between performance and heat release binding strength of concrete based on basicity; approach to the evaluation of heat release hardening cement unisothermal conditions that are programmed; kinetics of heat release in the early stages of hydration of cement, which expanding; heat release rate of cement at high temperatures.

Directions of research results using heat release of hydration of cement during its rise to certain features of the relevant experiments.

In the source [6] states that traditionally heat release of hydration of cement during its adiabatic or isothermal measured methods and measurement results are not always adequate to the real non-isothermal conditions of technological processes.

The method of determining the specific heat release of cement in concrete, which solidifies in adiabatic conditions given in the standard [7]. This method is used in the construction of massive structures. The results of studies using the above method are given, for example, in the sources [8, 9]. But the process of solidification heat insulated concrete products and samples are not adiabatic.

To determine the effect of concentration super-plasticizer and type complex additives plasticizing effect on cement solidification temperature dependence of the authors [10] used a device that has a cell for placing samples inside a heat-insulated casing. In work emphasizes that investigations conducted using the specified device were carried out on specimens made of cement paste, cement-sand mortar and concrete mix. But the article is not considered thermotechnical aspects of these tests.

In [11,12] presented the results of research of temperature change cement paste with different types of chemical additives (and no additives), which solidifies in insulated containers. In the above articles are not thermotechnical peculiarities of these studies. In addition, it is known that the intensity of heat release cement products driven by temperature (sample). Hardening concrete significant proportion of the heat is spent on heating fillers. Therefore which hardens concrete temperature is lower than the temperature of the cement paste which hardens on what should be considered.

In [13] a set of principles modeling strength concrete by hydration of cement and noted that the proposed model can be used for fixed values of the temperature of concrete. It must be emphasized that the change in temperature of concrete products for their thermal treatment using only the heat that is released during cement hydration previously unknown.

The sources [11, 14] analyzed the advantages and disadvantages of the proposed authors forecasting model performance concrete.

Summary. The intensity of solidification concrete and concrete products associated with temperature and humidity conditions of the process.

The Temperature mode of hydro-insulated concrete products, which harden using only heat that is released during the interaction of cement with water, driven by a number of factors, including: the composition of the concrete mix and its initial temperature; thermal properties of structures fence chamber in which the process of thermal treatment of these products; thermotechnical properties heat insulating structures, which are covered products (provided that this design is used); the air temperature workshop.

The method of forecasting intensity solidification hydro-insulated concrete and concrete products in their thermal treatment using only the heat released during cement hydration, based on research in laboratory conditions temperature mode solidification concrete. Laboratory research of this process should be divided into two stages. The main objective of the first phase of research - approximately forecasting intensity solidification hydro-insulated concrete and concrete products in their thermal treatment using only the heat released during cement hydration. Purpose of the second phase of research - a more accurate prediction of this indicator.

The basic principles of the first stage of laboratory research.

Experimental research of the first phase are carried out as follows:

- The composition of concrete mix made in laboratory conditions must match the composition of concrete mix produced in factory conditions;
- Concrete samples after their manufacture located in laboratory cell; if necessary, the surface of concrete samples hydro-isolated;
- Initial temperature materials, shapes and equipment used in the study should be identical;
- Allowed in the insulating chamber one sample cube; in this case it is necessary to conduct several tests with the same initial temperature of the investigated system and the same air parameters laboratory; the analysis of experimental data should be considered a possible difference between the specified temperatures;
- During the period solidification concrete samples is determined by temperature change components of the investigated system, the temperature inside each sample; temperature forms; temperature distribution inside

structures that fence heat-insulating chamber; The surface temperature of these structures;

- In terms of concrete hardening heat-insulating chamber is divided into various periods of time; for these periods consist of thermal balances; using heat balances calculated heat release of hydration of cement it for a certain period of time, J., and determined the corresponding specific heat release cement, J / kg.
- After a selected period of solidification concrete samples in the insulating chamber defined by their compressive strength; This indicator can be set by a devastating one of the terms specified appropriate standard; to determine the kinetics of recruitment strength concrete after unloading samples from the camera can be used non-destructive method (Fig. 1).

Figure 1. Determination of compressive strength using the device IPS-MG- 4.03

Methodology of calculating the specific thermal release cement by hydration during temperature increase which hardens in the heat-insulating chamber hydro-insulated concrete samples is given below.

If the temperature of the outer surface layer of insulation is equal to room temperature, the amount of heat $Q_1^{/}$, J, released by the interaction of cement with water for a certain period of time, calculated by the dependence

$$Q_1^{/} = Q_1 + Q_2 + Q_3 + Q_4 , \qquad (1)$$

where Q_1 – the amount of heat it takes to heat the concrete samples during their solidification during the selected time interval, J;

Q_2 – the amount of heat it takes to heat forms for the selected time interval, J;

Q_3 – the amount of heat it takes for a certain period of time to warm up the heating of structures, fence camera, J;

Q_4 – the amount of heat it takes for a certain period of time to heat the capsules, which are sensors designed to measure the temperature at which hardens concrete specimens, J;

The amount of heat it takes to heat the waterproofing material and temperature sensors, is neglected; if under certain circumstances influence value that neglect will be essential, they should be taken into account when drawing up the heat balance.

If the temperature of the outer surface layer of thermal insulation is higher than room the air temperature, the amount of heat $Q_1^{/}$, released by the interaction of cement with water for a certain period of time, J, is equal to

$$Q_1^{/} = Q_1 + Q_2 + Q_4 + Q_5 + Q_6, \quad (2)$$

where Q_5 – the amount of heat which is consumed for heating designs fence camera for a certain period of time, J;

Q_6 – chamber heat loss to the environment for a certain period of time, J; heat loss to the environment the system under study, it is useful to define as recommended sources [15] - [18];

Explanation of the other components of this relationship above.

The amount of heat it takes for a certain period of time to heat for arbitrary material calculated by the general formula

$$Q = c \cdot m \cdot (t_f - t_i), \quad (3)$$

where c – heat capacity per unit mass of material, J / (kg · ºC);

m – mass of material, kg;

t_i – initial temperature material for time period selected, ºC;

t_f – final temperature material for time period selected, ºC;

The experimental results obtained in accordance with the provisions of the first stage of laboratory research. Experiments were carried out on samples of heavy concrete. Sample size - 15×15×15 cm. The composition of the concrete mix was part Portland cement 500 normalized composition.

Figures 2 - 7 shown the change in temperature which hardens in the heat-insulating chamber hydro-insulated concrete samples. The initial temperature of the samples shown in these figures corresponds to the temperature of the concrete mix right after placing forms of this mixture in the chamber.

On figure 2 shows the change in temperature of heavy concrete, which hardens in the heat-insulating chamber during the 46 hours (C = 450 kg/m^3, W / C = 0.65). During 7 hour concrete temperature increased from 18,1 °C to

21,6 °C (Δt = 3,5°C), and after 22 hours the temperature of the concrete was 31,1 °C (Δt = 13°C). From the 23 th to the 26 o'clock temperature of concrete unchanged and equal to 31,0 °C, and then gradually decreased.

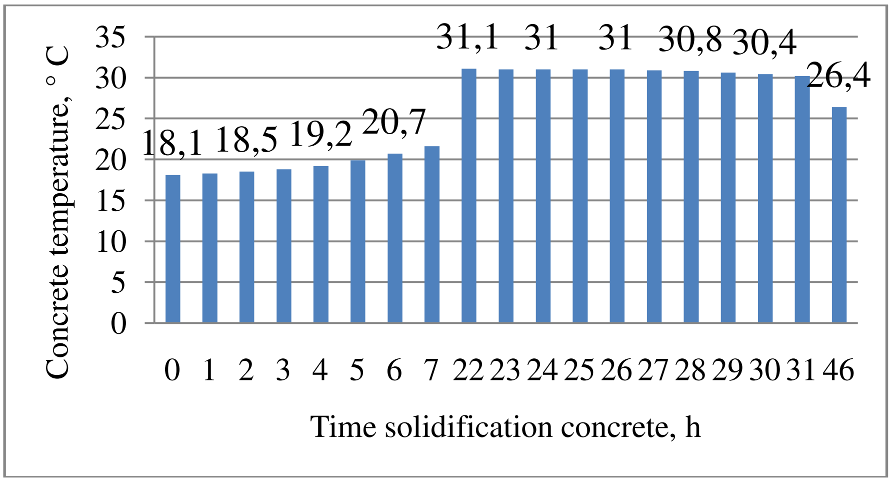


Figure 2. Change in temperature of heavy concrete
(C = 450 kg/m^3 W/C = 0.65)

Figure 3 shown change in temperature of heavy concrete, which hardens in the heat-insulating chamber during the 46 hours (C = 450 kg/m^3, W/C = 0.65). Beginning concrete hardening occurred at the end of the day. Concrete temperature within 15 hours solidification changed from 19.0 to 31,6 °C (Δt = 12,6 °C), and after 21 hours was 33,1 °C (Δt = 14,1 °C). The temperature concrete of 33,1 °C and kept within 22 o'clock solidification and thereafter began to decline gradually and over 46 hours amounted to 27,5 °C.

Compressive strength thermal and hydro-insulated concrete examples of this composition after stripping on average 34.5% higher than the compressive strength of concrete hydro-isolated samples hardened in air conditions.

Figure 4 shows the change temperature of heavy concrete, which hardens in the heat-insulating chamber for 48 hours (C = 450 kg/m^3 W/C = 0.55). 6 hours concrete temperature increased from 15,7 °C to 18,0 °C (Δt = 2,3 °C). After 24 hours, the temperature of the concrete was 29,1 °C (Δt = 13,4 °C), and then gradually decreased.

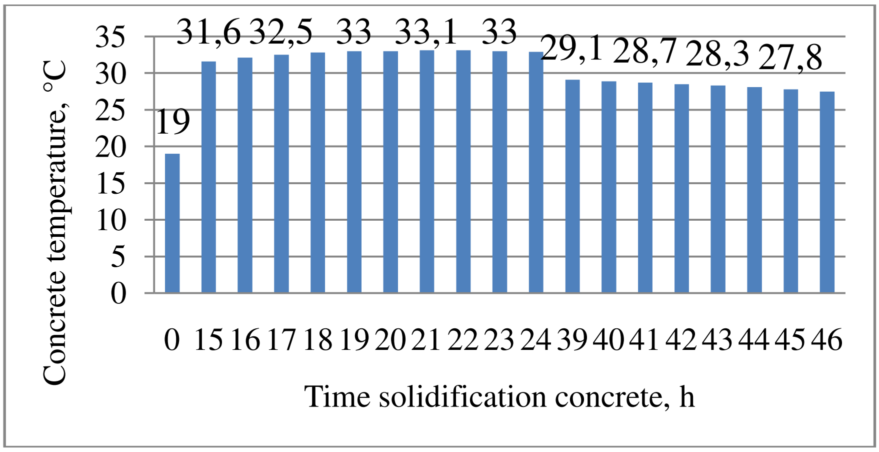


Figure 3. Change in temperature of heavy concrete (C = 450 kg/m^3 / C = 0.65; beginning of concrete hardening occurred at the end of the day)

Compressive strength thermal and hydro-insulated concrete examples of this composition after stripping on average 32.9% higher than the compressive strength of concrete hydro-isolated samples hardened in air conditions.

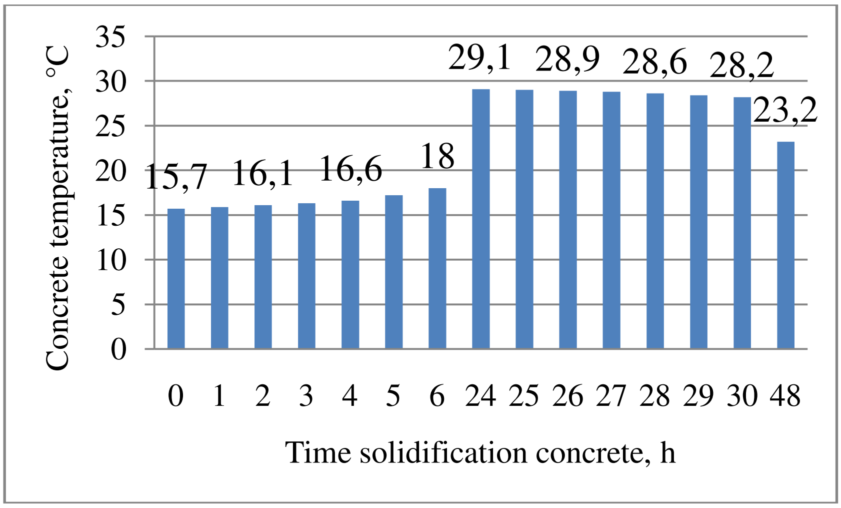


Figure 4. Change in temperature of heavy concrete
(C = 450 kg/m^3 W/C = 0.55)

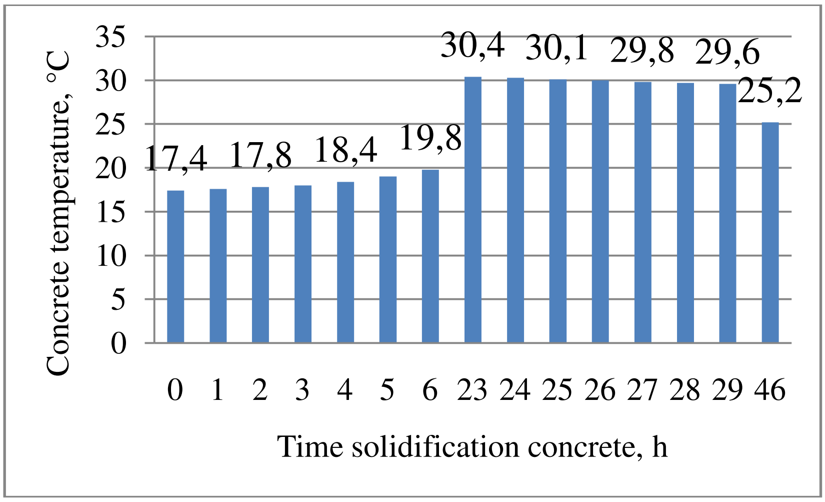


Figure 5. Change in temperature of heavy concrete
(C = 450 kg/m^3 W/C = 0.45)

Figure 5 shows the change in temperature of heavy concrete, which hardens in the heat-insulating chamber during the 46 hours (C = 450 kg/m^3 W/C = 0.45). During 6 hour concrete temperature increased from 17,4 °C to 19,8 °C (Δt = 2,4 °C). After 23 hours the temperature of the concrete was 30,4 °C (Δt = 13,0 °C), and then gradually decreased.

Compressive strength thermal and hydro-insulated concrete examples of this composition after stripping on average 33.7% higher than the compressive strength of concrete hydro-isolated samples hardened in air conditions.

Figures 6 and 7 shown change in temperature heavy concrete, which hardens in the heat-insulating chamber for 48 hours (C = 250 kg/m^3 W/C = 0.8). During the first 7 hour of concrete hardening its temperature changed from 15.0 to 16,9 °C (Δt = 1,9 °C), and after 23 hours was 22,1 °C (Δt = 7,1 °C). Then gradually lowered temperature of concrete and 48 hours equal to 18,2 °C.

