Use of solar energy for heliothermal treatment of concretes on the basis of alkali cements

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ABSTRACT

Production of precast concrete requires a large amount of thermal energy, especially the technological process to accelerate concrete hardening. Application of helioforms with various translucent and solar perceptive coatings can be considered as one of the directions of solar energy application for thermal treatment of precast concrete. Heliothermal treatment of precast concrete products in helioforms, using such coatings, has been developed in the late 70th of the last century on the basis of research, conducted by scientists of scientific-research institutes of the Commonwealth of Independent States. Various ways of heliothermal treatment of concrete using translucent and solar perceptive coatings were proposed and tested. One of the simplest and most effective ways to accelerate hardening of concrete using solar energy, which found quite wide application in practice, is thermal treatment of heavy concrete products in helioforms with translucent and heat insulating coatings (THIC). This method of heliothermal treatment in regions with hot climate allowed to abandon for 5-6 months a year (for a number of slab products) the heat-humidity treatment with the use of other heat carriers; to reduce demand for water used to generate saturated water steam; to create seasonal testing grounds for thermal treatment of concrete with solar energy application; to create a clean quality environment for the production; and with all this, to ensure the diurnal cycle of manufacture of products. However, for heliothermal treatment with the use of THIC coatings helio top covers are needed, that require constant care of translucent liners; impossibility to use the existing helio top covers for the manufacture of products of another type/size; difficulty in manufacture of products of complex shapes according to this technology, etc. Development of advanced technologies of solar energy application to accelerate the hardening of concrete in the manufacture of concrete products will ensure high quality of precast concrete products due to creation of optimal structure of concrete as a result of the most favorable temperature-humidity conditions of concrete hardening, rational formation of temperature fields in products and heat -and -mass transfer. New approaches to the technology of heliothermal treatment of precast concrete structures in dry hot climate of the Republic of Kazakhstan save 50-100% of traditional fuel at their thermal treatment of precast concrete; ecologically clean quality environment, free of smoke emissions from boiler installations; guaranteed high quality of products and constructions at the diurnal cycle of turnover of the forms, reduction of the cost and energy intensity of construction.

Keywords: heliothermal treatment, alkali cements, solar energy

1 INTRODUCTION

Solar energy is virtually an unlimited source, the power of which on the Earth's surface is estimated at 20 TWh. This is more than 100 times higher than the predicted values of electric power required for the planet as a whole at the level of 2000 y.; and at that the use of this huge source of energy is not associated with any pollution of the environment. Today, in conditions of increasing limitations of nonrenewable fuel-energy resources, complication and increased cost of their output great significance is given to the use of solar energy.

Construction in the Republic of Kazakhstan is developing rapidly and moves in two directions – precast and monolithic ones. Unilateral orientation at monolithic construction, which prevails in some
countries (for example, in Ukraine) is not the best solution, since the other direction in construction has its advantages and weaknesses, that is why the development of two directions is a rational way. In all technically developed countries (France, Germany, USA, Sweden, etc.) precast construction is 40% of total volume of construction and only in seismic regions these volumes are somewhat less (Japan, etc.) and are about 20%. For precast construction in the Republic of Kazakhstan there is a good industrial base, created away back in the years of the Soviet Union, and it continues to develop.

However, precast concrete industry is a large consumer of thermal energy, and thermal treatment of products is the most energy-consuming technological process, which consumes more than 70% of energy. In our republic the southern regions are notable for dry hot climate, in order to reduce energy consumption for the production of precast concrete it is advisable to use solar energy, so among the applied methods of thermal treatment of concrete in conditions of dry hot climate, the methods of helio thermal treatment are the most rational ones. In recent years, such effective methods of thermal treatment of concrete products, using solar energy in conditions of open shops and testing grounds, as helio thermal treatment of them, using translucent heat insulating coatings THIC, among them in helio forms with heat accumulating elements; helio warming up with application of special film-forming compositions have been developed and implemented. Since the advent of combined methods of helio thermal treatment all year-round use of solar energy for thermal treatment of concrete and reinforced concrete products appears to be possible.

Methods of thermal treatment with the use of solar energy start to be developed in the factories of precast concrete, where until recently only steam warming up has been used. The variety of ways of helio thermal treatment provides optimal and economical choice for warming up of this type of construction with minimal costs. Helio technology in concrete production increases the coefficient of useful utilization of energy in the acceleration of concrete hardening, whereas soft modes of warming up and cooling the products facilitate the manifestation of the internal source — cement heat evolution and provide high quality of the products being warmed up.

