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CONSTRUCŢII. ARHITECTURĂ

OPTIMIZING THE THERMAL REGIME DURING THE ACCELERATION OF CONCRETE'S HARDENING

BY

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Researches conducted at the Faculty of Construction in Jassy showed several factors that may help finding technical solutions which will make possible to economically apply acceleration procedures of concrete hardening by thermal treatment with solar energy. It has to be mentioned the fact that the thermal treatment do not exclude, but it is based on the acceleration methods of concrete hardening through "composition" with or without the usage of different additives – plasticizer type (to reduce the quantity of water from the concrete) and accelerators for cement binding or hardening. These methods also take into account the climate where the process of hardening takes place.

1. Introduction

Aiming to increase the velocity of hardening more than the performances that can be obtained in natural climate – even warm periods of time – it is a necessity to accelerate the concrete's hardening in case of industrialization of the construction works, whose economical efficiency directly depends on the short period of time in which the material basis from one work can be re-used.

When the work is performed during the cold seasons this necessity becomes even more imperious since the conditions required to reach the "critical point" of hardening before the frosting might jeopardize the quality of the material and therefore oblige to stop the production.

Researches conducted at the Faculty of Construction in Jassy showed several factors that may help finding technical solutions which will make possible to economically apply acceleration procedures of concrete's hardening by thermal treatment with solar energy. It has to be mentioned the fact that the thermal treatment do not exclude, but it is based on the acceleration methods for concrete hardening through "composition" with or without the use of different additives – plasticizer type (to reduce the quantity of water from the concrete) and accelerators for cement binding or hardening. These methods consider the climate where the process of hardening takes place.

2. The Solar Energy as Source of Heat for the Thermal Treatment of the Concrete

A. The solar energy may be a source of heat for the thermal treatment of the concrete if the following procedures are observed:

a) Realising on the external lines of production (polygons) several direct collectors of solar energy, consisting of a proper arrangement of the surface where the precast elements are produced.

b) Collecting the solar energy in collectors for general purposes, with or without a temporary storage, energy that can be used as warm water to prepare the concrete when there is no sun, including nights.

c) Collecting the solar energy in the same conditions as those mentioned above and using the warm water to heat the direct collectors during the periods when there is no sun or to heat some internal production lines, thus replacing the thermal agent provided by the conventional sources of heat.

We need to mention the fact that the solar energy can be collected and used in the same manner during the cold seasons but with reduced levels of efficiency and restrictive conditions of exploitation.

B. The desultory and aleatory character of the sunlight varies in intensity and duration and it is specific to every place in the country and, at the same time, it varies from one year to another.

The data acquired at the Centre of Physics in Jassy, which is not a city with best conditions as regards the sunlight, show the possibility to best use a minimum of 1,200 h of sunlight a year (an average of 5,...,6 h daily), so that the result would be a number of 240 days with sun which are unevenly distributed over a year's time. At first view, this unevenness could be perceived as a disadvantage; nevertheless this disadvantage, under certain circumstances, could be turned into a favourable factor to extend the period of use of the solar energy over the year.

C. The desultory and aleatory character of the usage of solar energy determines the imposing of preventive measures to ensure the quality of the concrete and to increase the reliability of the procedures based on its use.

The researches conducted in Jassy, at the Faculty of Constructions, offer viable, economical and technical solutions to solve the two aspects mentioned above. Thus, to prevent the quality imperfections, respectively insufficient levels of concrete hardening to safely pass through the typical technological stages, we propose to perform an *in situ* control of the concrete's ageing degree by measuring the temperature of the concrete at different moments.

The desultory and aleatory character that characterizes the solar energy can be significantly moderated by

a) Combining the proceeding of direct collection, which is the most efficient one although quite insecure, with the proceeding of collecting and storing the heat as warm water to be used at the heating of the concrete when there is no sun.

b) Activating the exothermic character of the cement as an intrinsic heat-source of the concrete from the early hours of treatment; this feature can be activated by a relatively high temperature obtained using all the procedures mentioned at point A.

c) Foreseeing the evolution of the concrete's temperature at different conjectures of variation in time and intensity of the sunlight, as well as practicing protection measures for the concrete and the heating system.

3. Procedures for the Collection of the Solar Energy

A. The direct collectors, intended to generate the greenhouse effect, can be realized by arranging on a thermal insulated or heated platform several series of micro-precincts (vats) with thermal protected walls and placed in such a pattern that creates a module of production.