Compressive strength thermal and hydro-insulated concrete examples of this composition after stripping on average 28.2% higher than the compressive strength of concrete hydro-isolated samples solidified in air conditions, and 4 hours after stripping the difference of these indicators was 26.5%.

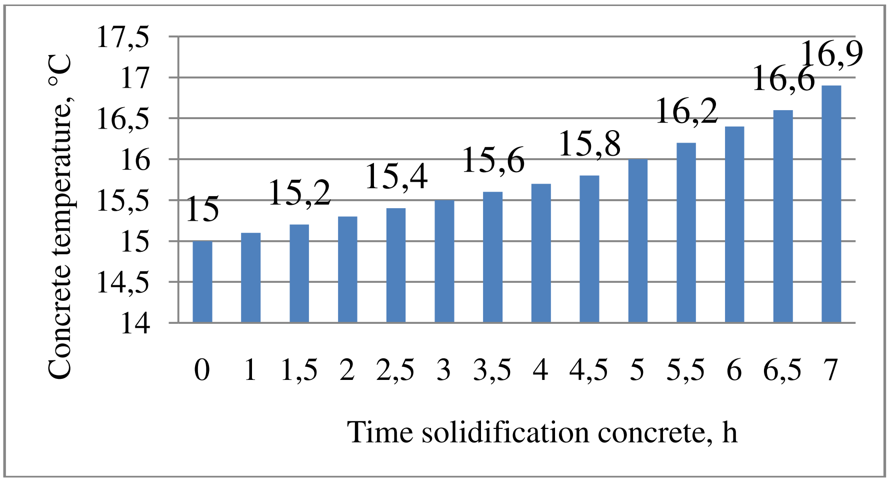


Figure 6. The change in temperature of the sample with heavy concrete (C = 250 kg/m^3 W/C = 0.8) for the first 7 hour solidification

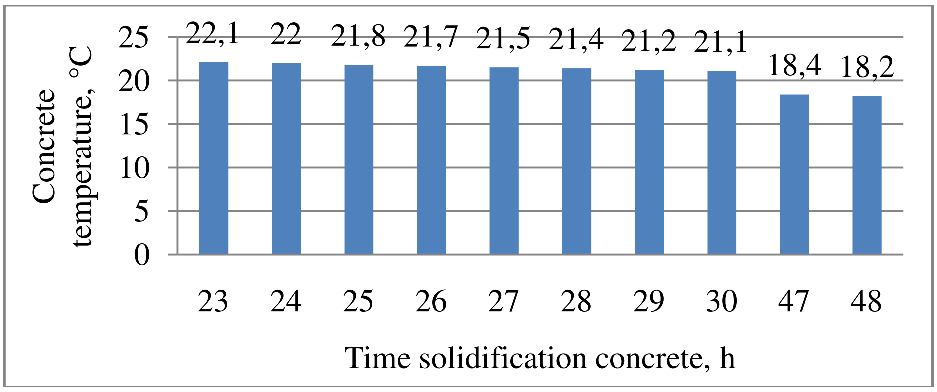


Figure 7. Change in temperature of the sample with heavy concrete (C = 250 kg/m^3 W/C = 0.8) from 23 to 48 o'clock solidification

Figure 8 shows the value of the specific heat release of cement, which is part of the heavy concrete (C = 450 kg/m^3 W/C = 0.65). Specific heat release of cement calculated using heat balances the investigated system. In Figure 9 shown corresponding total specific heat release cement, kJ/kg. The change temperature of the concrete during solidification in heat-insulating chamber shown in Figure 2.

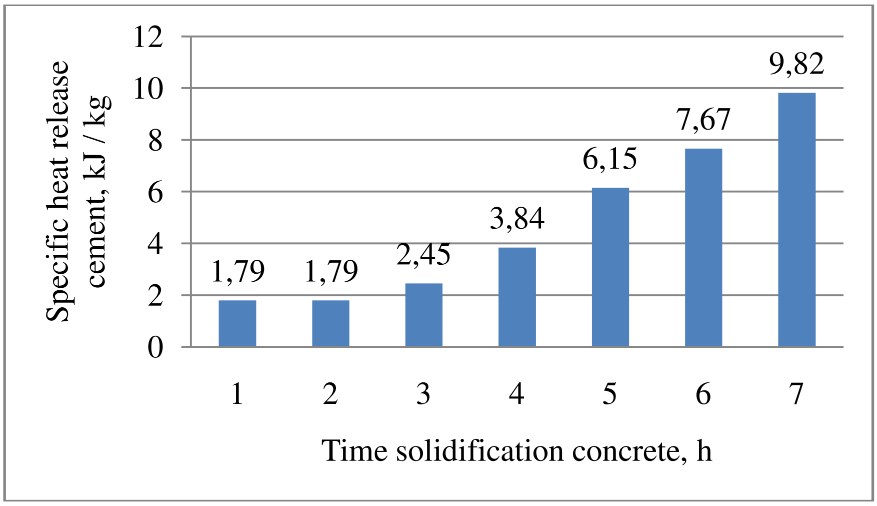


Figure 8. Specific heat release of cement during hydration, kJ / kg (C = 450 kg/m^3 W/C = 0.65)

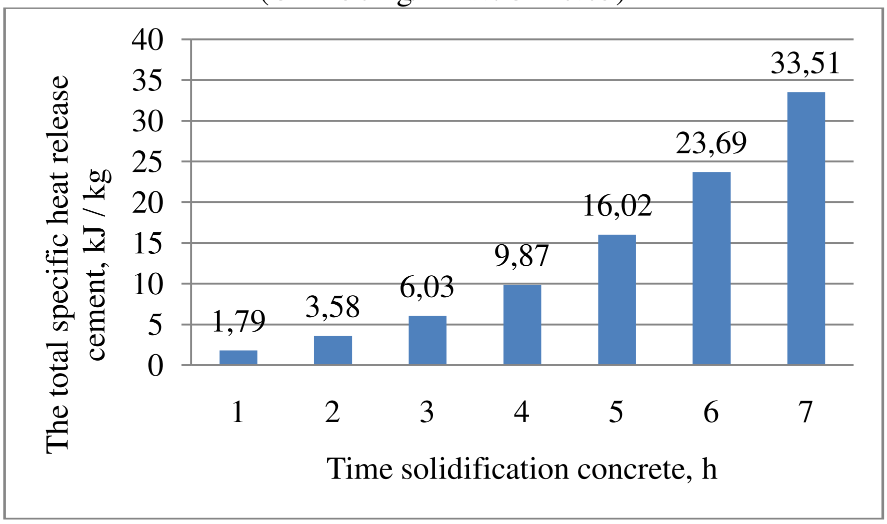


Figure 9. The total specific heat release cement during hydration, kJ / kg (C = 450 kg/m^3 W/C = 0.65)

In Figure 10, the values of specific heat release of cement, which is part of the heavy concrete (C = 450 kg/m^3 W/C = 0.55). Figure 11 shown the corresponding total specific heat release cement, kJ/kg. The change temperature of the concrete during solidification in heat-insulating chamber shown in Figure 4.

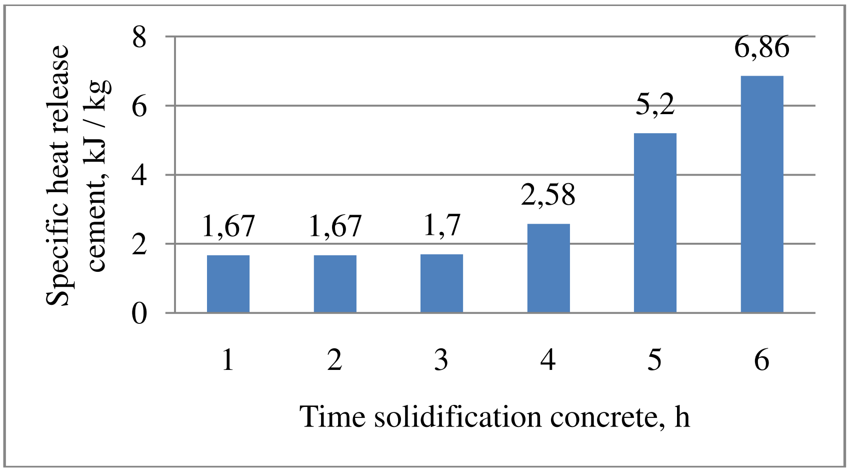


Figure 10. Specific heat release of cement during hydration, kJ/kg (C = 450 kg/m^3 W/C = 0.55)

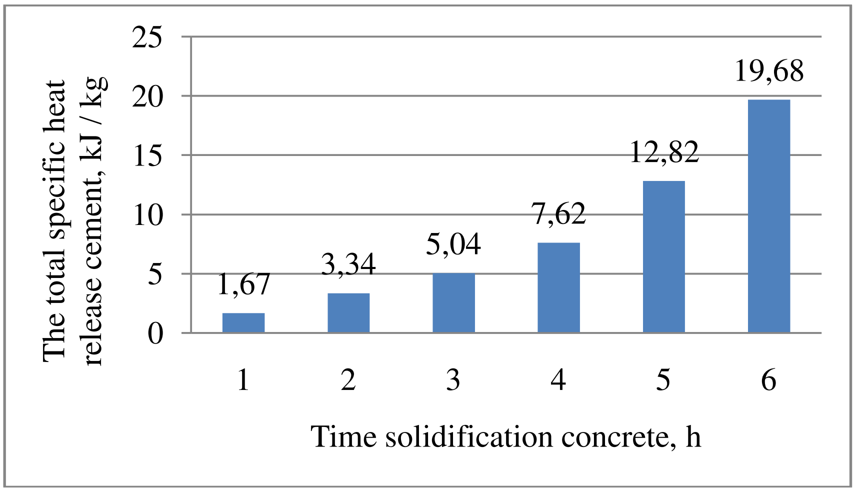


Figure 11. The total specific heat release cement during hydration, kJ / kg (C = 450 kg/m^3 W/C = 0.55)

In Figure 12 shows the value of the specific heat release of cement, which is part of the heavy concrete (C = 450 kg/m^3 W/C = 0.45). In Figure 13 shows the corresponding total specific heat release cement, kJ/kg. The change temperature of the concrete during solidification in heat-insulating chamber shown in Figure 5.

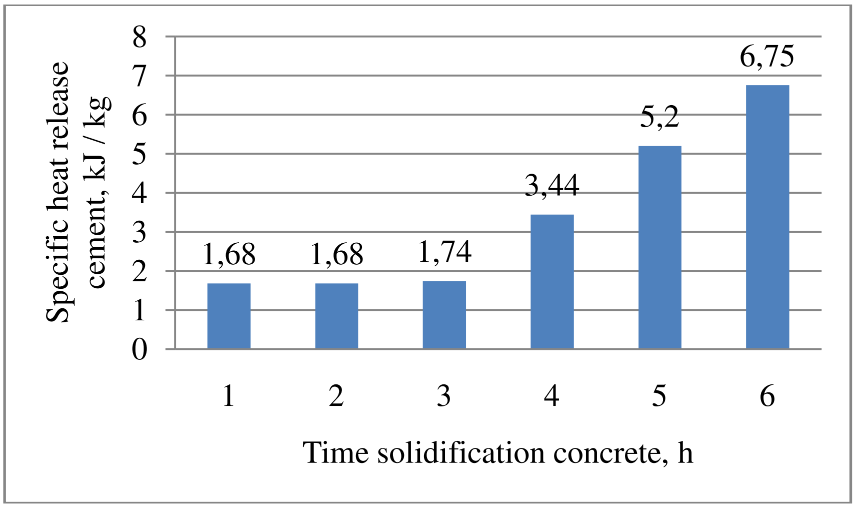


Figure 12. Specific heat release of cement during hydration, kJ/kg
(C = 450 kg/m^3 W/C = 0.45)

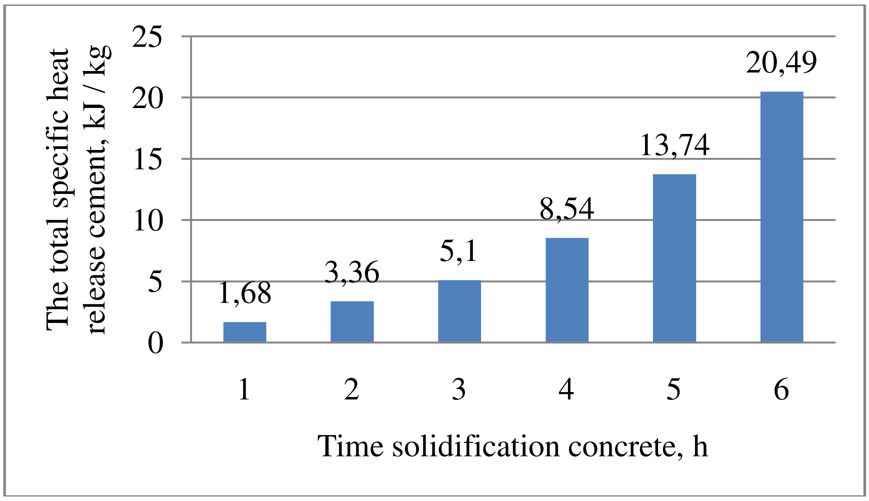


Figure 13. The total specific heat release cement during hydration, kJ / kg
(C = 450 kg/m^3 W/C = 0.45)

The total specific heat release of hydration of cement to 6 pm on solidification concrete in severe heat-insulating chamber equals: 23.69 kJ/kg (with W/C = 0.65), 19.68 kJ/kg (with W/C = 0.55) and 20.49 kJ/kg (with W/C = 0.45). The total specific heat release of cement W/C = 0.55 within 6 hours is lower compared to other indicators. This is explained by a lower initial temperature of concrete mix and other components of the system under study.

Conclusions for the first phase of laboratory research.

1. Studies have shown that the intensity of temperature rise of concrete samples heat treatment which occurs in laboratory chamber using only the heat released during cement hydration, lower than the intensity increase of temperature:

- Concrete samples solidified in adiabatic conditions [7] as a certain percentage of heat is lost to the environment;

- Heat-insulated samples with cement paste [11], [12] as the share of heat spent on heating and concrete aggregate is lost to the environment.

2. Methodology of calculating heat release of hydration of cement for the following cases should be divided into periods:

- The first period - temperature components the investigated system is increased, but the system heat losses to the environment are absent; method of settlement and experimental investigations of this period developed;

- The second period - temperature components the investigated system increases the available system heat loss to the environment; method of settlement and experimental investigations of this period developed;

- Third period:

a) concrete temperature is increased or not changed, and the temperature of designs that fence chamber decreases;

b) decreasing the temperature of all components of the system; justification for this step can be completed in the cooling system components to ambient temperature;

Technique for studies of the third period developed.

3. The experimental data of the first phase of laboratory research is recommended to apply:

- For an approximate forecasting the intensity of a set of concrete products compressive strength;

- For planning the second phase experimental investigations.

