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ENERGY SAVING FACTORS IN WINTER CONCRETING

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Abstract. *This article considers energy-saving technologies for winter concreting of building structures and constructions. Various authors have studied mathematical models of the thermal regime of a three-dimensional building structure. The mathematical model of the heat balance equations in the concrete structure, the thermal conductivity coefficient, the dependences of the heat balance equations in the concrete structure and the junction, the thermal conductivity coefficient, the volumetric thermal conductivity, respectively, in the erected fragment and the previously erected part of the wall was implemented on a computer. The article considers the processes of cement and concrete strength gain during early freezing of concrete. In previous studies by various authors, it was found that with an increase in the time for gaining critical strength, the cost of electricity is reduced by 25-50%, due to the use of thermal inertia of the structure. The rate of cooling of monolithic structures at negative temperatures is revealed. The chemistry of cement hardening processes during early freezing is shown. Thermodynamic calculations set the limits of negative temperatures at which concrete strength curing stops, but under the action of repeated positive temperatures, the cement hydration process resumes and concrete continues to harden. The aluminum minerals of Portland cement clinker are usually the first to hydrate when the cement hardens with water, and in the presence of gypsum they form calcium hydrosulfoaluminate. This connection is very fragile and is destroyed by mechanical stress (repeated vibration) and over time even at normal temperatures. The article reviews the foreign experience of winter concreting and the preferred methods of work in this case.*

Keywords: *Winter concreting, massiveness of the structure, hydration of Portland cement minerals, additives in winter concrete, electric heating of the concrete mix, concreting in "greenhouses".*

ҚЫСТА БЕТОНДАУДАҒЫ ЭНЕРГИЯНЫ ҮНЕМДЕУ ФАКТОРЛАРЫ

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Аңдатпа. *Бұл мақалада құрылыс конструкциялары мен құрылымдарын қысқы бетондаудың энергия үнемдейтін технологиялары қарастырылған. Әртүрлі авторлар үш өлшемді* *құрылыс конструкциясының жылу режимінің математикалық үлгілерін зерттеген. Бетон конструкциясындағы жылу балансы теңдеулерінің математикалық моделі, жылу өткізгіштік коэффициенті, бетон конструкциясы мен түйіспедегі жылу балансы теңдеулерінің тәуелділіктері, сәйкесінше тұрғызылған фрагменттегі жылу өткізгіштік коэффициенті, көлемдік жылу өткізгіштік және қабырғаның бұрын салынған бөлігі компьютерде жүзеге асырылды. Мақалада бетонды ерте мұздату кезінде цемент пен бетонның беріктігін арттыру процестері қарастырылады. Әртүрлі авторлардың алдыңғы зерттеулерінде сыни беріктікке ие болу уақытының ұлғаюымен құрылымның жылу инерциясын пайдалану есебінен электр энергиясының құны 25-50% -ға төмендейтіні анықталды. Теріс температурада монолитті құрылымдардың салқындату жылдамдығы анықталды. Ерте мұздату кезіндегі цементтің қатаю процестерінің химиясы көрсетілген. Термодинамикалық есептеулер бетонның беріктігінің қатаюы тоқтайтын теріс температуралардың шектерін белгілейді, бірақ қайталанатын оң температуралардың әсерінен цементтің гидратация процесі қайта басталады және бетон қатаюды жалғастырады. Портландцемент клинкерінің алюминий минералдары әдетте цемент сумен қатқанда бірінші болып ылғалданады, ал гипстің қатысуымен кальций гидросульфоалюминат түзеді. Бұл байланыс өте нәзік және механикалық кернеумен (қайталанған діріл) және уақыт өте келе тіпті қалыпты температурада бұзылады. Мақалада қысқы бетондаудың шетелдік тәжірибесі және бұл жағдайда жұмыс істеудің қолайлы әдістері қарастырылады.*

Түйінді сөздер: *Қысқы бетондау, құрылымның массивтілігі, портландцемент минералдарының гидратациясы, қысқы бетондағы қоспалар, бетон қоспасын электрмен жылыту, «жылыжайларда» бетондау.*