Despite this, the possibilities of thermal treatment methods of concrete, using solar energy, at present are far from being disclosed and they have not yet taken a proper place in industry. This is due to the relative youth of the majority of methods and due to the fact that producers have insufficient knowledge of helio thermal treatment technology because of lack of information.

Thus, conducted studies have shown that the use of solar energy is a promising method of thermal treatment of concrete in dry hot climate, the possibilities of which have not yet been exhausted. Today, extensive studies are needed that would allow to develop helio thermal treatment methods, to develop new ones and promote their implementation into production, including the construction of buildings and structures from cast-in-place reinforced concrete.

Production of precast concrete requires a large amount of heat energy, especially the technological process to accelerate the hardening of concrete. In RCSRI several efficient ways of thermal treatment of concrete goods using solar energy in open shopfloors and testing ground have been developed and put into production (Aymenov 1992). Of great interest is heliothermal treatment with the use of THIC (translucent heat insulating coatings) in various combinations. This enables, for example, to produce concrete goods in testing grounds of all year-round operation at combined heliothermal treatment.

Each of the used methods of heliothermal treatment of concrete has its strengths and weaknesses, taking into account which their appropriate field of application is determined (Aymenov 1999).

The use of helioforms with various translucent and solar perceptive coatings can be considered another area of use of solar energy for heat treatment of precast concrete. Heliothermal treatment of concrete products in helioforms, applying such coatings, was developed in the late 70s on the basis of studies, conducted in RCSRI and in A-USRPI. Among the scientists who have made a great contribution to the development of this method of heliothermal treatment one should note (Krylov et al 1984).

2 RESEARCH METHODS

Essence of heliothermal treatment is in the following: the product heated in the form acts as a solar-heat collector, at this the hardening concrete is an absorbing and accumulating element, metallic form is the frame and cover, with definite lighting and heating technical parameters, acts as a transparent coating of helioforms (Zasedatelev et al 1985). Various ways of heliothermal treatment of concrete, using translucent coatings and solar perceptive coatings, were proposed and tested. One of the most simple and effective ways to accelerate concrete hardening using solar energy, quite widely used in practice, is thermal processing of heavy concrete goods in helioforms with translucent and heat insulating coating (THIC). It anticipates the application of helioforms, including two main elements: metal frame, wooden or reinforced-concrete forms and helio coating THIC, which is a construction of several layers of translucent material with organized air gaps between them, the parameters of which should ensure, on the one hand, the maximum use of solar energy radiation for heating the concrete, and on the other hand - the accumulation of heat in goods in non-solar time of the day.
For effective implementation of such heliothermal treatment it was required to create a pressure sealed air gap of definite sizes between helio-coating and freshly laid concrete, the parameters of which are determined both from the standpoint of forming the physical structure of concrete and thermo-physical considerations. When the air gap is being formed over the freshly laid concrete, the closed environment, saturated in the process of heliothermal treatment by water vapors, is created; it is characterized by high relative humidity and provides favorable conditions for concrete hardening.

Heliothermal treatment using coatings THIC, implemented at a number of plants for the production of precast concrete, proved to be rather successful.

3 RESULTS AND DISCUSSION

In this respect, the way of heliotreatment of concrete, using damp proof (formed by film-forming compositions) coatings in combination with removable heat-insulation –THIC, developed at RCSRI by B.A.Krylov, E.N.Malinsky, BykovaV. and Rybasov V.P. has a great versatility. The essence of this method is in applying damp proof coatings on molded articles. Products are heated by absorption of solar radiation and heat evolution of cement during daylight hours, and then the goods are heat insulated and kept in thermos conditions up to the acquisition of required strength by concrete. This method is characterized by high efficiency and operational efficiency of implementation into production. Practically for its implementation no accessory and special equipment is required, and for application of film-forming compositions the equipment, used in construction for finishing work, can be successfully used. This method is particularly effective for use in hot summer months, when environment humidity is low and evaporation from concrete occurs quickly.

