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Учредитель
ООО "Издательский дом Медиа Паблишер"

Главный редактор
Тихвинский Валерий Олегович

Издатель
Дымкова Светлана Сергеевна
ds@media-publisher.ru

www.media-publisher.ru

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Founder
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Publisher
Dymkova Svetlana Sergeevna
ds@media-publisher.ru

Editor in Chief
Dr. Valery Tikhvinskiy

www.media-publisher.ru

CONTENT

MICROWAVE METHOD OF CURING OF CONCRETE

Alexandr V. Mamontov,
National research University "Higher school of Economics" (HSE), professor, Moscow, Russia, **a.mamontov@hse.ru**

Vladimir N. Nefedov,
National research University "Higher school of Economics" (HSE), professor, Moscow, Russia, **6034348@mail.ru**

Valentin P. Simonov,
National research University "Higher school of Economics" (HSE), professor, Moscow, Russia, **vsimonov@hse.ru**

Alexandr A. Chechetkin,
National research University "Higher school of Economics" (HSE), 1st year master student, Moscow, Russia, **Figur09@mail.ru**

Keywords: *microwave technology, electrodynamic system, source of microwave energy, temperature distribution, dielectric material.*

Theoretical and experimental results of heat curing of concrete using ultra-high fre-quencyelectromagnetic energy as a source of heat are presented. The advantages of microwave method of heat curing of concrete are compared with traditional methods. The results of studies on the accelerated curing of concrete slabs in a beam-type microwave setup are presented.

A beam-type microwave setupwas developed to accelerate the curing the concrete slab, with the size of 200 mm x 2000 mm x 3000 mm, weight 2760 kg at the temperature of +70°C and the electromagnetic field frequency oscillations of 2450 MHz, and power output of 38.4 kW. A setup allows to reduce the energy consumption for the technological process of the heat treatment of concrete products, increase productivity and improve working conditions for the staff.

Basic expressions for the temperature distribution calculation along the thickness and the surface ofconcrete slabs are presented. The time of heating a slabto the temperature of +70°C, 2760 kg of weight, was 50 minutes. The deviation from the nominal value of the temperature of the concrete slab across the area doesn't exceed 2°C, and across the thickness of the plate does not exceed 5°C.

As a result, the research shows the prospects of using microwave radiation for the pro-duction processes associated with accelerated hardening of the concrete. Currently work is un-derway to improve the strength characteristics of concrete due to uniform heating of the con-crete, which contributes to the absence of internal stresses and other defects in the structure.

The results of accelerating curing of the concrete slabs with the use of microwave radiation as a source of heat were obtained, that allows to refuse the use of expensive foreign addi-tives for accelerated hardening of concrete, which lead to degradation of strength characteristics due to the increase of acidity.

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I. Introduction

Traditional methods of heat treatment of concrete products are associated with the solution of the following technological processes:

– heating the concrete to a predetermined temperature by different methods: steam; electric heating; induction heating in the electromagnetic field; heating of different electro heating devices (contact, convection, including the use of infrared radiation);

– heating the formwork, typically made of metal, in which the concrete is placed, to a predetermined temperature;

– keeping the set temperature of concrete and formwork for a period of time necessary to obtain the stripping strength of concrete taking into account the heat transfer to the ambient environment;

– accounting for heat generation in the volume of concrete due to the reaction of hydration (determined experimentally).

Traditional technological processes of heating of concrete products were accounting for heat conduction and are accompanied by a high expenditure of time and energy. Low speed heating of concrete products is related to the transfer of heat by conduction from the outer layers to the inner layers of the concrete slab. Internal stresses between the outer and inner layers of concrete products may occur during the heating, which can lead to various defects of the material structure and may reduce the strength characteristics of concrete

Research conducted in many countries to accelerate the strength development of concrete products showed high efficiency of the microwave radiation energy use for these purposes. The use of microwave radiation allows to significantly intensify the process of heat curing of concrete products, to reduce the area occupied by the heating units, to improve economic performance of the process.