Estimation of forecasting intensity solidification concrete products. The tentative forecasting intensity solidification of concrete products for their thermal treatment using only the heat released during cement hydration, based on experimental data of the first stage of laboratory research follows.

1. Fold heat balances of the camera for the selected time intervals with the use experimentally established indicators heat release intensity cement. The purpose of drawing up the heat balances - determining the change in temperature of concrete products during solidification them in a production chamber using only the heat released during cement hydration.

2. The analysis of calculated change in temperature of concrete products, which harden in the manufacturing equipment. If the intensity change of this index is slightly different from the experimental data, it probably, and compressive strength of concrete products over the period will differ slightly

from the experimental data. If the intensity changes in calculated temperature of concrete products is much less than during laboratory experiments, it probably and the intensity set compressive strength of concrete products will be significantly lower.

The basic principles of the second phase of laboratory research. The main difference of the *second phase* of the first stage of the research is that when modeling in laboratory equipment process solidification heat and hydro-insulated concrete products need to keep the ratio between losses and heat-studied systems.

That is the task of the second phase of research - to reproduce for concrete samples harden in a laboratory equipment, the change in temperature of concrete products, which harden in the production chamber (as selected initial conditions). This modeling is based on heat balance which consist for investigated systems.

The heat balance of the camera for the selected time interval with thermal treatment concrete or ferroconcrete products using only the heat released during cement hydration, is as follows:

$$Q_1^{/} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9, \qquad (4)$$

where $Q_1^{/}$ – heat release during hydration of cement, J; This part of the heat balance chamber is determined experimentally;

Q_1 – loss of heat for heating concrete mix (concrete), J; Q_2 – loss of heat for heating fittings (for concrete products), J;

Q_3 – loss of heat for heating forms, J;

Q_4 – loss of heat for heating designs camera located above ground level, J;

Q_5 – loss of heat for heating designs camera located below ground level, J;

Q_6 – loss of heat on heating heat-insulation constructions, which cover goods (subject to the application of this design), J;

Q_7 – loss of heat for heating materials for waterproofing products in the process of heat treatment (assuming the use of such material), J;

Q_8, Q_9 – heat loss to the environment aboveground part designs fence camera, and the loss of heat for heating the soil, J (provided that such loss and expenses in the heat of my moment of time; requires that thermal properties designs that fence camera, were such as to $Q_8 = 0$ and $Q_9 = 0$); loss of heat for heating the air layer, which can in the chamber is possible, proposed in the balance ignored.

Showing below up the principle of reproduction in laboratory installation temperature change of concrete products for the initial time interval during their solidification using only the heat released during cement hydration. It is assumed that concrete products in the chamber will be covered waterproofing materials and heat-insulating structure.

The Temperature mode solidification concrete products using only heat that is released during the interaction of cement with water - transient. Thus, to analyze the conditions of his term expedient modeling of products in the chamber divided into intervals.

The heat balance of the production equipment in which harden concrete products for the initial period of time (when heat insulating structure and heated floor thickness not completely) is:

$$Q_1^{/} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5, \qquad (5)$$

$$\text{or } Q_1^{/} = c_1 \cdot m_1 \cdot (t_{1E} - t_{1B}) + c_2 \cdot m_2 \cdot (t_{2E} - t_{2B}) + c_3 \cdot m_3 \cdot (t_{3E} - t_{3B}) +$$

$$+ c_4 \cdot m_4 \cdot (t_{4E} - t_{4B}) + c_5 \cdot m_5 \cdot (t_{5E} - t_{5B}), \qquad (6)$$

де $Q_1^{/}$ – the amount of heat released during cement hydration during the initial time interval, J;

Q_1 – the amount of heat it takes to heat the concrete mix (concrete) to install, during the initial time interval, J;

Q_2 – the amount of heat it takes to heat forms during the initial time interval, J;

Q_3 – the amount of heat it takes to heating warm the part of heat-insulation construction during the initial time interval, J;

Q_4 – the amount of heat it takes to heat to warm part the floor of the chamber during the initial time interval, J;

Q_5 – the amount of heat it takes to heat waterproofing material during the initial time interval, J;

c_1, c_2, c_3, c_4, c_5 – heat capacity per unit mass under concrete mix (concrete), material forms, insulation material, flooring material cameras, waterproofing material, J / (kg • ºC);

t_{1B}, t_{1E} – temperature of the concrete mix (concrete) respectively at the beginning and end of the selected time interval, ºC;

t_{2B}, t_{2E} – temperature forms respectively at the beginning and end of the selected time interval, ºC;

t_{3B}, t_{3E} – temperature of the heated part of the heat-insulation under construction at the beginning and end of the selected time interval, ºC;

t_{4B}, t_{4E} – the temperature of the heated floors respectively at the beginning and end of the selected time interval, ºC;

t_{5B}, t_{5E} – waterproofing material temperature at the beginning and end of the selected time interval, ºC;

m_1, m_2, m_3, m_4, m_5 – mass of under concrete mix (concrete), forms part of the heated thermal insulation design, the heated part floors, waterproofing material, kg;

Explanation of the other components of the formula above.

The temperature of the concrete mix (concrete) at the end of the initial time interval in production equipment is equal to

$$t_{1E} = t_{1B} + \frac{Q^{/} - c_2 \cdot m_2 \cdot (t_{2E} - t_{2B}) - c_3 \cdot m_3 \cdot (t_{3E} - t_{3B})}{c_1 \cdot m_1} + $$

$$+ \frac{- c_4 \cdot m_4 \cdot (t_{4E} - t_{4B}) - c_5 \cdot m_5 \cdot (t_{5E} - t_{5B})}{c_1 \cdot m_1}. \quad (7)$$

The temperature of the concrete mix (concrete) in laboratory equipment at the end of the same time interval will be the same as in the production equipment, if the numerator and denominator of the last two components of this equation is reduced several times (for example - *n* times). This transformation is possible if the similar initial conditions *simultaneously*:

- decrease in *n* times the mass of the concrete mix relatively appropriate mass concrete mix in the production equipment, then:

a) the amount of heat $Q_1^{/}$, released by the interaction of cement with water for a certain period of time, reduced in n times, because decrease the number cement at a constant W/C;

it should be emphasized that the intensity heat generation cement during hydration depends on the temperature at which the process because it is assumed that the temperature regime of concrete hardening will be saved as a result of measures listed;

b) the amount of heat Q_1, which is spent on heating concrete mix (concrete) for the selected time interval, reduced in *n* times;

- decrease in n times the mass of forms and waterproofing material, then the amount of heat Q_2 and Q_5 reduced in *n* times;

- decrease in *n* times the mass part the hot heat-insulation and construction part the heated floor, the amount of heat Q_3 and Q_4 reduced in *n* times; it is possible to recreate in modeling thermal properties of these structures.

Thus, temperature mode solidification samples in laboratory equipment will close temperature mode solidification products in a production equipment, if the income and expenses of heat these systems will be proportionate, and the initial temperature of the components - the same.

For a more accurate modeling of this temperature mode, follow these tenets of the theory of similarity: similar phenomena occur in geometrically similar systems. In the case in question must be geometrically similar size samples and products as well - the size of laboratory and industrial equipment. This condition can be met if concrete products are small. But when concrete products are large, they produce geometrically similar samples for testing in the laboratory equipment is not possible. These factors should be considered in the analysis of experimental studies.

Determining the loss of heat for heating designs fence camera for thermal treatment of concrete products. In random mode the heat treatment of concrete and ferroconcrete products it is important to assess the loss of heat for heating designs fence camera as well - the heat loss through these constructions.

The sources [18] - [20], the methodology for determining the loss of heat for heating designs fence camera for thermal or steam treatment of concrete and ferroconcrete products, and heat losses through these constructions. It is necessary to improve these techniques based on unsteady temperature field in these constructions.

During the increase in temperature of the medium chamber for thermal treatment of concrete or ferroconcrete products is a gradual heating designs her fence. Suppose that the temperature of these structures varies only in the direction normal to the surface.

The mathematical characteristic the process of non-stationary heat conduction in equation

$$\frac{\partial t}{\partial \tau} = a \cdot \frac{\partial^2 t}{\partial x^2}\ , \qquad (8)$$

and uniqueness conditions (geometrical, physical, initial and boundary).

Solve the differential equation (8) proposed FDTD method, which are, in particular, in the book [21]. This source also provides guidance on the application of this method for multilayer constructions.

According to the FDTD method design conventionally divided into layers of thickness Δx and time - at intervals $\Delta\tau$. For each time interval determined by the temperature distribution in the construction of a dependency recommended in this manner.

The loss of heat for heating the layers for each time period are calculated based on the temperature distribution in the structure. Accordingly, the loss of heat for heating designs fence camera consist of heat for heating loss each design. Loss of heat structure (after heating) as determined by the change in time surface temperature of the structure.

General conclusions to chapter 1.

1. Developed basic principles of forecasting intensity solidification of concrete products for their thermal treatment using only the heat released during cement hydration.

2. The laboratory experiments under the provisions of the first phase of research.

3. Thereafter, you should: make experimental studies in accordance with the provisions of the second stage; to analyze the method thermal treatment of concrete products under study taking into account different production technology of ferroconcrete products.

Chapter 2. The method of forecasting intensity solidification of concrete products for their thermal treatment air heated in the solar collector. The researchers are paying great attention to the improvement of heat treatment of concrete and concrete products with the use solar energy.

In the book [22] shows different ways with treating concrete using solar energy. In [23] analyzes the features of the process thermal treatment of concrete products during their heated by solar energy in the form of concrete. In [24] shows the benefits of solar-thermal treatment of concrete structures under conditions of Kazakhstan. In the source [25], the heat treatment technology of concrete products in landfills with the use solar energy. In [26] considered solidification of concrete products in the form of solar translucent coating.

In the patent [2], [3] the exercise cooked concrete and concrete products with the use coolant heated in the solar collector. In [27], [28] shows principle of operation of laboratory equipment designed to determine the optimal modes thermal treatment concrete heated in the collector solar air.

It is necessary to develop a method of forecasting the intensity of solidification concrete and concrete products, heat treatment which is performed using heated in the collector solar air.

The method of heat treatment of concrete and ferroconcrete products using heated in the collector solar air. We consider the principle of heat supply chamber for heat treatment of concrete and concrete products with the use solar energy. In this process, solar energy is the primary coolant and secondary - air that is heated in the solar collector. In addition, the equipment for thermal treatment of concrete and concrete products there is an internal source of heat - exothermic reaction between cement and water.

Thermal processing of these products is carried out in closed forms to prevent evaporation of moisture needed for cement hydration.

In Figure 14 shows a diagram of heat supply chamber for heat treatment of concrete and concrete products in closed form with the use heated in the collector solar air and with the use additional (the reserve) sources of heat. The air is heated in the solar collector 1 and moves an air pipe 2 to camera 3, which gives a certain amount of heat removed from the chamber and directed to the collector of solar energy. If necessary, use an additional source of heat - blast stove 4. The movement of air in the system provides ventilator 5. The direction of air flow is regulated by valves 6.

If the intensity of the flow of solar energy in a given period is negligible, in this period of time it is advisable to heat the air just a backup heat source 4. In this case, the movement of air through section 7, and not through the solar collector. Some adjustments in the circuit camera system heat supply can be done because of the aerodynamic calculation of the system.

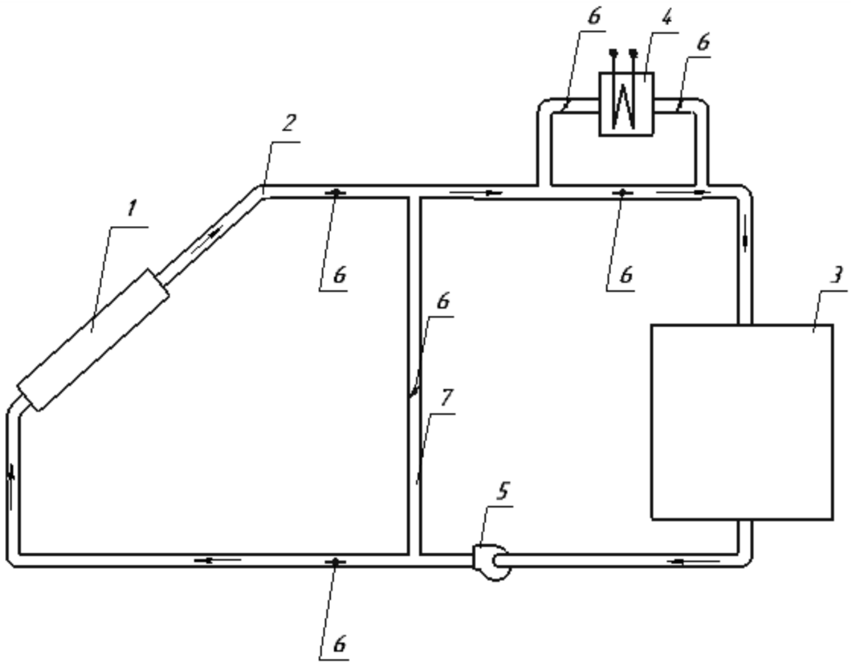


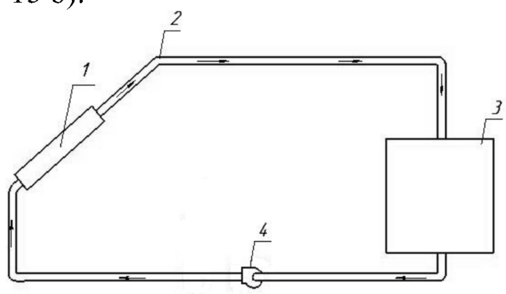
Figure 14. Scheme of the heat supply chamber for heat treatment of concrete and concrete products in closed form with the use heated in the collector solar air and with the use additional (the reserve) source of heat

Features correcting intensity heat supply chamber for heat treatment of concrete and ferroconcrete products related in particular to the presence of internal heat source - the exothermic reaction of hydration of cement. With the lack heat generating capacity solar collector at a certain point thermal treatment of concrete or ferroconcrete products of temperature can be higher than the temperature of the heated air in the collector. In this case, heated in the collector solar air will flow into the chamber, and continue to heat removed from the chamber with a temperature higher than the temperature of the inlet air to the chamber. Creating such a situation is unacceptable. If the air temperature after collector solar energy will be lower than the temperature of the product, you should:

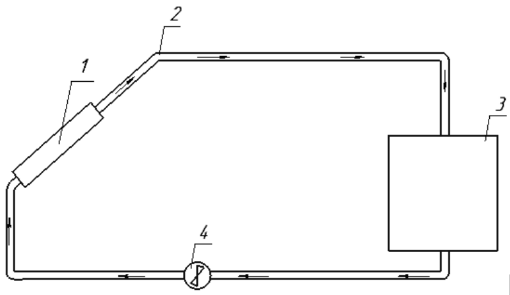
- Use an additional source of heat for increasing temperature, provided that heat release of hydration of cement due to insufficient to continue the process solidification products;
- Stop for some time supply of heated air to the chamber provided the heat release of hydration of cement when it sufficient to continue the process solidification products during this period.