The treatment procedure takes place considering the following stages:

a) Firstly, the precast elements are realized and placed in a production module, then the exterior surface of the concrete or all elements are covered with a black file of polyethylene so as to prevent the transfer of humidity between the concrete and the air within the place and to prevent the intensification of the heat absorption (Fig. 1 *a*).

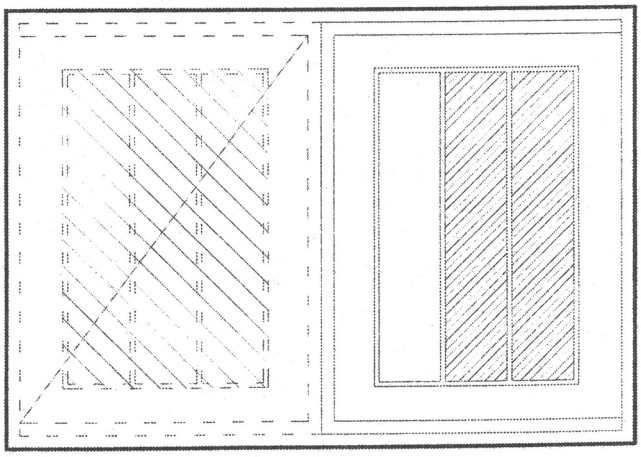

Fig. 1 *a*.– Procedures for the thermal treatment of concrete; general ensemble.

b) The micro-precinct is covered with transparent elements made of film and each module will be sealed. It is recommended to install pipes and to splash warm water over the film so as to create a thermo-wet microclimate which will be favourable for the hardening process. At the same time, there are installed thermometers to control the temperature; the best idea is to install checking gauges connected to the automatic temperature recorders located at the exterior (Fig. 1 *b*).

c) After the sunny period has ended – daytime, but especially during night-time – the transparent surface is covered and protected for losses of heat and bad weather (Fig. 1 *c*). The devices used are various, ranging from the simple canvas to the "cushions" with a high thermal insulating capacity.

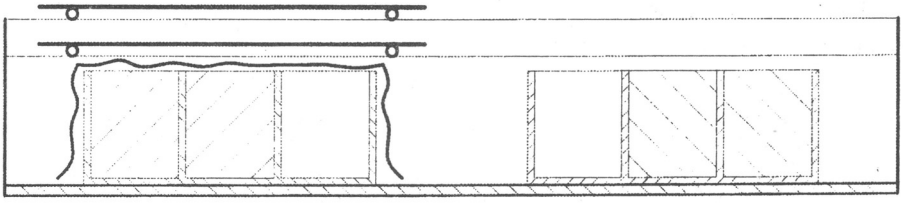

Fig. 1 *b*.– Procedures of thermal treatment of the concrete; the treatment applied during the sunny period.

d) Once the favourable sunny period has come, the transparent surfaces are uncovered simply by removing the protection mentioned at point c). The operations from c) and d) are to be repeated every time it is necessary, until the thermal treatment cycle is completed.

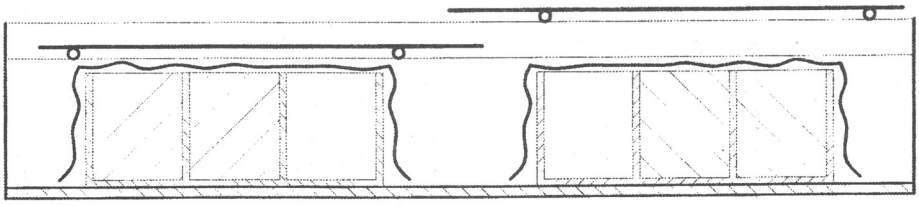

Fig. 1 *c*.– Procedures of thermal treatment of the concrete; the treatment applied during the non-sunny period.

e) During the entire period of thermal treatment there will be observed the evolution of the temperature within the concrete and will be evaluated the degree of ageing.

The variant presented in Fig. 1 has been experimented on three external polygons belonging to a precast factory and the results were extraordinary. The direct collectors can create an instant power of 450...700 W/m^2, in accordance with the intensity of the sunlight and the sealing conditions of the micro-precinct.

