Evaluation of the efficiency of using solar energy in the production of building composites

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Abstract. The results of research of speed of set of durability of fine-grained concrete are in-process presented on a compression which hardened in solar chamber of cyclic action. The analysis of existent types of industrial solar chambers is conducted and basic structural elements are considered. Resulted calculation of thermal balance of solar chambers. Experiments are conducted on compositions of fine-grained concrete on cement astringent with the use of additions of superplasticizers of firm MC - Bauchemie: MC - PowerFlow 3100 and MC - PowerFlow 2695. After self-control in solar chamber of cyclic action durability was determined at the different terms of hardening. The comparative analysis of results of durability is conducted on the compression of concrete in solar chamber and chamber of the normal hardening.

1. Introduction

The analysis of literary data showed that industry of the collapsible reinforced concrete is the large consumer of thermal energy. The most power-hungry process in this area is a technological process of thermal treatment of wares, which more than 70% energy is expended on. About 90% of general volume of reinforce-concrete wares (RFC) is exposed to treatment steam. On the receipt of steam the unprocessed in natural energy sources is spent. Taking into account the growing increase of their cost, heat and moisture treatment it is necessary to acknowledge inefficient in a power relation. In this connection the problem of the rational use of traditional fuel and energy resources and plugging in power balance of untraditional sources of energy becomes all sharper, such, as energy of a sun, winds, deep warmth of earth and secondary warmth of various productive processes. Presently there is a tendency of increase of scales of the use of proceeded in energy sources and foremost by a sun. Application of sun energy finds the application in the various areas of productive processes, that especially topically for the south areas of Ukraine [1-3]. The large variety of the solar radiation engineering systems thermal treatment of building composites can be carried out in which is known. Thermal options, different inverter devices, sun batteries, behave to them.

From data of the World power agency [4] sun energy sources to 2019 attained 9% of world electro-generation, and to 2040 must make 24%. It is possible only on condition of speed-up development and mastering of untraditional sources energies which sun energy belongs to the number. All types of energy, producible on the surface of planet, in the end transformed in a warmth and heat an atmosphere. Before humanity there is a new problem of “thermal contamination” of air pool of planet.
A sun radiation, coming on Earth, does not change thermal balance of planet and is the "clean" type of energy.

Use of sun energy for thermal treatment of concrete in daylight saving time and, foremost, in districts with a dry hot climate allows considerably to shorten labour intensiveness and terms of humidity care of concrete, and consequently, and terms of handing over of monolithic constructions under loading as a result of speed-up set of durability at enhanceable temperatures, practically assuredly to provide the required quality of concrete, his longevity and firmness to atmospheric influences as a result of the rapid physical and chemical fastening of water, management the mode of heating and maintenance of more homogeneous temperature field in a construction in the process of all thermal treatment.

In the world certain experience is already accumulated in area of the use of sun energy in a national economy. Worked out and the different industrial and domestic solar energy systems and options are used. For providing of safety of surface of concrete different film-forming suspensions and composition compositions are worked out, including, hydrophobic or as self-destructive suds and another ways of care of concrete with the use of polymeric tapes for defense of surface arcwise extensive concrete constructions [5,6].

Solar energy treatment is warming up of concrete direct influence of solar radiation through translucent coverages or sun receivers. The simplest method of the use of sun energy for warming up of concrete is application of helioform, which consist of two basic elements: actually forms and lids with translucent heat-insulation coverage or in forms with the use of moisture-proof perceiving sun coverage in combination with thermostat self-control. At thermal treatment 0.6 ... 0.75 makes in solar chambers or solar chambers coefficient of the useful use of sun energy. Except for it, the stream of sun energy can influence on solar thermal receiver, coolant (water, butter of and other) circulates in which, that heats thermoforms or thermal compartments additionally. Polymeric photo-electric elements are promising coverage for refractions of visible spectrum. As spectrums of absorption organic polymeric and low-molecular types of semiconductors, are not continuous, as in inorganic semiconductors. As a result, a construction from organic materials is able to skip visible light and take in an invisible spectrum, for example infra-red. According to power distribution of sun spectrum the more than half of sunlight is distributed in an infra-red area. Consequently, theoretical efficiency of polymeric photo-electric elements with absorption only of infrared can be the same high, as at a device with absorption only of visible light. (7-9).

On the first stage of researches experimental works are conducted on determination to influence of solar chambers on a cement matrix for the concretes of reinforce-concrete wares and arblite concrete under influence of additions of superplasticizers of the German firm MC - Bauchemie.

On the second stage of research a calculation is executed on determination to the amount of energy, necessary for heating of wares in solar chambers. Main part of helioforms are sun elements, which are semiconductor photo-electric elements, intended for direct transformation of sun radiation to electric energy. They are included in more wide range of devices of photocells. Usually sun elements have a large area of receiving surface and major parameters for them are temperature stability, coefficient of transformation of light energy in electric one, radiation firmness and others. Mostly sun elements are the constructions from semiconductor materials, well absorptive a sun radiation, metallic and dielectric layers. If the device contains electrolyte solutions, they are called photoelectrochemical converters.