When heat treatment concrete and concrete products with the use solar energy can be used battery heat. Then, at a time when there is no need for heat supply chamber (or want to reduce the intensity of heating products), air (or portion thereof) after collector solar energy is directed to heat the battery and heats it. Heated battery heat source is heat reserve. On a par with battery heat in heat supply chamber can be used also blast stove.

Heat supply chamber for thermal treatment of concrete and concrete products with the use heated in the collector solar air can be achieved without the use of additional sources of heat (air heater) and without the use of heat battery (Fig. 2). In this case, the air is heated in the solar collector 1 and moves along the an air pipe 2 to camera 3, which gives a certain amount of heat. Then the air is removed from the camera and againis directed to the collector of solar energy. The movement of air in the system provides ventilator 4 (centrifugal - Fig. 15 a, or axis - Fig. 15 b).



a)



b)

Figure 15. Scheme of the heat supply chamber for thermal treatment of concrete and ferroconcrete products in closed form with the use heated in the collector solar energy Air
a) with centrifugal ventilator; b) with axial fan

Experimental research of heat treatment of concrete samples air heated in the solar collector. Investigates the process thermal treatment in laboratory equipment hydro-isolated samples of heavy concrete (Figure 15 b). Coolant - air, which is heated by the warm season in the collector solar energy own design.

Previous excerpt concrete samples before thermal treatment in laboratory chamber was 1 hour. Heated in the collector solar energy air for several hours was directed into the chamber by a ventilator. The gradual cooling of the samples was in the closed chamber, their total stay in the chamber - 28 hours. On the temperature regime concrete at this time affects heat release cement by hydration. The strength of concrete in compression was determined at 2 and 5 days.

Figures 16 - 18 shown change in temperature of heavy concrete samples investigated composition, heat treatment are heated in the collector solar energy air was over 3 hours (the samples cooled in the chamber).

In experiment 1 (Fig. 16), the temperature of concrete samples during their thermal treatment hot air for 3 h increased from 22.1 before 40,5ºC (Δt = 18,4ºC).

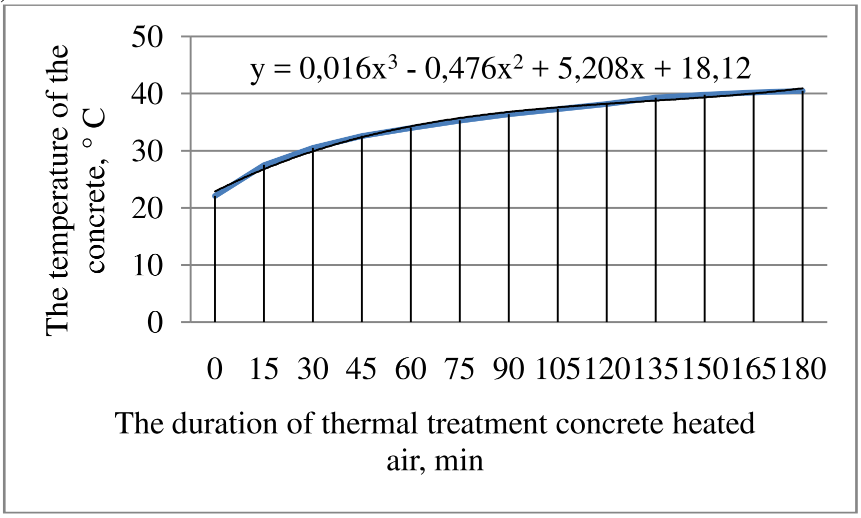


Figure 16. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiment 1)

In experiment 2 (Fig. 17), the temperature of concrete samples during their thermal treatment heated air for 3 hours increased from 21.9 before 37,6ºC (Δt = 15,7ºC).

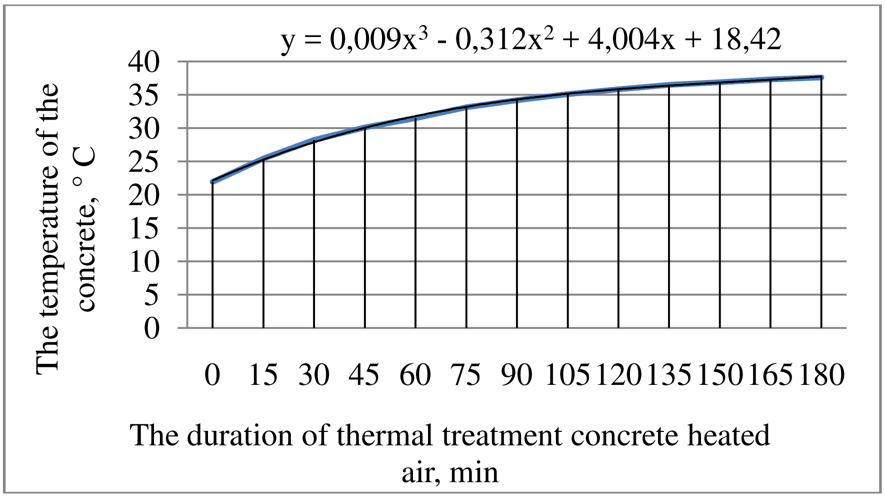


Figure 17. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiment 2)

In experiment 3 (Fig. 18), the temperature of concrete samples during their thermal treatment heated air for 3 hours increased from 22.3 before 41,2ºC (Δt = 18,9ºC).

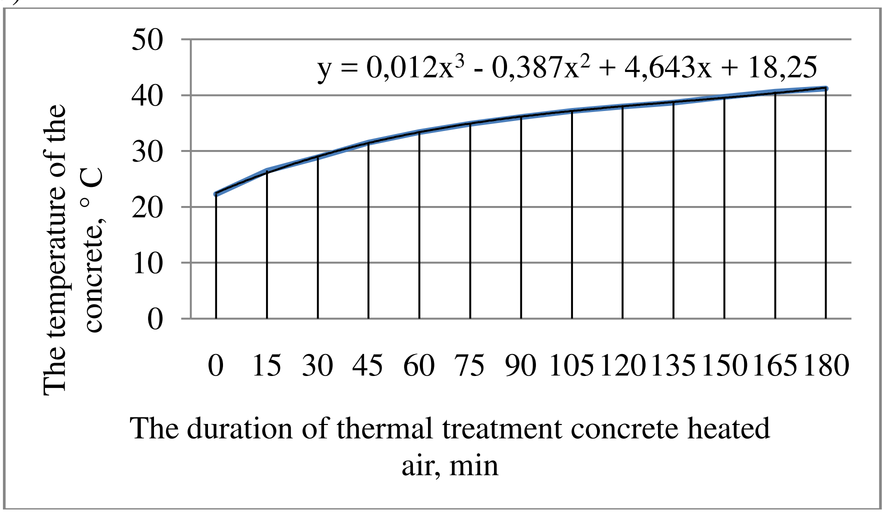


Figure 18. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiment 3)

Figures 19 and 20 show the change in temperature of heavy concrete samples investigated composition, heat treatment are heated in the collector solar energy air was within 4.5 hours (the samples cooled in the chamber). In experiment 4 (Fig. 19), the temperature of concrete samples during their thermal treatment heated air over 4.5 hours increased from 22.7 before 38,1ºC (Δt = 15,4ºC) in experiment 5 (Fig. 20) - from 20.8 before 42,9ºC (Δt = 22,1ºC).

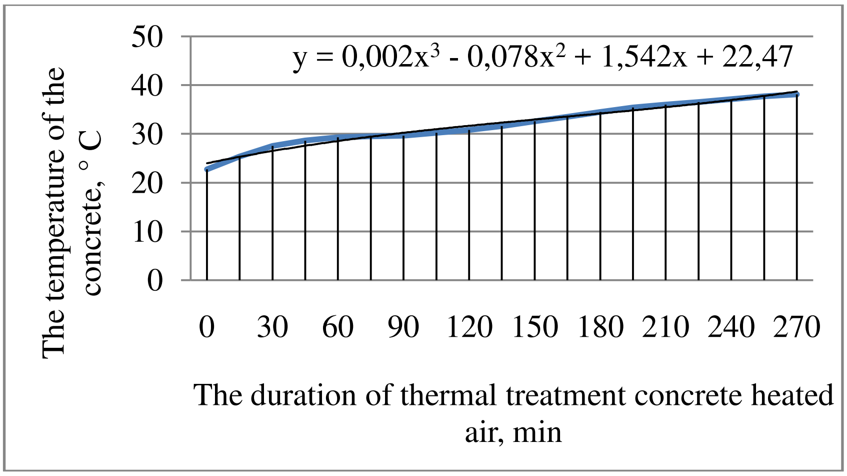


Figure 19. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiment 4)

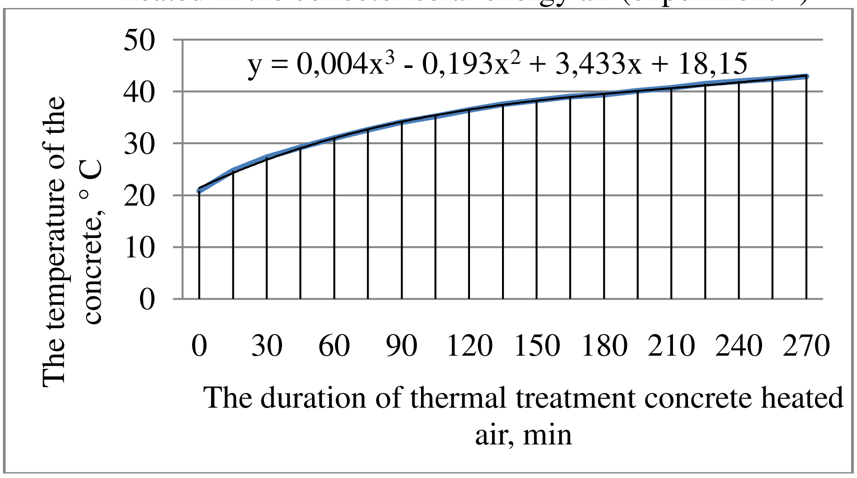


Figure 20. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiment 5)

In Figure 21 shows the change temperature of the samples investigated heavy concrete composition (experiment 6), heat treatment are heated in the collector solar energy air occurred within 6 hours (the samples cooled in the chamber). The temperature of samples increased over 6 hours from 20.1 before 48,4ºC (Δt = 28,3 °C).

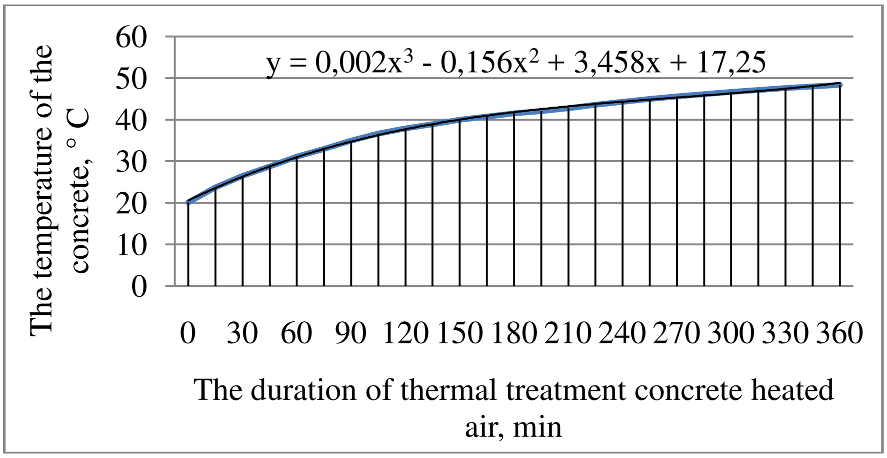


Figure 21. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiment 6)

Ha In Figure 22 shows the change in temperature heavy concrete composition investigated during the period of thermal treatment air heated in the collector solar energy (experiments 1, 2, 4).

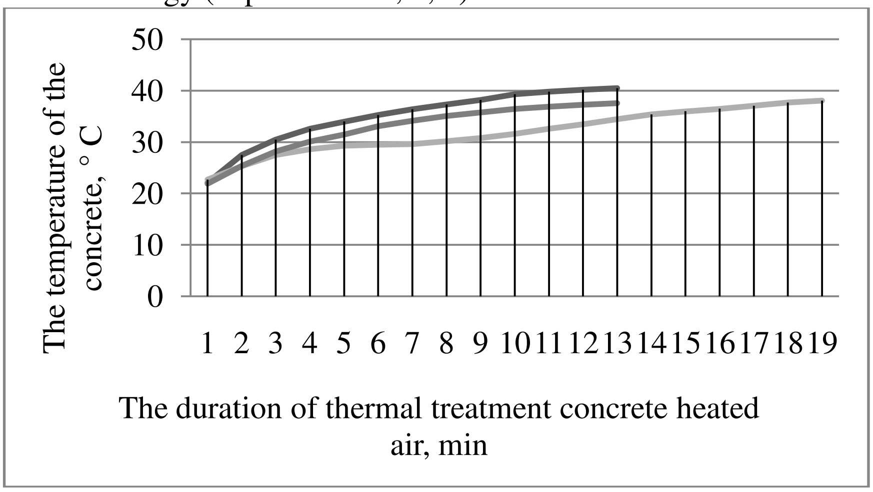


Figure 22. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiments 1,2,4)

In figure 23 shows the percentage of the design strength of concrete samples in compression at 2 days, heat treatment which took place in by heated air collector solar energy (experiments 1, 2, 4) and hydro-insulated control samples which hardened in natural conditions.

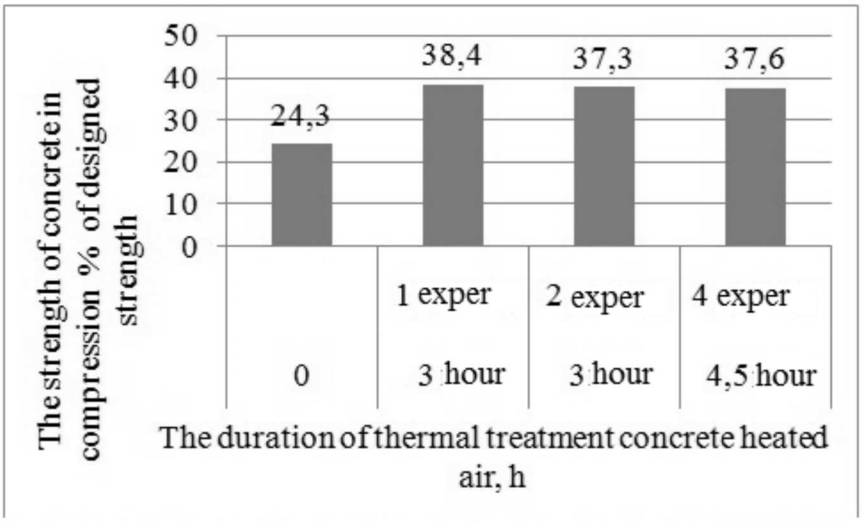


Figure 23. Compressive strength of concrete at the age of 2 days, the percentage of design strength (Experiments 1, 2, 4)

In Figure 24 shows the change in temperature heavy concrete composition investigated during the period of thermal treatment air heated in the collector solar energy (experiments 3, 5, 6).