However, only film-forming composition is not enough for intensive hardening of concrete at using solar energy. Therefore, the authors have developed a method of heliothermal treatment of precast concrete products in translucent chambers made of polymeric materials using film-forming compositions for dry hot climate of the Republic of Kazakhstan. The main requirements set to film-forming compositions are: non-toxicity, environment friendliness, fire safety and explosion safety. Effective water-dispersion film-forming compositions (WDFFC), that have been used in studies, meet these requirements. This method of heliothermal treatment in regions with hot climate allowed to refuse for 5-6 months in the year (for a number of slab by goods) from traditional steaming or heat treatment with the use of other heat carriers; to reduce the demand in water, used to generate saturated water steam; to create seasonal testing grounds for thermal treatment of concrete using solar energy; to create a clean environment for the production; and with all this, to provide the diurnal cycle of production of goods. However for helio thermal treatment with the use of coatings THIC helio top covers are needed, they require constant care of translucent liners; the inability to use the existing helio top covers for the manufacture of goods of other standard sizes; difficulty in manufacturing goods of complex shapes according to this technology and etc.
combine with the influence of solar radiation, is designed to compensate the lack of solar energy for thermal treatment of products on diurnal cycle of their production, as a rule in spring and autumn, on the basis of their operational regulable switching on. Electrical energy is the preferred type of additional heat source of helioforms. Heating elements can be: tubular (TEHs), various heating cables and wires; rod-tube, netted, flexible, strip ones and others. The redundant sources of energy must at unfavorable conditions (e.g. in winter) completely replace the solar energy. It is also possible to use additional electrical heating of concrete mixture as a backup method to accelerate the hardening of concrete on helio testing grounds during cold season. Previous experience in the use of combined helio-electrothermal treatment of precast concrete products is available (Zasedatelev and Shifrin 1982).

The method of combined helio-electrothermal treatment is known as one in which entry of solar radiation to the concrete of products is realized through THIC, and heat energy comes from additionally redundant conventional heat-carriers (steam, electricity, hot water, oil, etc.). The application of this method in absence of solar radiation enabled to save 748 kg of steam per each 1 m of structures and to get the desired transfer strength of more than 70% R28 at daily age, and also to increase the turn over of forms, to improve greatly the quality of structures.

At developing methods of combined heliothermal treatment of concrete products M.O. Orozbekov found that THIC is effective even in absence of solar radiation in cold period of year. Their use in heating, for example, products with thickness of 0.15 m with redundant power supply made it possible to increase the degree of concrete maturity in daily age compared to heating in open molds by 1.6-2.8 times, and daily strength of concrete by 1 -to , 5-5.1 times.

Figure 2. Diagram of the intensification of concrete hardening by TEHs in translucent chamber
1 - translucent coating; 2 - as-formed product; 3-film-forming composition; 4- TEHs

Analysis of various technologies of heliothermal treatment of concrete products found out that combined heliothermal treatment of products ,using translucent and heat insulating coatings, is the most effective one (Aymenov. 2000).

The use of combination of translucent chambers simultaneously with film-forming composition, that protects against dehydration under the action of solar radiation with significant participation of heat evolution of cement in this and regulated supply of thermal energy from additional sources at lack of solar radiation has a special impact on concrete .

Therefore, it is more efficient to use the method of combined helioelectrothermal treatment in translucent chambers using film-forming compositions, to use one type of electric heaters as heating elements. This method has also been developed for conditions of Kazakhstan. The authors of this work developed and implemented other varieties of ways of helioelectrothermal treatment for dry hot conditions of Kazakhstan (Aymenov 2010). The main difference between them and already available ones is arrangement of heaters in the upper part and the lower part of heliochamber. Supply of thermal energy is done from top, bottom and top simultaneously, using film forming composition and solar energy at this. Application of the combined heliothermal treatment in translucent helio chambers in absence of solar radiation resulted in economy of 50 kg of equivalent fuel, 0.5 tons of water.

Development of modern technologies of using solar energy to accelerate the hardening of concrete in the production of concrete products will ensure high quality of precast concrete products due to the optimal structure of the concrete because of creating the most favorable temperature - humidity conditions of concrete hardening, rational forming of temperature fields in products and heat- and mass transfer.

New approaches to technology of heliothermal treatment of precast concrete structures in the dry hot climate of the Republic of Kazakhstan provide economy of 50-100% of traditional fuel at their heat treatment of precast concrete; clean environment, free of smoke emissions of boiler houses; guaranteed high quality of products and structures with the daily cycle of turn over of forms, reduction of the cost and energy consumption of construction.

CONCLUSIONS

The proposed combined helio technology for the intensification of concrete hardening provides high quality of concrete products due to the optimal structure of the concrete thanks to the creation of favorable temperature-humidity conditions.

Supply of thermal heat from above and below simultaneously at using a film-forming composition and solar energy contributes to the rational formation of temperature fields in concrete products and heat- and mass transfer.

The proposed combined helio technology in dry hot climate of Kazakhstan saves 50-100% of traditional
fuel at thermal treatment of reinforced concrete, reduces cost and energy intensity of construction and provides quality environment.

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