The functioning of solid-state solar cells is based on the phenomenon of the photoelectric effect of the valve. The eaten up by a semiconductor light quanta release electrons and holes from intracrystalline connections and transfer them in the mobile state. Whereupon the oppositely charged free charge carriers are spatially divided and move in opposite directions in investigation of diffusion or drift in the power field which initially must be in a semiconductor [10].

The most essential task for sun elements is an increase of their efficiency. Efficiency of work of photocell increases at the use of the concentrated sunlight, however it is here necessary to delete a surplus heat from a photo consumer. To date the highest index efficiency, the scientists of the National laboratory attained on the study of proceeded in energy (THE USA) and attained a mark in 47% [11],
by the concentrated sun light, setting thus a new pestilent record for sun batteries. Among industrial prototypes shows the best indexes elements on the basis of silicon, although with the mass production of high-efficiency and expensive sun elements economic ineffective elements compete from more cheap explorers. Industrial sun batteries work with the use of different sun elements, basic from which are silicic, single-crystal, polycrystalline, amorphous pellicle, polymeric, photo sensitized, which differ on efficiency and cost. At development of effective elements of effort, it is necessary to send not only to their efficiency but also on the compactness of the systems. It is needed to pay attention to plastic crystals due to which it is possible to promote the compactness of the systems and shorten expenses on their production (12-15).

Advantages of solar thermal treatment:
- it is an economy of unprocessed in fuel and energy resources,
- it is application ecologically of clean thermal energy source,
- it is a decline of prime price of concretes,
- it is diminishing of capital costs on a boiler room, heating mains of and other,
- allows to yield up to traditional thermal treatment in warm periods of year in districts to the south of a 50° north breadth.

For heating of concrete, fine-grained concrete and arblite concrete wares a calculation is executed on determining the necessary amount of energy.

The methods of calculation consist of three parts:
- it is a calculation of thermal balance of chamber heat treatment is carried out in which, as a result of calculation, the amount of energy, necessary for heating is determined,
- to define the amount of heat which can be got a sun collector. Such data for the set geographical co-ordinates are presented NASA. For the basic cities of Ukraine information of presented in the Internet [16],
- to find the area of sun collectors which will provide the necessary amount of energy. Equalization of thermal balance has a next kind [17]:

\[
Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9 + Q_{10} + Q_{11} - Q_{12} \tag{1}
\]

where \(Q_1\) is an expense of heat on heating of components of raw material mixture of concrete, \(Q_2\) is an expense of heat on heating of shuttling water, \(Q_3\) is an expense of heat on evaporation of part of water, \(Q_4\) is an expense of heat on heating of armature, \(Q_5\) are expenses of heat on heating of forms, \(Q_6\) - warm, which is accumulated by the walls of chamber, \(Q_7\) is an expense of heat on heating of lid of chamber, \(Q_8\) is an expense of heat on heating of free space in a chamber, \(Q_9\) are defervescences due to the loss of heat through unclosenesses, \(Q_{10}\) are defervescences in an environment the walls of chamber, \(Q_{11}\) are defervescences in an environment the lid of chamber, \(Q_{12}\) is a heat of exothermic reactions, flowing in a concrete, \(Q\) is an amount of energy, necessary for heating, \(\text{kJ} / \text{cycle}\).

Amount of heat which can be got a sun collector [18,19]:

\[
\mathcal{E}_K = E \cdot S \cdot \eta \tag{2}
\]

where \(E\) is a middle daily level of solar radiation, \(\text{kW} \, \text{o'clock} / \text{of} \, \text{m}^2 / \text{day}\), \(S\) is a working area of sun collector, \(\text{m}^2\), \(\eta\) is an output-input of sun collector ratio.

Area of sun collectors which will provide the necessary amount of energy, \(\text{m}^2\):

\[
S = \frac{Q}{E \eta} \tag{3}
\]

2. The methods of realization of experiment consisted in the following: the laboratory model of solar chambers of cyclic action of type was set the "Hot box". The construction of solar chambers consisted of wooden framework on which polyethylene tape was strained in two layers, with a gap between layers 2 sm. A size was appointed so that to cover all threefold forms with concrete mixture. Forms with concrete mixture were placed in solar chambers and maintained there to testing. The coulisse of standards for tests was produced on 1, 3, 7, 14, 28 twenty-four hours. For the investigated compositions in parallel control standards-ware were made twins which was kept in the chamber of the normal hardening with a temperature 20±3°C and by humidity 95±5 %. Making of standards of beams was produced in accordance with DSTY B V. 2.7-214:2009 [20]. Tested on an attorney equipment of
Ukraine accredited by national Standard scientifically to the research laboratory. Durability was measured on a 100 ton press on a minimum range with the maximal loading in 20 t and scale of division in 40 kg. Treatment of results passed in the program Excel on calculations in accordance with DSTY B V. 2.7-214:2009, cited data as middle arithmetic from all results of one party of standards.