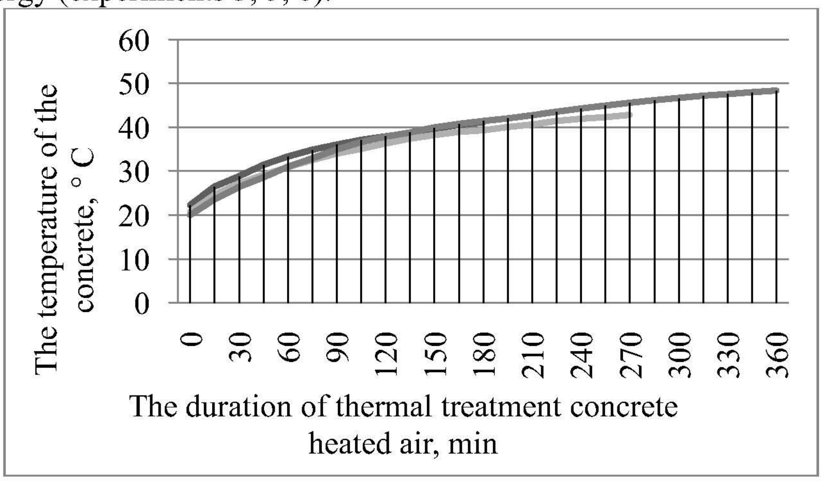


Figure 24. Changing the temperature of concrete in its thermal treatment heated in the collector solar energy air (experiments 3,5,6)

In Figure 25 shows the percentage of the design strength of concrete samples in compression aged 5 days thermal treatment which took place in by heated air collector solar energy (experiments 3, 5, 6) and hydro-insulated control samples which hardened in natural conditions.

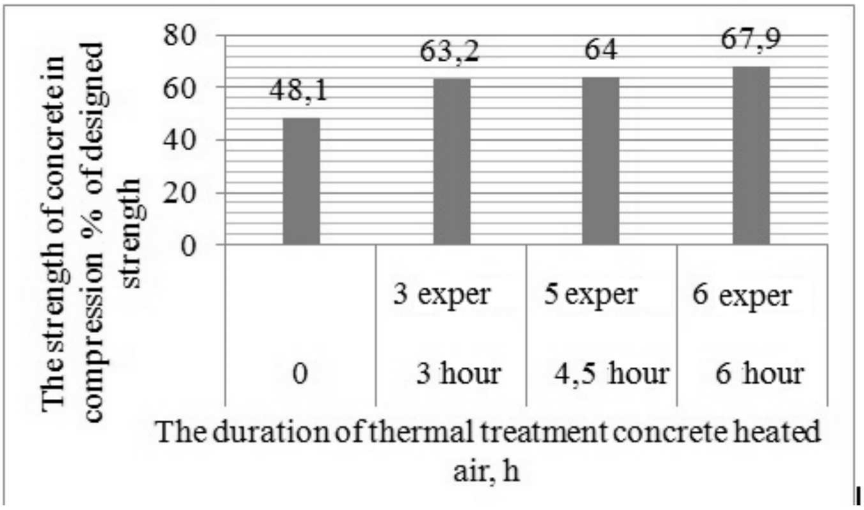


Figure 25. Compressive strength of concrete at the age of 5 days, the percentage of design strength (Experiments 3, 5, 6)

Experimental research of heat treatment of concrete samples air heated by infrared heater. In the cold season it is advisable to perform modeling process air heating collector energy using an infrared heater.

Cited in this paragraph experimental results conducted using the same laboratory setting, with which performed research process thermal treatment of concrete samples air heated in the collector solar energy own design (Fig. 15 b). However, heating the air in the collector was using an infrared heater. Correcting the intensity of heat flow of energy to the collector was within the stipulated construction of the heater.

Previous excerpt concrete samples investigated composition (by thermal treatment in a laboratory chamber) was 1 hour. The heated air in the collector of energy for several hours was directed into the chamber by a fan. The gradual cooling of the samples was in the closed chamber, the total length of their stay in the chamber - 28 hours. The strength of concrete in compression was determined at 2 and 5 days.

Figures 26 - 29 shown change in temperature of heavy concrete samples investigated composition, thermal treatment are carried out for 3 hours with air heated in the collector of energy by means of infrared heater (the samples cooled in the chamber).

In experiment 7 (Fig. 26), the temperature of concrete samples during their thermal treatment heated air for 3 hours increased from 16.0 before 33,9ºC (Δt = 17,9ºC).

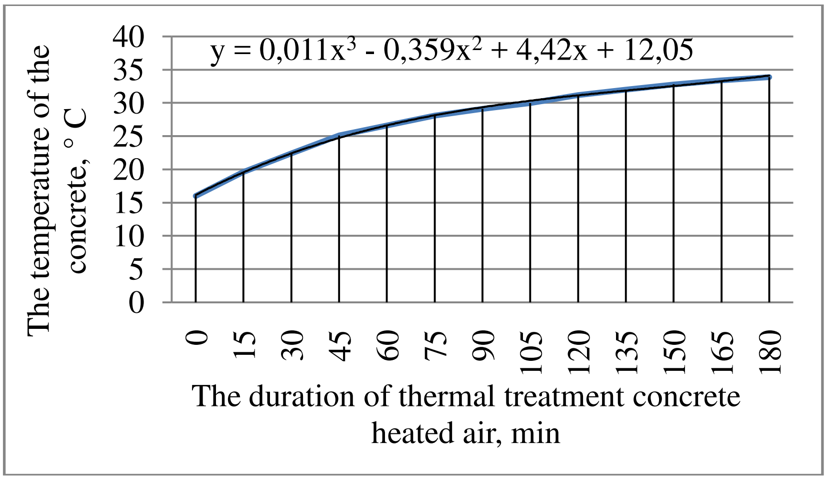


Figure 26. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 7)

In experiment 8 (Fig. 27), the temperature of concrete samples at their thermal treatment heated air for 3 hours increased from 14.9 before 47,8ºC (Δt = 32,9ºC).

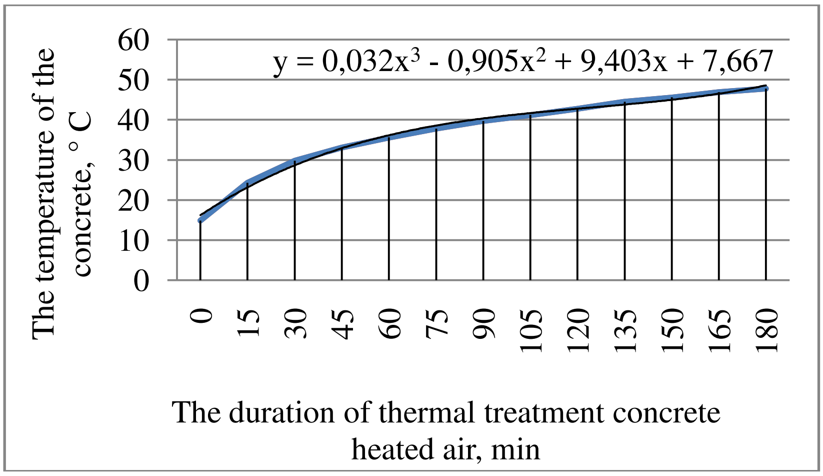


Figure 27. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 8)

In experiment 9 (Fig. 28), the temperature of concrete samples at their thermal treatment heated air for 3 hours increased from 16.8 before 49,5 ºC (Δt = 32,7 °C).

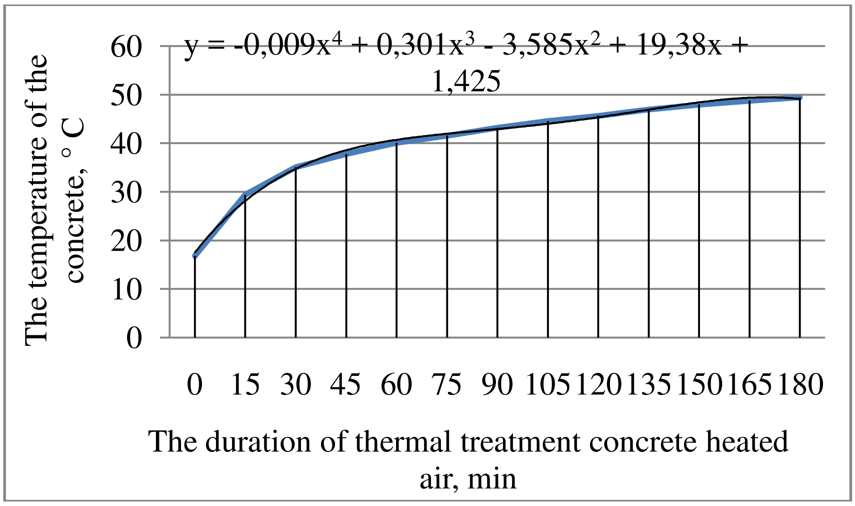


Figure 28. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 9)

In the experiment, 10 (Fig. 29), the temperature of concrete samples at their thermal treatment heated air for 3 hours increased from 16.0 before 53,4 ºC (Δt = 37,4 ºC).

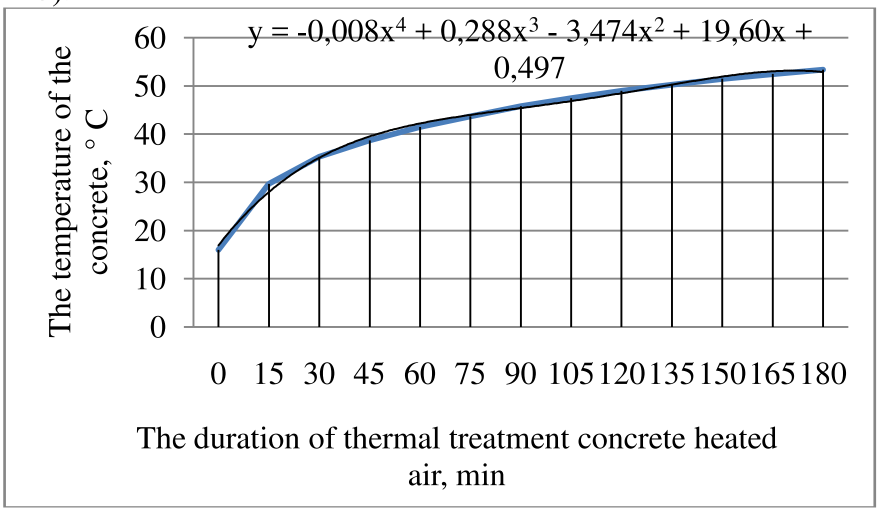


Figure 29. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 10)

Figures 30 and 31 show the change in temperature of heavy concrete samples investigated composition, thermal treatment where heated air was within 4.5 hours (the sample cooled in a closed chamber). In the experiment, 11 (Fig. 30), the temperature of concrete samples at their thermal treatment heated air over 4.5 hours increased from 14.4 before 35,5 ºC (Δt = 21,1 ºC), 12 in the experiment (Fig. 31) - from 16.3 before 56,4 ºC (Δt = 40,1ºC).

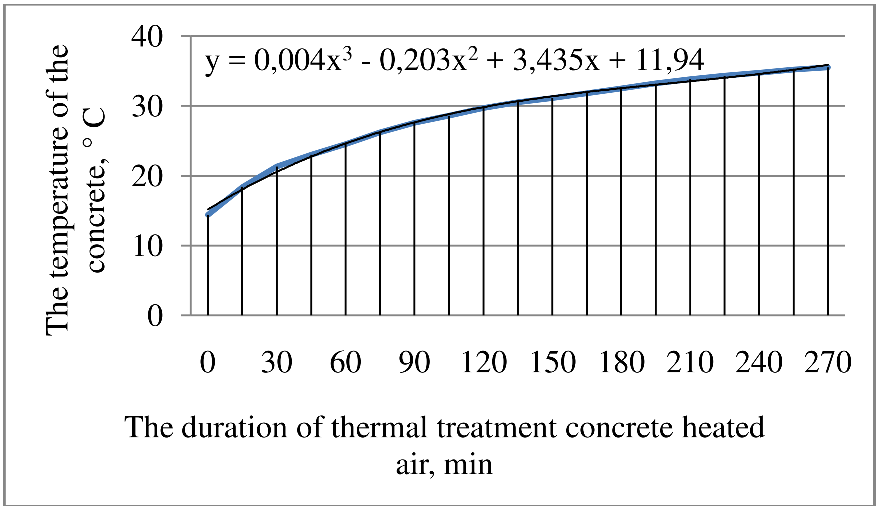


Figure 30. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 11)

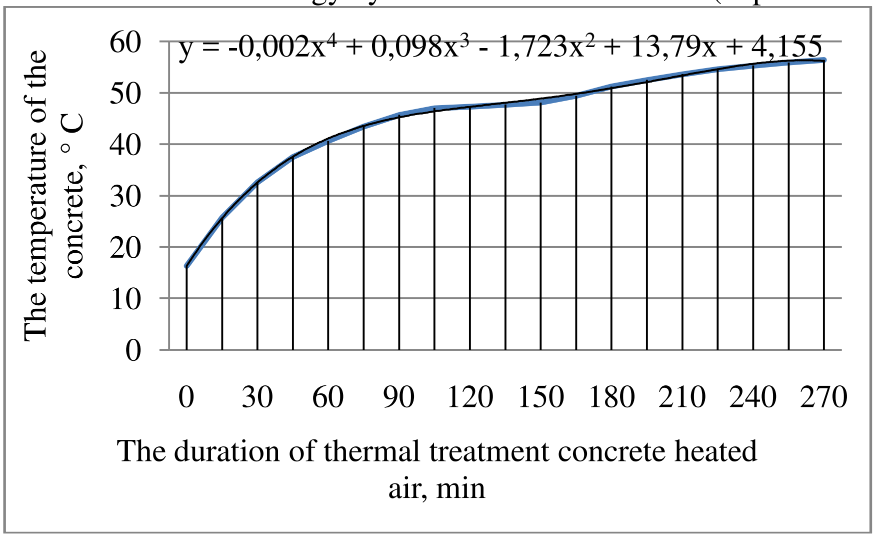


Figure 31. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 12)

Figures 32 and 33 show the change in temperature of heavy concrete samples investigated composition, thermal treatment where heated air was within 6 hours (the samples cooled in the chamber). In the experiment, 13 (Fig. 32), the temperature of concrete samples at their thermal treatment heated air during 6 hours increased from 15.3 before 39,1ºC (Δt = 23,8ºC), 14 in the experiment (Fig. 33) - 14, 5 60,8ºC (Δt = 46,3ºC).