In works [1-3] it is shown that the microwave method has the following main advantages compared to conventional methods of heat treatment of concrete:

– microwave radiation instantly penetrates deep into the treated material and accelerates the reaction of hydration with the heat dissipation inside the processed material;

– technological processes accelerate in several times due to the volumetric nature of the heating of concrete products;

– volumetric character of heating of concrete products does not depend on its thermal conductivity and does not lead to the appearance of internal stresses and other mechanical defects of the internal structure of concrete products;

– the technological process of heat curing of concrete products has no inertia, allowing precisely enough to regulate it;

– microwave radiation does not heat up the surrounding space, which significantly saves energy consumption for the technological process of accelerated curing of concrete products;

– if a heat-insulating radio-transparent material is used as a form for concrete, it is possible not to take into account the heat transfer into the surrounding space, which also leads to significantly save of energy costs;

– simplicity of the technological process associated with the supply of electricity only;

– using insulating material for the formwork, for example, made of polypropylene, allows to save electrical energy for maintaining the desired temperature in the concrete products during the time needed to set the required strength due to the thermos effect;

– simple design of the microwave setup and it's high performance.

II. The main part

In this paper, we present the results of studies on the accelerated curing of concrete slabs 2000mm×3000mm×200 mm of size by using microwave radiation. The aim of the research was to study the main features of heat curing of concrete products to create a technological regimes of accelerated curing of concrete products of various shapes and sizes in the future.

For the heat treatment of a concrete slab the beam-type microwave setup was chosen. The working chamber of the microwave setup has the following dimensions: length – 3500 mm; width – 1500 mm; height – 2750 mm.

Sources of microwave energy are arranged on the lateral surfaces of the working chamber in a particular order that ensure uniform heating of the concrete slab on each side. 24microwave energy sources are located on each side of the working chamber. Maximum output power of each source of microwave energy is 0.8kW. Thus, 48 sources of microwave energy are installed, with a total capacity of 38.4kW at the frequency of oscillation of the electromagnetic field 2450MHz.

Cover of the working chamber is lowered at the camera with a crane and has an electrical contact with the braid of a soft springy metal to prevent microwave radiation into the surrounding space. Concrete slab is placed in formwork made of dielectric radio-transparent material, such as polypropylene, which has low thermal conductivity and keeps heat inside of the material being processed and to maintain the desired temperature for curing of concrete, that is, acts as a thermos, which ensures high efficiency of the setup. The thickness of the dielectric material and construction of the formwork are determined by the strength characteristics required for fixing and lifting slabs of concrete, the material does not come into contact with the concrete and can be easily detached from the concrete.

Formwork filled with concrete is lifted by crane and lowered on special guides in the working chamber at equal distances from the side surfaces of the microwave chamber, on which the sources of microwave energy are located. Then the cover made using special equipment to prevent the leakage of microwave energy is lowered upon the chamber. After the preparatory work the switched-on sources of microwave energy irradiate concrete slab over time (50 minutes) required to reach the set temperature +70°C.

After reaching the slab of concrete a predetermined temperature, the cover is removed from the working chamber, formwork is lifted by crane and placed for a time in the room where the slab of concrete reaches the necessary stripping strength.

A source based on foreign components is used as a source of microwave energy,. The source of microwave energy has mass 12 kg and overall dimensions: length – 400 mm width – 200 mm; height – 200 mm. The output of microwave energy from the source is carried out using waveguide with cross-section (72×34)mm on the main wave type H_{10}.

In Figure 1 schematically shows a cross section of a beam-type microwave setup for the heat treatment of concrete slabs on the electromagnetic field oscillation frequency 2450 MHz.