B. The solar energy collectors used at the preparation of the warm water are those of normal usage. Researches that are still in progress regard several important changes in the distribution of the collectors so that to reduce the horizontally occupied surface. Meanwhile, another major problem for the research team is finding the best conditions to use the solar energy collectors during winter time.

4. The Effect of Exothermy on the Cement

The researches showed the variant of the ageing degree in accordance with the temperature and the possibility to correlate it with the ageing degree at a normal temperature using the coefficient k_θ with subunitary values for the temperatures which are inferior to the normal one and over-unitary values for the higher temperatures. This is expressed by the relation

$$\Delta M_j = M_{\theta i} K_{\theta i} = (\theta_i + 10) t_i k_{\theta i} = m_i t_i, \tag{1}$$

where: ΔM_j is the ageing degree at normal temperature, realized within the interval of time t_i and significantly correlated with the increase of the hardening level, $\Delta\beta_j$, at a normal temperature of +20°C, [h.°C]; $M_{\theta i}$ – the ageing degree effectively realized within the interval of time t_i at an average temperature θ_i, [h.°C]; t_i – the period of time to realize the average temperature θ_i, [h]; θ_i – the average temperature in the interval of time t, [°C]; $K_{\theta i}$ – correlation coefficient of the ageing degrees $M_j - M_{\theta i}$; m_i – the unitary degree of ageing which is characteristic to the temperature θ_i, [h.°C/h].

Based on these facts and also accepting the balance that exists between the quantity of heat emitted through exothermy and the hardening level, as a consequence of the fact that both parameters reflect phenomena having chemical reactions of hardening as cause, the result consists of different intensities of emission of the exothermy for different levels of concrete's hardening, since this is a non-linear process even when the temperature is invariable.

To estimate the intensity of the exothermy the quantity of heat is referred to the estimated time using the relation (1). Thus it is evaluated an auxiliary parameter which depends only on the type of cement used

$$\overline{P}_{exj} = \frac{\Delta\beta_j}{100} \cdot \frac{E_{28}}{\Delta M_j}, \tag{2}$$

where: $\Delta\beta_j$ is the increase of the hardening level correlated with the increase of the ageing degree, ΔM_j, [%]; ΔM_j – the increase of the ageing degree at a normal temperature, [h.°C]; E_{28} – the total exothermy of the cement corresponding to the hardening process at a normal temperature for 28 days, [kWh/kg].

The intensity of emission of the exothermy can be found out using the relation

$$P_{sexij} = \overline{P}_{exj} C m_i \tag{3}$$

where: C is the dosage of cement, [kg/m^3]; m_i – the unitary degree of maturation, [h.°C/h].

The fact that the intensity of the cement's exothermy depends on the concrete's temperature may be exploited during the thermal treatment process by increasing the temperature of the concrete from the first hours after the pouring process, using all the available external sources of energy.

5. Conclusions

The problem studied in this paper is one of present interest considering that the prices of all forms of conventional energy keep rising.

There could be made some economies by rationally using these powers and this fact will be easily observed in the price of the structural concrete units, especially in the price of the precast units.

Using the sun power for the thermal treatment of the concrete, even though it has an aleatory behaviour, represents the most convenient and cheap solution to partially replace the conventional one.

The arrangements required by this system are simple, easy to maintain and not expensive.

Aiming to obtain the level of the concrete's hardening by the ageing degree is an essential facility to ensure the quality of works, even though in many occasions there will be needed an extension of the thermal treatment period due to the lack of sunlight.

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OPTIMIZAREA REGIMULUI TERMIC ÎN TIMPUL ACCELERĂRII ÎNTĂRIRII BETONULUI

(Rezumat)

Cercetări efectuate la Facultatea de Construcţii din Iaşi au pus în evidenţă unii factori ce pot contribui la găsirea soluţiilor tehnice care să permită aplicarea, în condiţii economice, a unor procedee de accelerare a întăririi betonului prin tratare termică cu ajutorul energiei solare. Trebuie precizat că tratarea termică nu exclude, ci se bazează pe metodele de accelerare a întăririi betonului prin „compoziţie", fără sau cu folosirea diverşilor aditivi atât de tip plastifiant (prin care se reduce cantitatea de apă din beton) cât şi prin utilizarea acceleratorilor de priză sau întărire, metode ce nu fac însă abstracţie de condiţiile climatice în care se întăreşte betonul.