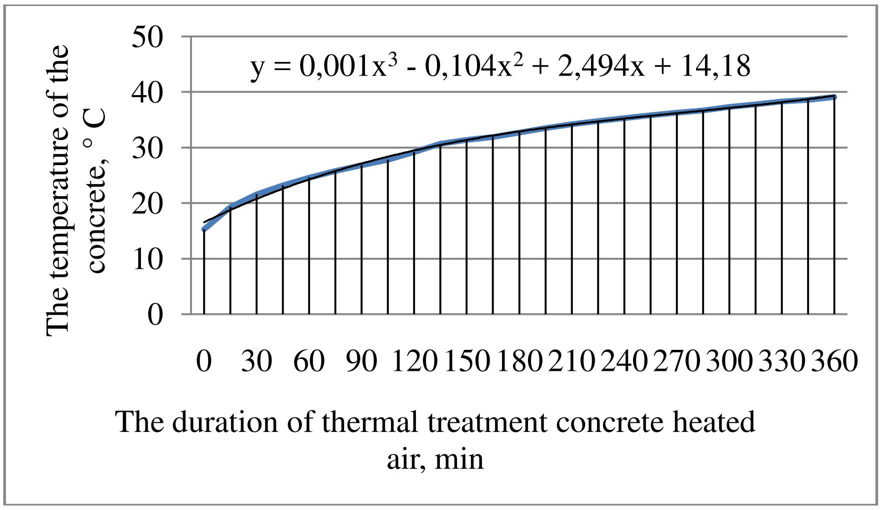


Figure 32. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 13)

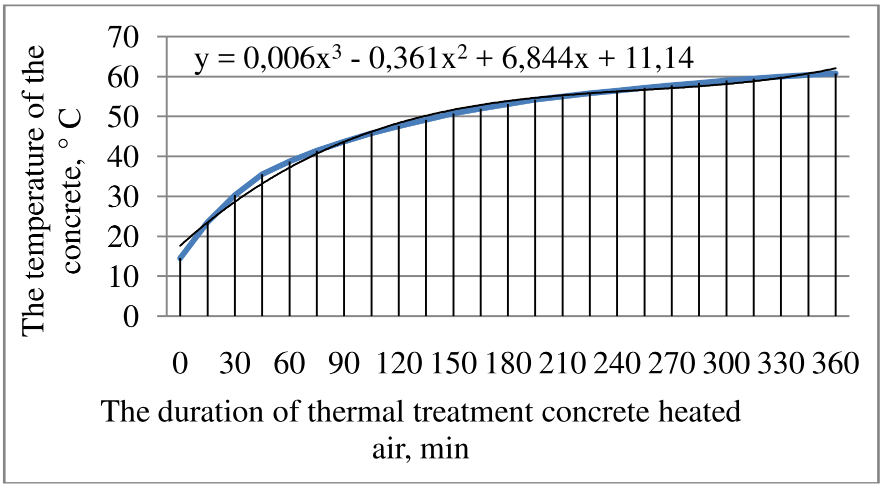


Figure 33. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 14)

In Figure 34 shows the change in temperature samples of heavy concrete composition investigated during the period of thermal treatment heated air (experiments 7, 8, 10, 11, 13).

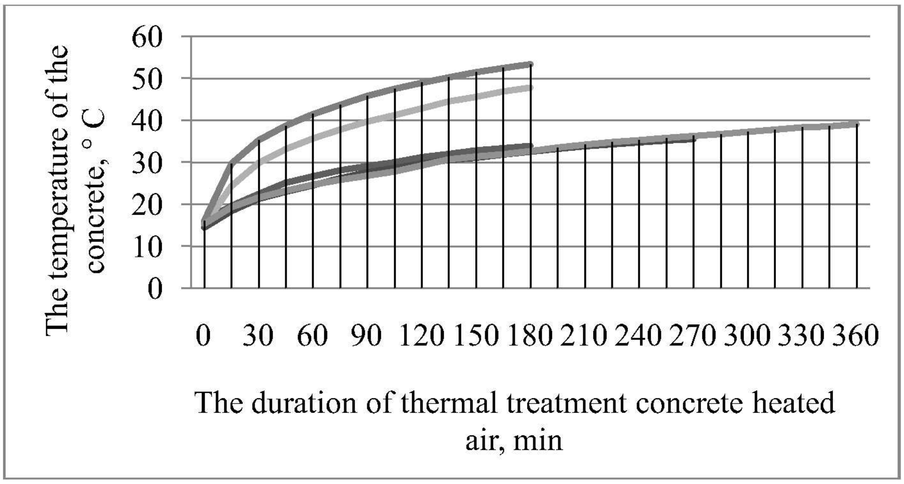


Figure 34. Changing the temperature of concrete at its thermal treatment air heated in the collector of energy by means of infrared heater (experiment 7, 8, 10, 11, 13)

In Figure 35 shows the percentage of the design strength of concrete samples in compression at 2 days, thermal treatment which occurred air heated in the collector of energy by means of infrared heater (experiments 7, 8, 10, 11, 13) and hydro-insulated control samples, which solidified in natural conditions

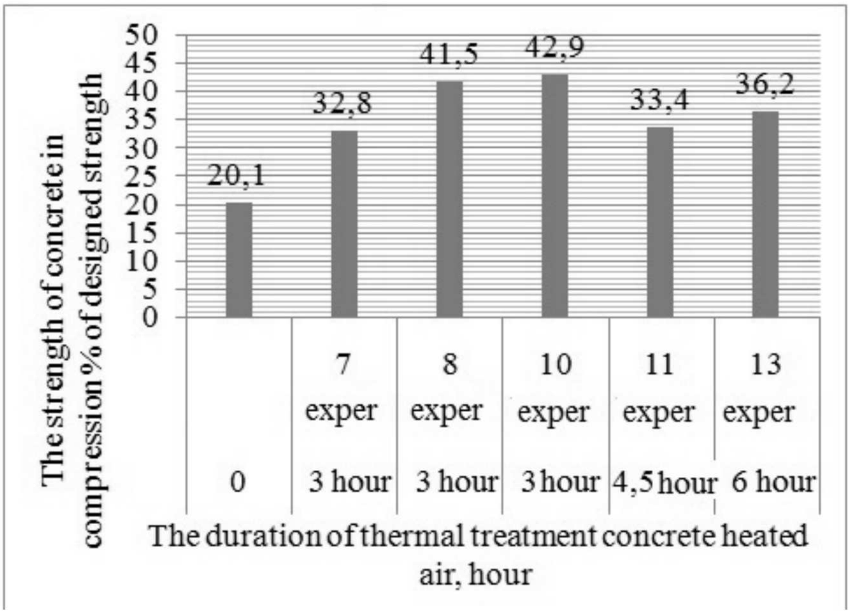


Figure 35. The strength of concrete in compression at 2 days percentage of project strength (experiments 7, 8, 10, 11, 13)

In Figure 36 shows the change in temperature of heavy concrete samples investigated during the period of thermal treatment heated air composition (experiments 9,12, 14).

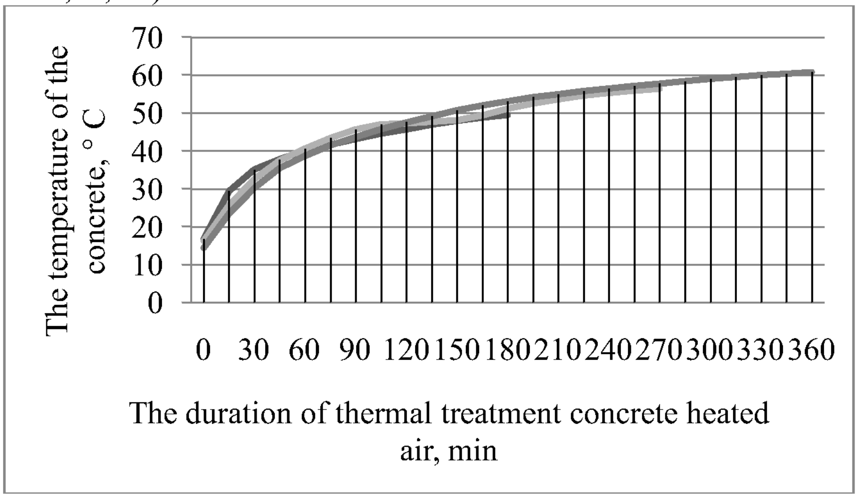


Figure 36. Changing the temperature of concrete at its thermal treatment air by heated in the collector of energy by means of infrared heater (experiments 9,12,14)

In Figure 37 shows the percentage of the design strength of concrete in compression samples aged 5 days, thermal treatment which occurred air heated in the collector of energy by means of infrared heater (experiments 9, 12, 14) and hydro-insulated control samples which solidified in natural conditions.

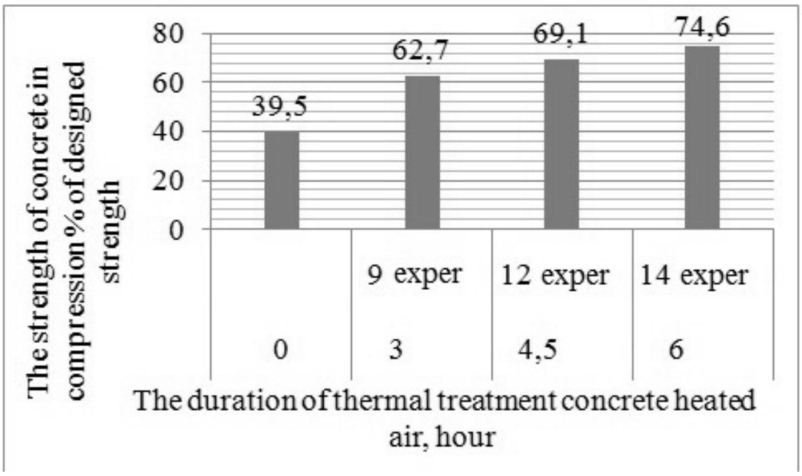


Figure 37. The strength of concrete in compression at 5 days percentage of project strength (experiments 9,12,14)

General conclusions to chapter 2.

1. The results experimental investigations showed that the studied conditions prevailing influence on the strength of concrete in compression has a the intensity of its heat.

2. In the warm season compressive strength of control samples with heavy concrete composition investigated at 2 and 5 days more than the corresponding strength during the cold period;

reason is that in the warm season temperature mode solidification control samples more favorable than in the cold season.

3. The results of experimental investigations showed that the studied conditions significant impact on the strength of concrete in compression is the presence of the cooling period termosnoho concrete samples (after submission to the equipment of heated air), for example:

a) under condition heating the air in the collector solar energy:

- Concrete compressive strength at the age of 2 days, thermal treatment was carried out by heated air over 4.5 hours (experiment 4) is less than the corresponding strength of concrete, which thermal treatment was carried out for 3 hours (experiment 1);

reason is that in the experiment 4 concrete examples to stop the flow of air to the equipment had a lower temperature than in experiment 1, namely 38,1ºC - in experiment 4; 40,5ºC - in experiment 1;

b) subject to heating the air in the collector of energy by means of infrared heater:

- concrete compressive strength at the age of 2 days, thermal treatment was carried out by heated air over 4.5 hours (experiment 11) and within 6 hours (experiment 13) is less than the corresponding concrete strength, thermal treatment was carried out by heated air for 3 hours (experiments 8, 10);

reason is that in experiments 11 and 13 samples of concrete to stop the flow of air to the equipment had a temperature lower than in experiments 8 and 10, namely 35,5ºC - 11 in the experiment; 39,1ºC - 13 in the experiment; 47,8ºC - 8 in the experiment; 53,4ºC - 10 in the experiment;

- duration of the thermal treatment heated air in the experiment 13 is equal to 6 hours, which is 2 times more than in experiment 7, but concrete compressive strength at the age of 2 days in these experiments differ not so much, because his presence termosnoho cool.

4. The results experimental investigations showed that the studied conditions influence the strength of concrete in compression has the air temperature in a room where there is laboratory equipment, for example:

- concrete compressive strength at the age of 2 days, by thermal treatment heated air was carried out for 3 h in experiments 8 and 10 differ slightly, although the temperature of concrete samples to stop the flow of air into 8 is equal to 47,8ºC experiment, and the experiment 10 is equal to 53,4ºC;

reason is that the ambient temperature in the experiment 10 was lower than in experiment 8, which increased the intensity of the heat losses to the environment chamber during cooling termosnoho concrete samples;

- concrete compressive strength at the age of 2 days, by thermal treatment heated air was carried out for 3 hours (experiment 7) and over 4.5 hours (experiment 11) differs slightly because the ambient temperature in the experiment was 11 lower than in experiment 7, which increased the intensity of the heat losses to the environment chamber during cooling termosnoho concrete samples.

5. Modelling of heating the air in the collector solar energy by means of infrared heater (in the cold season) allowed:

- to research the process thermal treatment concrete heated air in the cold season;

- to analyze potential opportunities increasing intensity set concrete strength during their thermal treatment heated air with increases in the intensity of heat;

6. The need for further research:

- improve solar energy collector of his own design in order to increase its thermal power;

- analyze the impact of different types of chemical additives for concrete solidification intensity when it thermal treatment in by heated air solar energy collector.

Chapter 3. The method of determining the change in temperature of concrete mix in forming shop. In the study of arbitrary method thermal treatment of concrete and concrete products is necessary to know the temperature of the concrete mix, where the process begins. Initial (thermal treatment process for cement products) concrete mixture temperature is caused by the temperature at which the mixture enters the mold shop and a change in temperature of concrete mix during molding products and stay in the open chamber during the gradual filling of its products.

It should be emphasized that the minimum allowable temperature of the concrete mix at the outlet of concrete mixers in the cold season is equal to 5 ºC (at its conclusion in the shop, not on the landfill), and the maximum allowable temperature of the mixture is heated 60ºC [29].

In the book [22] states that in the warm season under favorable climatic conditions pre-heating by means of solar radiation fillers concrete mix and water mixing allows the mixture to warm to 50 – 60 ºC.

The temperature of the concrete mix will change during the formation of products and their stay in the open chamber (with the gradual filling chamber molded products).

In the literature of reference ([30], [31]) provides general formulas for determining the intensity of heating or cooling materials in industrial plants. However, these processes for the concrete mix (during her stay in forming concrete products factory shop) have certain features that should be considered.

Methods for determining the heat release cement hydration in air conditions. When forming concrete and concrete products and their location in an open chamber (before close the camera cover) is the interaction of cement with water. To determine the amount of heat released in the process, offered 2 experimental and computational methods.

Determination of heat release cement hydration in air conditions. The essence of this method:

- the composition of concrete mix made in laboratory conditions must match the composition of concrete mix produced in factory conditions;
- the ratio between the mass of concrete mixture and mass of forms in laboratory experiments must match the corresponding ratio in factory conditions; If concrete products are relatively small in size, it is necessary to fulfill the condition of geometric similarity samples and products;
- concrete samples after their manufacture hydro-insulated;
- initial temperature of the concrete mix and forms should be the same;
- between the lower surface of the form in which the concrete mixture, and the surface on which it is located, this form must be air layer (you need to stand, these coasters osculation area with the surface should be minimal);
- during the experiment determined the following temperature:

a) the temperature inside the samples;

b) surface temperature of the system under study.