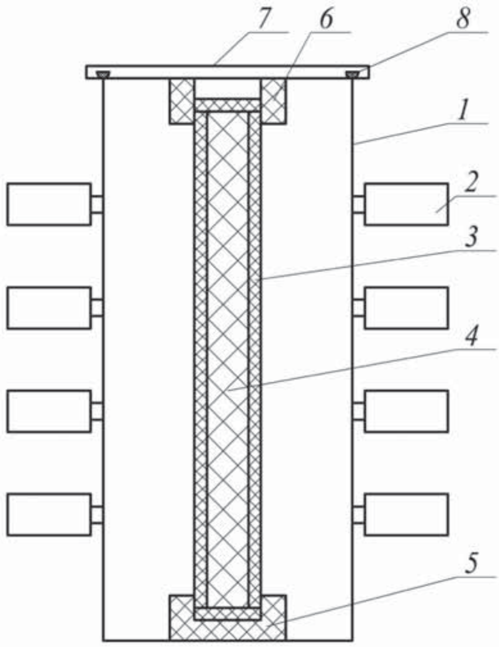

Fig. 1. Microwave beam-type setup for thermal curing of concrete slabs: 1 – working chamber; 2 – the source of microwave energy; 3 – formwork made of polypropylene, 4 – concrete slab, 5 – lower clamp made of polypropylene, 6 - upper retainer made of polypropylene; 7 – top cover, 8 – metallic braid to prevent microwave radiation

The location of sources of microwave energy on a side wall of the working chamber must be such as to ensure a uniform temperature distribution on the surface of the concrete slab with an area of 6m^2, situated at a distance of 650 mm from the lateral surface. The waveguide of rectangular cross section of the microwave energy source operates on the main wave type H_{10} and the opening of the waveguide is used as radiating antenna. Method of Huygens – Kirchhoff [4] was used when calculating the radiation diagram of the aperture of the opened rectangular waveguide.

The main objective of the calculation is to provide a uniform temperature distribution on the surface of the concrete slab, located at a distance of 650mm from the side wall of the microwave installation. To address this problem, the source of microwave energy in the amount of 24 pieces are arranged on the side wall of the working chamber is thus to provide a uniform temperature distribution in accordance with the directional diagrams of the radiation power.

The distance between the source of microwave energy along the length and height of the wall of the working chamber is 500 mm and the distance from the center of the waveguide source to the edge of the concrete slab is 250 mm. Under these conditions uniform temperature distribution over the area of the lateral surface of the concrete slab +70°C is ensured.

Experimental study on determination of temperature distribution was carried out on a similar device, but instead a concrete slab the sheet of dry wood with moisture content of 7% and a thickness of 20mm was placed. Moisture content of 7% was chosen in order to eliminate heat transfer to the wood by conduction.

The discrepancy of calculated and measured characteristics of the temperature distribution on the surface of the processed material, in particular sheet of wood, at a distance of 650mm from the side wall of the working chamber is not more than 2°C, as shown in the figure 2. The calculation of the temperature distribution along the thickness of concrete slabs can be calculated by the formula:

$$T(z) = T(0) \cdot e^{-2\alpha \cdot z} \qquad (1)$$

Here $T(z)$ is the temperature of the concrete slab at a distance z from the surface; $T(0)$ is the temperature at the surface of the concrete slab (+70°C); α – damping constant of the electric fieldamplitude, which is determined by the expression [4]:

$$\alpha = \frac{\pi}{\lambda} \cdot \frac{\varepsilon''}{\sqrt{\varepsilon'}}. \qquad (2)$$

The relative permittivity of concrete is $\varepsilon' = 4{,}5$. The tangent of dielectric loss for the mixture of concrete is $tg\delta = 0{,}03$ In this case, the effective component of the imaginary part of relative permittivity of the concrete mix is $\varepsilon''_{ef} = 0{,}13$. The temperature change in the thickness of slabs of concrete, according to expression (1) is changed from +70°C to +35°C.

Figure 2 shows the calculated dependence of the temperature distribution along the thickness of concreteslab from the sources located at both lateral walls of the working chamber of the microwave setup. Thus the heating of the slabs on each side must be made to a temperature at which the addition of two exponential dependencies will create on the surface of the plate and in its volume the temperature of +70°C.