ФАКТОРЫ ЭНЕРГОСБЕРЕЖЕНИЯ ПРИ ЗИМНЕМ БЕТОНИРОВАНИИ

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Аннотация. *В данной статье рассматриваются энергосберегающие технологии зимнего бетонирования строительных конструкций и сооружений. Различными авторами исследованы математические модели теплового режима объемной строительной конструкции. Математическая модель уравнений теплового баланса в бетонной конструкции, коэффициент теплопроводности, зависимости уравнений теплового баланса в бетонной конструкции и примыкании, объемная теплопроводность соответственно в возведенном фрагменте и ранее возведенной части стены реализована на ЭВМ. В статье рассмотрены процессы набора прочности цементом и бетоном при раннем замерзании бетона. Предыдущими исследованиями разных авторов установлено, что при увеличении времени набора критической прочности затраты электроэнергии снижаются на 25–50% за счет использования тепловой инерции конструкции. Выявлена скорость охлаждения монолитных конструкций при отрицательных температурах. Показана химия процессов твердения цемента при раннем замерзании. Термодинамическими расчетами установлены пределы отрицательных температур, при которых прекращается набор прочности бетоном, но при действии повторных положительных температур процесс гидратации цемента возобновляется и бетон продолжает твердеть.*

Алюминиевые минералы портландцементного клинкера обычно первыми гидратируются при затвердевании цемента водой, а в присутствии гипса образуют гидросульфоалюминат кальция. Это соединение очень непрочно и разрушается при механическом воздействии (повторной вибрации) и со временем даже при нормальных температурах. В статье рассмотрен зарубежный опыт зимнего бетонирования и предпочтительные методы работ в этом случае.

Ключевые слова: *зимнее бетонирование, массивность конструкции, гидратации минералов портландцемента, добавки в зимний бетон, электроразогрев бетонной смеси, бетонирование в «тепляках».*

Introduction

Peculiar offers of energy-saving technology of winter concreting of constructions and structures are specified in the work [1]. On the basis of a mathematical model of the thermal regime of a three-dimensional building structure, a fragment of the concrete wall is investigated during the intermittent electric heating mode. An example of concrete of a wall adjacent to the existing wall is considered. The mathematical model of the dependence of the heat balance equations in the concrete structure and adjoinment, the coefficient of heat conductivity, the volume heat conductivity respectively in the elevated fragment and the previously erected part of the wall is implemented on the ECM [2]. Approximation of differential equations is made by the implicit difference scheme of Douglas Ghan's alternating directions. Based on the graphs shown here, the following conclusions can be drawn:

1. With an increase in the time for gaining critical strength, the cost of electricity is reduced by 25-50%, due to the use of thermal inertia of the structural design;
2. The softer thermodynamic characteristics of the controlled heating mode ensure flat heating and hence the quality of the concrete;
3. The mathematical model, executed in the algorithmic language Pascal, allows to vary the production technology of works and winter concrete methods.

Relevance of the article

The influence of ambient temperature on the temperature of internal layers is ambiguous and depends on the insulation capacity of the formwork, the massive structure, the exothermic cement. These factors are also influenced by other factors, i.e. the process of collecting concrete strength in winter concreting is very complicated.

Research conditions and methods

When considering the hydration processes of minerals of Portland cement in the presence of additives, it was noted that new hydrate phases are formed as a substitute for a hydrate compound occurring under normal conditions. Let's consider the role of new hydrate phases in forming the strength of cement stone. The formation of $3CaOAl_2O_{3*}Ca(NO)_{2*}10H_2O$ during the hydration of three-calcium aluminium in solution $Ca(NO)_2$ greatly increases the strength of the samples [3]. The strength of the samples with $NaN0_3$ is not much different from that of the test samples. Since the formation of calcium hydronitrialuminate requires a significant amount of calcium hydroxide in the system. As a result of the formation of complex calcium aluminium salts, the strength of aluminium containing clinker minerals in the cement hydration is slightly reduced, and the strength of potash and nitritentatrium as well as chlorinated salts has slightly remained unchanged.

More significant is the role of new phases formed on the basis of calcium hydroxide - $3CaO_*CaC1_*10H_2O$ и $CaCOз*6H_20$. When hardening in frost, especially in the early stages, their formation leads to an increase in the hydration rate of silicate minerals, due to the lower solubility of these phases compared to $Ca(OH)_2$. However, hydrochloride and calcium hydrocarbonate are not stable phases. The first one breaks down over time, and the second one breaks down with ambient temperatures. New phases formed instead of $Ca(OH)_2$ play a significant role in the formation of the structure of the cement stone, as their breakdown in some cases reduces the strength [4].