The amount of heat $Q_1^{/}$ released by the interaction of cement with water for a certain period of time, J, is equal to

$$Q_1^{/} = Q_1 + Q_2 + Q_3 + Q_4, \qquad (9)$$

where Q_1, Q_2, Q_3, – the amount of heat it takes to heating under concrete sample forms and shapes stands at his hardening for a certain time, J;

Q_4 – heat loss system under study in the environment for a certain period of time, J; these heat losses expedient to determine as recommended sources [15] - [18].

"Method plate" for an approximate determination of the intensity of heat release in cement hydration in air conditions.

The essence of "plate method":

- the composition of concrete mix made in laboratory conditions must match the composition of concrete mix produced in factory conditions;
- concrete is shaped sample plate;
- to create a one-dimensional temperature field of heat-insulated facets sample (except for its two lateral sides, which have a greater surface area); "Open" surface of the sample (which is not in contact with the wall forms) can be pre-hydro-insulated;
- during the experiment determined surface temperature of each sample and the degree of heating insulation layer;
- during the experiment determined the temperature of the system components.

The differential equation of heat conduction for this case has the form

$$\frac{\partial t}{\partial \tau} = a\,\frac{\partial^2 t}{\partial x^2} + \frac{q_\upsilon}{c\rho}, \tag{10}$$

where q_υ – the volume density of the heat flux due to the presence of internal heat sources (heat rise cement), W/m^3;

a – coefficient of thermal diffusivity of the material sample, m^2/s, which is equal to

$$a = \frac{\lambda}{c\rho}, \tag{11}$$

where λ – coefficient of thermal conductivity of the material sample, W/(m·°C);

c – specific heat capacity of the material sample mass, J / (kg ·°C);

ρ – the density of the material sample, kg/m^3.

Under the terms of the theory of heat conduction (present as a source [16]), the temperature of the plate is slightly different from temperature at its center, if the criterion Bi → 0 (almost criterion Bi <0.1) (Fig. 38).

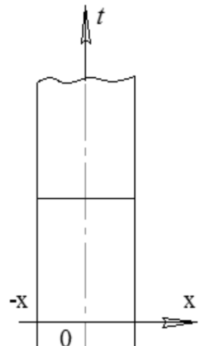


Figure 38. Temperature distribution in the sample-and-plate in time and Criterion Bio calculated by the ratio

$$Bi = \frac{\alpha\delta}{\lambda}, \quad (12)$$

where α – heat transfer coefficient of exchange surface to the environment, W / (m^2·ºC);

δ – semi-thickness sample plate, m;

λ – coefficient of thermal conductivity of the material sample, W / (m·ºS).

The total period of solidification concrete is divided into regular intervals to make up the heat balances.

Use this simplifying premise: since coefficient of thermal conductivity metal is relatively great importance then take the temperature of the sample surface is equal temperature to appropriate forms 2 metal walls that are not insulated.

If the temperature of the external surfaces of the heat-insulating layer is higher than the ambient temperature, the amount of heat $Q_1^{/}$, released by the interaction of cement with water hardening for a certain period of time, J, is equal to

$$Q_1^{/} = Q_1 + Q_2 + Q_3 + Q_4, \quad (13)$$

where Q_1, Q_2, Q_3, – the amount of heat it takes to heating under concrete sample forms and the heated part the heat-insulating material during its solidification for a certain time, J;

Q_4 – the heat loss for a certain period of time under study in the environment because 2 is not heat-insulated facets of design, J; these the heat loss expedient to determine as recommended sources [15] - [18].

If the temperature of the external surfaces of the heat-insulating layer higher than ambient temperature, this factor must be considered in the heat balance; loss of heat for heating light hydro-insulation material can be neglected.

Determination of temperature change concrete mix in forming shop factory concrete products. In the source [17] provides recommendations for determining the temperature distribution in an infinite plate (called unlimited plate thickness is small compared to its length and width).

Consider the process, which produced reinforced concrete slabs. Assume that the temperature of the concrete mix is higher than the air temperature of the shop.

Suppose that for molded reinforced concrete slabs can determine the temperature distribution in the thickness of its dependencies characterizing the temperature distribution over the thickness of unlimited plate.

Consider the capabilities that characterize the process of cooling unlimited plate thickness 2δ [17]. The axis of coordinates is placed in the center of the plate (Figure 39).

The change in temperature of the plate is only axis 0x.

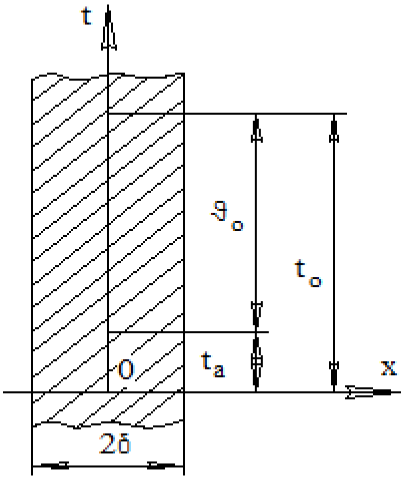


Figure 39. Unlimited plate

The countdown temperature of the plate is made of ambient temperature:

$$\vartheta = t - t_a, \qquad (14)$$

where t – temperature in any section of the plate (perpendicular axis 0x) to any point in time, ºC;

ϑ – temperature in any section of the plate (perpendicular axis 0x) to any point in time, the count of which the ambient temperature t_a, ºC.

At the initial time the temperature in the plate uniformly distributed, ie

$\vartheta_0 = t_0 - t_a = const$ (fig. 39).

The boundary conditions of the third kind - given ambient temperature t_a and the law of heat exchange between the surface of the body and the

Environment:

- on the axis of the plate at "x = 0" $\left(\frac{\partial\vartheta}{\partial x}\right)_{x=o} = 0;$ (15)

− on the plate surface at x = δ $\left(\frac{\partial\vartheta}{\partial x}\right)_{x=\delta} = -\frac{\alpha}{\lambda}\vartheta_{x=\delta}.$ (16)

As the temperature of the plate in the direction of 0y axis 0z and does not change, then

$$\frac{\partial\vartheta}{\partial y} = 0\,, \qquad \frac{\partial\vartheta}{\partial z} = 0.$$

The differential equation of heat conduction for this case has the form

$$\frac{\partial\vartheta}{\partial\tau} = a\,\frac{\partial^2\vartheta}{\partial x^2}. \qquad (17)$$

Solution differential heat conduction equation (consistent with the terms of uniqueness - geometric, physical, initial and boundary) makes it possible to determine the temperature distribution in the plate at an arbitrary point in time:

$$\Theta = \sum_{n=1}^{n\to\infty} \frac{2\sin\varepsilon_n}{\varepsilon_n + \sin\varepsilon_n\cos\varepsilon_n} \cos\left(\varepsilon_n \frac{x}{\delta}\right) e^{-\varepsilon_n^2 Fo} =$$

$$= \sum_{n=1}^{n\to\infty} \frac{2\sin\varepsilon_n}{\varepsilon_n + \sin\varepsilon_n\cos\varepsilon_n} \cos\left(\varepsilon_n \frac{x}{\delta}\right) \exp(-\varepsilon_n^2 Fo); \qquad (18)$$

at $Fo \geq 0{,}3$ temperature distribution in the plate at an arbitrary point in time with sufficient accuracy can be determined using equation

$$\Theta = \frac{2\sin\varepsilon_1}{\varepsilon_1 + \sin\varepsilon_1\cos\varepsilon_1} \cos\left(\varepsilon_1 \frac{x}{\delta}\right) e^{-\varepsilon_1^2 Fo} =$$

$$= \frac{2\sin\varepsilon_1}{\varepsilon_1 + \sin\varepsilon_1\cos\varepsilon_1} \cos\left(\varepsilon_1 \frac{x}{\delta}\right) \exp\left(-\varepsilon_1^2 Fo\right). \qquad (19)$$

where Θ – dimensionless temperature in any section of the plate (perpendicular axis 0x) to any point in time;

x – distance from the plate to the middle section, which is determined by the temperature of the plate, m;

Fo – Fourier criterion;

ε_n – Mathematics complex, which is determined according to the criteria Bi.

The dimensionless temperature in any section of the plate (perpendicular axis 0x) to any point in time is equal to

$$\Theta = \frac{\vartheta}{\vartheta_0} = \frac{t - t_a}{t_0 - t_a}, \qquad (20)$$

then the temperature in any section of the plate (perpendicular axis 0h) to any point in time is calculated by the equation

$$t = t_a + \Theta\,(t_0 - t_a), \qquad (21)$$

where ϑ – temperature in any section of the plate (perpendicular axis 0x) to any point in time, the count of which the ambient temperature t_a, ºC;

t – temperature in any section of the plate (perpendicular axis 0x) to any point in time, ºC;

ϑ_0 – plate temperature at the initial time, countdown which the ambient temperature t_a, ºC;

t_0 – plate temperature at the initial time, ºC.

Criterion Fourier calculated by the ratio

$$\mathrm{Fo} = \frac{a\tau}{\delta^2}, \tag{22}$$

where a – coefficient of thermal diffusivity of the material plate, m^2/s ;

τ – period of time, s;

δ – half-thickness of the plate, m.

The amount of heat, J, which gives the plate in the environment over time is calculated by dependence

$$Q = 2\delta F\rho c(t_0 - \bar{t}), \tag{23}$$

where $\bar{t}$ – average temperature of the plate after a certain period of time after the start of cooling, ºC.

The average temperature of the plate at an arbitrary point in time is determined by the equation

$$\bar{\Theta} = \sum_{n=1}^{n\to\infty} \frac{2\sin^2\varepsilon_n}{\varepsilon_n^2 + \varepsilon_n \sin\varepsilon_n \cos\varepsilon_n} e^{-\varepsilon_n^2 \mathrm{Fo}} =$$

$$= \sum_{n=1}^{n\to\infty} \frac{2\sin^2\varepsilon_n}{\varepsilon_n^2 + \varepsilon_n \sin\varepsilon_n \cos\varepsilon_n} \exp(-\varepsilon_n^2 \mathrm{Fo})\,; \tag{24}$$

a value criterion Fourier $\mathrm{Fo} \geq 0{,}3$ average temperature of the plate at an arbitrary point in time with sufficient accuracy can be calculated using equation

$$\bar{\Theta} = \frac{2\sin^2\varepsilon_1}{\varepsilon_1^2 + \varepsilon_1 \sin\varepsilon_1 \cos\varepsilon_1} e^{-\varepsilon_1^2 \mathrm{Fo}} =$$

$$= \frac{2\sin^2\varepsilon_1}{\varepsilon_1^2 + \varepsilon_1 \sin\varepsilon_1 \cos\varepsilon_1} \exp\left(-\varepsilon_1^2 \mathrm{Fo}\right); \tag{25}$$

where $\bar{\Theta}$ – dimensionless average temperature of the plate at an arbitrary point in time; determined by the ratio

$$\bar{\Theta} = \frac{\bar{\vartheta}}{\vartheta_0} = \frac{\bar{t} - t_a}{t_0 - t_a}, \tag{26}$$

where $\overline{\vartheta}$ – average temperature of the plate at an arbitrary point in time count which the ambient temperature t_a, ^0C; $\overline{t}$ – average temperature of the plate at an arbitrary time, ^0C; ϑ_0 – plate temperature at the initial time, countdown which the ambient temperature t_a, ^0C; t_0 – plate temperature at the initial time, ^0C.

Then the average temperature of the plate in an arbitrary point in time, ^0C, calculated by the dependence

$$\overline{t} = t_a + \overline{\Theta}\,(t_0 - t_a). \qquad (27)$$

Summary.

1. Showing theoretical assumptions determine the intensity of cooling the concrete mix (slabs) in the molding shop.

2. The same dependence can also be used under condition that the temperature of the concrete mix is lower than the air temperature of the shop. In this case, the correction formulas to the changing direction of heat flow.

3. In determining the intensity change of temperature in forming concrete mix plant can use graphs presented in the literature of reference, built on the basis of the above relationships.

Determination of temperature change concrete mix in forming shop factory concrete products. We consider the technological process in which the temperature at which the concrete mixture enters the shop, is lower than the air temperature shop, equipment and structures, fence camera. Products - reinforced concrete slabs, thermal treatment process which takes place in the cellar type.

In the case under consideration, the temperature of the concrete mix will change during the formation of products and their stay in the open chamber (during the gradual filling of molded products) due to heat exchange with the environment and because of the presence heat rise cement.

Proposed the following algorithm for determining the intensity of heating concrete mixture (plates) in the molding shop for these conditions.

1.The analysis of the processes that affect the change in temperature of concrete mixture (plates) while its location in the shop.

The process of heating concrete mix roughly divided into three processes that occur simultaneously, but each process is proposed to calculate for certain dependencies. These processes to heating occur due: 1) collision mix with equipment; 2) heat exchange with the environment; 3) heat release cement in contact with water.

2. The period of time during which examines the change in temperature of concrete mixture (boards), divided into intervals.

The period of stay in the shop each plate consists of plates forming period and the period of her in an open chamber. Accordingly, the length of stay in the shop first plate is the longest and last plates - the lowest.

Temperature of the medium chamber may differ from the the air temperature shop. This factor should be considered when determining the amount of heat it takes to heating the concrete mix due to heat exchange with the medium shop and as a result of heat exchange with designs that fence camera (if the temperature is higher than the temperature of the concrete mix).

3. Determine the intensity of the first heating plate during its formation and finding the open chamber.

3.1 Calculate the average temperature t_a concrete mix, metal fittings and metal equipment, created as a result of collision.

The total heat content of concrete mix, metal fittings and metal equipment is equal to

$$c_a \cdot (G_c + G_m) \cdot t_c = c_a \cdot G_c \cdot t_c + c_m \cdot G_m \cdot t_m , \quad (28)$$

$$\text{then } t_a = (c_a \cdot G_б \cdot t_б + c_m \cdot G_m \cdot t_m) / c_a \cdot (G_c + G_m), \quad (29)$$

where t_a – average temperature of the concrete mix, metal, formed as a result of collision, ºC;

G_c – mass of concrete mix one plate, kg;

G_m – mass of metal faced by concrete mixture, kg;

c_c, t_c – specific heat capacity and concrete mixture temperature;

c_m, t_m – mass specific heat capacity and temperature metal;

c_a – specific heat per unit mass of concrete mixtures and metal, J/(kg·°C), which is calculated by the dependence

$$c_a = (c_c \cdot G_c + c_m \cdot G_m) / (G_c + G_m) . \quad (30)$$

Using temperature ta in subsequent calculations allow for the impact with the first 3 components (see. p. 1.1) on the the general process of heating the concrete mix.

3.2. Calculated heat Q_e costs for heating the concrete mix, fittings and form due to the presence of heat exchange with the environment.