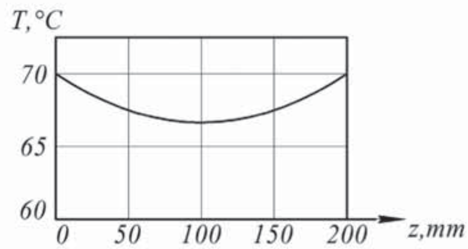

Fig. 2. The calculated dependence of the temperature distribution along the thickness of concreteslab from the sources located at both lateral walls of the working chamber of the microwave setup

The temperature deviation from the nominal value of the temperature across the thickness of the200mm concrete slab did not exceed 5°C.

III. Conclusion

To accelerate the of a curing concrete slab a beam-type setup weighing 2760 kg at the oscillation of the electromagnetic field of 2450 MHz and output power of 38.4 kW was developed. A setup allows to reduce the energy-related costs of the technological process of theconcrete slab heat curing, increase productivity and improve working conditions of staff. The heating time of the slab was 50 minutes.

The discrepancy of calculated and measured characteristics of the temperature distribution on the surface of the processed material during heating up to +70°C, 6 m^2 of area at a distance of 650 mm from the side wall of the working chamber did not exceed 2°C. Temperature deviation from nominal temperature value for the slab thickness of 200 mm did not exceed 5°C.

It is assumed that uniform heating of the concrete in its volume will increase strength characteristics due to the absence of internal defects and stresses. As a result, the research shows the prospects of using microwave radiation for the production processes associated with accelerated hardening of concrete products.

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МИКРОВОЛНОВЫЙ МЕТОД ОБРАБОТКИ БЕТОНА

Нефедов Владимир Николаевич, *профессор, Национальный исследовательский университет "Высшая школа экономики" (НИУ ВШЭ), Москва, Россия,* **6034348@mail.ru**

Мамонтов Александр Владимирович, *доцент, Национальный исследовательский университет "Высшая школа экономики" (НИУ ВШЭ), Москва, Россия,* **a.mamontov@hse.ru**

Симонов Валентин Павлович, *профессор, Национальный исследовательский университет "Высшая школа экономики" (НИУ ВШЭ), Москва, Россия,* **vsimonov@hse.ru**

Чечёткин Александр Андреевич, *магистрант 1-го года обучения, Национальный исследовательский университет "Высшая школа экономики" (НИУ ВШЭ), Москва, Россия,* **Figur09@mail.ru**

Аннотация

Представлены теоретические и экспериментальные результаты тепловой обработки изделий из бетона с использованием в качестве источника тепла энергии электромагнитного поля сверхвысоких частот. Показаны преимущества микроволнового метода тепловой обработки бетона по сравнению с традиционными методами. Приведены результаты исследований по ускоренному твердению плиты из бетона в микроволновой установке лучевого типа.

Разработана микроволновая установка лучевого типа для ускоренного твердения плиты из бетона, размерами 200 мм х 2000 мм х 3000 мм, весом 2760 кг при температуре +70°С на частоте колебаний электромагнитного поля 2450 МГц и выходной мощностью 38,4 кВт. Микроволновая установка позволяет сократить энергетические затраты на технологический процесс тепловой обработки изделий из бетона, увеличить производительность и улучшить условия труда обслуживающего персонала. Представлены основные выражения для расчёта распределения температуры по толщине и по площади плиты из бетона. Длительность нагрева плиты до температуры +70°С, весом 2760 кг, составляет 50 минут. Отклонение температуры от номинального значения температуры бетонной плиты по площади не превышает 2°С, а по толщине плиты не превышает 5°С.

В результате проведенных исследований показана перспективность использования микроволнового излучения для технологических процессов, связанных с ускоренным твердением бетона. В настоящее время ведутся работы по повышению прочностных характеристик бетона за счёт равномерного нагрева бетона, что способствует отсутствию внутренних напряжений и других дефектов структуры. Получены результаты ускорения процесса твердения плиты из бетона при использовании в качестве источника тепла энергии микроволнового излучения, что позволило отказаться от использования дорогостоящих зарубежных добавок для ускорения твердения бетонов, которые приводят к ухудшению их прочностных характеристик из-за повышения кислотности.

Ключевые слова: *микроволновая технология, электродинамическая система, ис-точник СВЧ-энергии, распределение температуры, диэлектрический материал.*

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