Research results

The cooling speed of monolithic structures according to standards is regulated as follows: 15°C/ /h at surface module Mp>14 m^{-1}, 10°C/h at Mp =10-44 m^{-1}, 5°C/ h at Mp= 5 -10 m^{-1}. The general positivity, the rate of rise and cooling during electric heating depends on the required strength of concrete by the time the structure is stripped and is assigned based on the results of experimental data obtained taking into account the type and grade of concrete, the cements used and the specific dimensions of the structure and the environment.

At the early freezing of concrete, which coincides with the first kinetic stage of the hydration process, which ends, from the perspective of Berkovich T.M., with the initial crystallization of hydrate neoplasms, the hydration rate is determined mainly by the chemical velocity of cement minerals with water. Temperature has a significant effect on the rate of the hydration reaction, since as the temperature rises, the number of active molecules increases sharply, and the total kinetic energy of the molecules increases.

The influence of temperature on the kinetics of heterogeneous processes can be described by the Arrhenius equation, the integral expression of which has the form:

$$Lnk = - E\backslash R_{*}T + B \qquad (1)$$

where lnk - reaction rate constant; E - apparent activity energy;

R - universal gas, constant; T - temperature; B - constant, taking into account the influence of different factors on the speed of reaction.

Studies by Berkovich G.M., and Heyker D.M. and others have shown the applicability of this dependence to diffusion processes as well [5].

Equation (1) is also valid for the insulated condition. Under real-life conditions, due to external and internal heat effects on the hardened concrete, this dependence has a different appearance.

Budnikov P.P., Royak S.M., and others show that as the temperature of the thermal treatment increases, the duration of the induction period of the cement hydration process decreases and the constant increases in proportion to the reaction rate.

The dissolution of the initial cement minerals and the chemical process of their hydration begin immediately after the cement is closed by water, and they continue under normal conditions for a relatively long time[6].

The second cement hydration period is characterized by the presence of stable, dense casings on the cement grains and by low rates of water diffusion and reverse diffusion of hydrated ions in solution.

The duration of each of these periods varies considerably depending on the environmental conditions. Thus, when the temperature increases, the length of not only the kinetic stage but also the first diffusion period (contact-heterogeneous process) decreases, based on this it can be assumed that electrical heating at an early stage of cement stone hardening will accelerate the onset of the film formation process and shorten the period of intensive hydration. In addition, the density and impermeability of the films on the cement grains will be much higher when the electric heating is forced than in normal, soft heat treatments[7].

Discussion of scientific results

Under these circumstances, it is reasonable to assume that the final degree of hydration of the binder will be slightly lower than in normal heat treatment, despite an increase in the quantity of the initial binder. The effect of intensive electric heating could be more rational if the concrete mixture was previously kept at low positive temperatures, which contributes to a deeper hydration process. Another measure that enhances the effect of intense electrical heating could be repeated vibration to destroy the loose film on the aggregate grains. Aluminium minerals of the Portland cement clinker are usually the first to be hydrated when cement is solidified with water, and in the presence of gypsum they form calcium hydrosulfonal aluminate. This compound is very weak and collapses during mechanical action (re-vibration) and over time, even at normal temperatures.

The application of rapid heating is optimal also from the point of view of thermodynamics of irreversible processes. As it is known, in accordance with the Le Châtellier principle, cooling contributes to the completeness of heat-emitting processes. The forced electric heating, which is carried out until the maximum exothermic effect appears in the concrete, and the subsequent natural removal of heat during thermostatic conditioning, most combine the thermodynamics and kinetics of the structures of formation of cement stone.

A number of works investigated the production of concrete works in winter in greenhouses. This method is used in concrete-laying of foundations, units of hydraulic structures with covered pits with flat or tented light fences. Thermosets can be structural: volumetric, sectional, floor, local, movable, tented, etc [8].

Recently, in France, Poland, Turkey and other countries, so-called inflatable heaters have been successfully used. Theoretical principles of erection of vertical monolithic constructions using heating pneumocarcane modular decks (HPMD) in winter conditions have been developed. Technological principles for the operation of HPMD in winter vertical fencing.

In Alaska, Finland, and Japan, tarpaulin greenhouses are widely used, the load-bearing frame of which is light aluminum structures [9,10].

Conclusion

The choice of winter concrete method depends on the size and purpose of the design, on the expected winter temperatures, which can vary widely. It is necessary to take into account the properties of the cements used and the presence of heat sources in construction, the modes of production of work, and the provision of appropriate working conditions for workers. When choosing a method of performing work, their comparative economy, ease of performing work operations for laying and maintaining concrete should be taken into account. Of these listed criteria for the selection of winter concreting, part is regulated and part of the criteria is not regulated.

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