In the literature of reference are the following dependence to determine the amount of heat Q_e, J, which takes material from the environment over time,

$$Q_e = c \cdot G \cdot (t_a - t_i) \cdot \beta , \quad (31)$$

where c – specific heat per unit mass of material, J / (kg·ºC);

G – mass of material, kg;

t_e – ambient temperature ° C;

t_i – initial temperature material °C;

β – coefficient, which takes into account what proportion of heat (relatively heat required to heat the material to ambient temperature) perceives material; β coefficient of reference data determined by means of Fourier criterion, which is equal to

$$F_O = \tau / c \cdot G \cdot R\,, \qquad (32)$$

where τ – period of time, s;

R – total resistance transfer of heat from the environment before exchange surface, ºC/W;

R value calculated by the formula

$$R = G / (\rho \cdot \lambda \cdot F^2) + 1 / (\alpha \cdot F)\,, \qquad (33)$$

where ρ – density material, kg/m^3;

λ – coefficient of thermal conductivity of the material, W/(m·ºC);

α – coefficient of heat transfer from the environment to the exchange surface, W/(m^2·ºC);

F – exchange surface area, m^2;

heat transfer coefficient α is calculated by the formula

$$\alpha = \alpha_c + \alpha_r, \qquad (34)$$

where α_c – convection heat transfer coefficient, W/(m^2·ºC);

α_r – radiation heat transfer coefficient, W/(m^2·ºC).

To use the above dependencies is proposed to apply the following simplified assumptions:

- take the temperature t_a (see. dependence 29) initial;
- mass of G equal to the sum the masses of concrete mix, shape and armature

$$G = G_c + G_a + G_{mf}\,, \qquad (35)$$

where G_c – mass of concrete mix one plate, kg; G_a, G_{mf} – маса mass of armature and metal form kg;

– value c, ρ and λ are equal

$$c = c_a = (G_c \cdot c_c + (G_a + G_{mf}) \cdot c_m) / (G_c + G_a + G_{mf})\,, \qquad (36)$$

$$\rho = \rho_a = (G_c \cdot \rho_c + (G_a + G_{mf}) \cdot \rho_m) / (G_c + G_a + G_{mf})\,, \qquad (37)$$

$$\lambda = \lambda_a = (G_c \cdot \lambda_c + (G_a + G_{mf}) \cdot \lambda_m) / (G_c + G_a + G_{mf})\,, \qquad (38)$$

where c_a, λ_a, ρ_a – average specific mass heat capacity, coefficient of thermal conductivity and mean average density of concrete mixture and metal.

Then the relationship (31) - (34) have the form

$$Q_e = c_a \cdot (G_c + G_a + G_{mf}) \cdot (t_a - t_a) \cdot \beta \,, \quad (39)$$

$$F_O = \tau / c_a \cdot (G_c + G_a + G_{mf}) \cdot R \,, \quad (40)$$

$$R = (G_c + G_a + G_{mf}) / (\rho_a \cdot \lambda_c \cdot F^2) + 1 / (\alpha \cdot F) \,. \quad (41)$$

3.3. Calculate the average temperature of the concrete mix, armature and forms t_{a1} end of the first period of time (due to the presence of heat exchange with the environment and the changing temperature the concrete mix, metal armature and metal equipment during their collision).

Change in the average temperature the concrete mix, armature and forms Δt_{a1}, °C, at the end of the first period of time (as a result of these factors) is equal to

$$\Delta t_{a1} = (t_a - t_a) \cdot \beta, \quad (42)$$

while the average temperature of the concrete mix, armature and forms t_{a1}, °C, at the end of the first period of time (due to the presence of heat exchange with the environment and the changing temperature the concrete mix, metal armature and metal equipment during their collision) is

$$t_{a1} = t_a + \Delta t_{a1}, \quad (43)$$

temperature t_a dependence is determined by 29.

3.4. Calculate the average for the first time interval the temperature of concrete mix, armature and form t_1 (due to the presence of heat exchange with the environment and the changing temperature the concrete mix, metal armature and metal equipment during their osculation).

The average for the first time interval the temperature of concrete mix, armature and form t_1, °C (due to the factors listed above) is

$$t_1 = 0{,}5 \cdot (t_a + t_{a1}). \quad (44)$$

3.5. Determine the amount of heat Q_{ek} released the first period of time due to cement hydration.

The amount of heat Q_{ek}, James released the first period of time due to the presence of exothermic reactions of cement with water is determined from experimental data based on temperature of the concrete mixture.

For the first time interval using temperature t_1, which in subsequent calculations (p. 3.7) should be clarified.

3.6. Calculate the average temperature of the concrete mix, armatureand forms at the end of the first time interval, taking into account the presence of heat exchange with the environment, heat rise cement by hydration and the changing temperature of concrete mix, metal armature and metal equipment due to their collision.

The amount of heat it takes to heating the concrete mix, armature and form for the first time interval can be calculated by the formula

$$Q_1 = Q_e + Q_{ek}, \quad (45)$$

or by the formula $Q_1 = c_a \cdot (G_c + G_a + G_{mf}) \cdot (t_{a1y} - t_a)$, (46)

then $t_{a1y} = t_a + Q_1 / c_a \cdot (G_c + G_a + G_{mf})$, (47)

where t_{c1y} – specified average temperature of the concrete mix, armature and forms the end of the first time interval (including the presence of heat exchange with the environment, heat rise cement and the changing temperature of concrete mix, metal armature and metal equipment due to their collision).

Note. Considering the change in temperature of concrete mix, metal armature and metal equipment during their collision is due to use in calculating the temperature t_a.

3.7. Clarifies the value of the average for the first time interval temperature of concrete mix, armature and forms t_{1y} .

Specify the average for the first time interval the temperature of concrete mix, armature and forms t_{1y}, ° C, is equal to

$$t_{1y} = 0{,}5 \cdot (t_a + t_{a1y}). \quad (48)$$

If the temperature is significantly different from t_{1y} temperature t_1, the calculation is repeated using temperature t_{1y}.

4. Similarly, the change in temperature is determined by the first molded plate for subsequent periods.

5. Similarly, the change in temperature is determined by the second and other molded boards during their stay in the molding shop.

Table 1 shows the correlation between the amount of heat it takes to heating the first plate and metal forms as a result of heat exchange with the environment and the amount of heat it takes to heating their heat release due to cement by hydration for the studied conditions. The estimated temperature shop adopted in accordance with the rules [32]. It is assumed that the average temperature of the concrete mix and metal, which is formed as a result of collision, t_a = 10 ºC.

Table 1 - Ratio between the amount of heat it takes to heating the first plate and metal forms as a result of heat exchange with the environment and as a result heat rise cement by hydration

The total length of time, min	Ratio between the amount of heat it takes to heating a metal plate and forms for 15 minutes due	
	heat exchange with the environment,%	heat rise cement by hydration,%
15	92,6	7,4
30	88,1	11,9
45	75,7	24,3
60	73,2	26,8
75	69,0	31,0
90	65,8	34,2

Since the boundary conditions and other factors change during the whilst the plate in an open chamber, then the intensity of the heat it changes over time.

Conclusions.

1. The method of determining the intensity of heating in forming concrete mix concrete products factory shop in the cold season.

2. The method can also be used provided that the concrete mixture and its preheat temperature higher than the air temperature of the shop. In this case, the correction formulas to the changing direction of heat flow.

The general conclusions. The basic principles of the methodology developed forecasting intensity solidification of concrete products in alternative methods of heat treatment. This methodology includes:

- the method of calculation and experimental forecasting intensity solidification concrete products with the use only the heat released during cement hydration, this method is based on of laboratory research techniques
- the method of calculation and experimental forecasting intensity solidification concrete products with the use heated in the collector solar energy air.
- the method of calculating the loss of heat for heating designs fence camera for thermal treatment of concrete products, and heat losses through these constructions considering the presence of non-stationary thermal field in these structures in that process;
- method of determining the intensity change of temperature in forming concrete mix shop; This method consists of methods for experimental determination of heat release of hydration of cement in air conditions and methods with calculating the intensity change of temperature in forming concrete mix shop.

2. The main objective of further research - implementation of the proposed production of patents [1], [3] of heat treatment of concrete and concrete products.

References

1. Pat. № 90487. Ukraine. MPK SO4B 40/02 (2006.01). Sposib teplovoï obrobki betonnih i zalizobetonnih virobiv / T.S. Kugaevska, V.V. Shulgin; zajavnik i vlasnik Poltava National Technical Yuri Kondratyuk University; appl. 13.01. 2014; publ. 26.05.2014, per. № 10.

2. Pat. № 83714. Ukraine. MPK (2013.01) F24H 3/00. Sposib vikoristannja sonjachnoï energiï dlja teplovoï obrobki betonnih i zalizobetonnih virobiv / T.S. Kugaevska, V.V. Shulgin, O.V. Svinin; zajavnik i vlasnik Poltava National Technical Yuri Kondratyuk University; appl. 1.04. 2013; publ. 25.09.2013, per. № 18.

3. Pat. № 84944. Ukraine. MPK (2013.01) F24J 2/00, F24J 3/00. Sposib vikoristannja sonjachnoï energiï dlja priskorennja tverdinnja betonnih i zalizobetonnih virobiv / T.S. Kugaevska, V.V. Shulgin, O.V. Svinin; zajavnik i vlasnik Poltava National Technical Yuri Kondratyuk University; appl. 01.04. 2013; publ. 11.11. 2013, per. № 21.

4. Volzhensky A.V. Mineral knitting substance. 4th ed., revised and supplemented. - M: Stroyizdat, 1986, 464 p.

5. O.P. Mchedlov, Petrosyan, A. Usher-Marshak, A. Urzhenko Heat release hardening binding materials and concrete . M .: Stroyizdat, 1984, 224 p.

6. Usherov-Marshak, A. AV Calorimetry cement and concrete: Selected Works. H .: Fact, 2002, 183 p.

7. DSTU B V.2.7-225:2009 Building materials. Concrete. Method of determining heat release during solidification. – Kyiv.: Minregionbud Ukraine, 2010. – 12 p.

8. Troyan V.V. Thermostressed state as an aspect of the durability of reinforced concrete monolithic structures http://beton-profi.ru/papers/14.pdf.

9. Runova R.F. Analysis of thermal-stress state foundation slab and tips on caring for her during concreting. http://beton-profi.ru/matmod.pdf.

10. Temperature monitoring systems hardening cement. A.V. Kabus, N.N. Isayenko, E.A. Moroz E.V. Ivashchenko, E.B. Voropaeva // Scientific Bulletin of the construction, № 65. - Kharkiv: HNUBA, HOTV OMB, 2011. - S. 256 - 265.

11. Bibik, M.S., V.V. Babitsky, S.D. Semeniuk. Determination of the main periods trapezoidal mode of steam treatment concrete. Resource-economical materials, structures and buildings. - Rivne: NUWMNRU, 2011. - Vol. 22. - P. 22 - 28.

12. V.V. Pavlyuk, L.V. Tereshchenko, K.V. Bondar. Evaluation of heat release Cements for general construction purpose, modified chemical additives. Resource-economical materials, structures and buildings. - Rivne: NUWMNRU, 2010. - Vol. 20. - P. 82 – 87.

13. S.V. Fedosov, V.I. Bobylev, A.M. Ibragimov, V.K. Kozlov, A.M. Sokolov. Modeling of strength development concrete with cement hydration. Building Materials. - 2011. - № 11. - S. 38 - 41.

14. V.V. Babitsky, S.D. Semeniuk, M.S. Bibik. Forecasting characteristics of hardening of heavy concrete. Resource-economical materials, structures and buildings. - Rivne: NUWMNRU, 2009. - Vol. 18. – P. 3 – 12.

15. Amethystov E.V. Heat and mass transfer. Heat-Technical eksperiment. Reference Guide. - M .: Energoizdat, 1982. - 512 p.

16. V.P. Isachenko, V.A. Osipov, A.S. Sukomel. Heat transfer: a textbook for high schools. M .: Energoizdat, 1981, 486 p.

17. M.A. Mikheev, I.M. Mikheev. Fundamentals of heat transfer. M .: Energia, 1977, 343 p.

18. Maryamov N.B. Heat treatment products for precast concrete factories. M: Stroyizdat, 1970, 272 p.

19. V.V. Boiko, E.V. Tikhomirov. The heat treatment in the production of precast concrete. K .: Budivelnik, 1987. - 144 p.

20. Tsvetkov V.V. Heat treatment products for precast concrete factories. K: Budivelnik, 1978, 112 p.

21. Fokin K.F. *Stroitel'naja teplotehnika ograzhdajushhih chastej zdanij*. [Building Heat Engineering enclosing parts of buildings]. M.: AVOC PRESS, 2006, 256 p.

22. Podgornov, N.I. *Termoobrabotka betona s ispol'zovaniem solnechnoj jenergii* [Heat treatment of concrete using solar energy]. – Moscow.: Publ ASV, 2010. 328 p.

23. N.I. Podgorny, T.V. Apparovich, D.D. Koroteev. Heat treatment of concrete formwork forms using solar energy. Izvestiya Vuzov. Stroitelstvo.- Novosibirsk NSABU, 2009. - № 6. - S. 35 - 42.

24. L.B. Aruova, N.T. Dauzhanov. Using solar energy in heat treatment f concrete in the republic of Kazakhstan.
http://zimbeton.ru/article/2012_10_3.pdf.

25. N.T. Dauzhanov, B.A. Krylov. Small energy intensive heat treatment technology foam concrete products in landfills with solar energy. http://www.rusnauka.com/28_NII_2012/Tecnic/5_118020.doc.htm.

26. Shhukina, T.V. Geliotermoobrabotka s ispol'zovaniem sredstv povyshenija jenergoobluchjonnosti stroitel'nyh izdelij [Solar thermal treatment using a means of increasing the irradiation energy construction products].
http://www.rusnauka.com/28_NII_2012/Tecnic/5_118020.doc.htm.

27. Kugaevska, T.S. Thermal treating of concrete samples heated air / T.S. Kugaevska, V.V. Shulgin // Collection of scientific articles «Energy, energy saving and rational nature use» / Kazimierz Pulaski University of Technology and Humanities in Radom. – Radom, Poland, 2014. – P. 21 – 25.

28. Kugaevska, T.S. Thermal treatment the concrete samples heated air in the collector energy / T.S. Kugaevska, V.V. Shulgin // Collection of scientific articles «Energy, energy saving and rational nature use» / Kazimierz Pulaski University of Technology and Humanities in Radom, № 2 (3) 2014. – Radom, Poland, 2014. – P. 66 – 73.

29. DBN A.3.1-7-96. Management, organization and technology. Production of concrete and concrete products. - K .: Derzhkommistobuduvannya Ukraine, 1997. - 53 p.

30. Internal sanitary-technical device. At 3 ch. Part 3. Ventilation and air conditioning. Book 1: The reference designer / V.N. Bogoslovsky, N.N. Pavlov and Y.I. Schiller. 4th ed. - M .: Stroyizdat, 1992. - 319 p.

31. Volkov O.D. Ventilation engineering industrial building: a tutorial. Kharkov: Vishcha School, 1989. - 240 p.

32. DBN A.3.1-8-96. Development of plants for the production of concrete products. - K .: State Building Ukraine, 1998. - 47 p.