3. Basic material
Results are presented of the conducted experiment on speed of set of durability of standards of cement compos, kept in solar chamber for comparing to the results of control standards, which was kept in the standard chamber of the normal hardening. For comparison standards were made with the use of two additions of firm MC - Bauchemie: by complex addition accelerating of hardening of MC - PowerFlow 3100 and superplasticizer of MC - PowerFlow 2695.

Control standards are kept in the chamber of the normal hardening collected vacation durability of 70-80%, the got durability provides removal of planking on a 7 twenty-four hours, for standards which was made with the use of addition of MC - PowerFlow 3100. At the use of addition of MC - PowerFlow 2695 vacation durability was attained on a 14 twenty-four hours. The results of realization of strength tests are driven to the table. 1 and on a fig. 1.

Table 1. Results of tests of concrete at storage in the chamber of the normal hardening

| Name             | W/B | Twenty-four hours | Tensile strength on a compression, MPa |
|------------------|-----|-------------------|---------------------------------------|
| MC - PowerFlow   | 0,3 | 1                 | 12,6                                  |
| 3                |     | 27,8              |                                       |
| 7                |     | 35,4              |                                       |
| 14               |     | 41,6              |                                       |
| 28               |     | 49,9              |                                       |
| MC - PowerFlow   | 0,32| 1                 | 1,1                                   |
| 3                |     | 5,1               |                                       |
| 7                |     | 11,8              |                                       |
| 14               |     | 16,3              |                                       |
| 28               |     | 26,5              |                                       |

Figure 1. Dependence of durability on the compression of concrete from his age, at the use of addition of MC - PowerFlow 3100 and MC - PowerFlow 2695, at storage in the chamber of the normal hardening

In solar chamber due to the solar thermal warming up of standards the accelerations of set of durability of concrete are provided. Vacation durability in 70-80% attained in the flow of a 3 twenty-
four hours for a standard with the use of addition of MC - PowerFlow 3100. In also time standards, for making of which addition of MC was used - PowerFlow 2695 collected the same percent of durability arrived at after a 7 twenty-four hours of hardening it is presented on a fig. 2.

Figure. 2. Dependence of durability on the compression of concrete, at storage in solar chamber from his age, at the use of additions of MC - PowerFlow 3100 and MC - PowerFlow 2695

Comparison of durability was also conducted between standards from solar chamber and chamber of the normal hardening. Standards, collecting durability in solar chamber showed the speed-up set of durability, at equal terms of hardening. Results are driven to the table. 2.

| Name                  | W/B | Twenty-four hours | Tensile strength on a compression, MPa | Increase of durability on a compression in solar chamber, % |
|-----------------------|-----|-------------------|----------------------------------------|----------------------------------------------------------|
| MC - PowerFlow 3100   | 0.3 | 1                 | 21.4                                   | 169.8                                                   |
|                       |     | 3                 | 35.5                                   | 127.7                                                   |
|                       |     | 7                 | 43.2                                   | 122.0                                                   |
|                       |     | 14                | 49.4                                   | 118.8                                                   |
|                       |     | 28                | 50.7                                   | 101.6                                                   |
| MC - PowerFlow 2695   | 0.32| 1                 | 3.9                                    | 354.5                                                   |
|                       |     | 3                 | 12.3                                   | 241.2                                                   |
|                       |     | 7                 | 19.8                                   | 167.8                                                   |
|                       |     | 14                | 26.5                                   | 162.6                                                   |
|                       |     | 28                | 28.2                                   | 106.4                                                   |

During realization of experiments strength descriptions of concrete mixture were set. Standards are maintained in solar chamber on the first twenty-four hours showed durability higher on 254.5%, what analogical standards from the chamber of the normal hardening. On a 3 twenty-four hours of storage a maximal increase made 141.2%, on a 7 twenty-four hours of 67.8%, on a 14 twenty-four hours of 62.2% and on a 28 twenty-four hours of 6.4%.
Experiments were conducted in springtime of year, which is not the hottest, and solar chambers work fully on sun energy and fully depends on an ambient temperature. For determination of efficiency of work of solar chamber thermometers were set taking temperature environment, to concrete mixture and temperature inwardly solar chambers. In the process of realization of experiment, the maximal values of temperature were educed: environment - 38 °C, solar chambers - 46 °C and concrete mixture 52 °C.

Basic conclusions
Experiments, conducted on two additions superplasticizers of production of firm MC, - Bauchemie, showed that application of solar chamber improved the primary set of durability considerably, and helps in the earliest possible dates to collect vacation durability, that accelerates building in turn. Also on a 3 twenty-four hours of self-control standards with addition of MC - PowerFlow 2695 showed to 43% durability, and standards with addition of MC - PowerFlow 3100 showed to 70% durability. The variant of calculation of solar chamber is in-process presented which can be applied for further perfection of existing and creation new effective solar chambers and is one of directions of development of production of concrete wares in districts with a hot climate.

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