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Theoretical Solutions for Calculating the Height of the Capillary Rise of Water in the Foundation of a Building

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ABSTRACT

Today, special attention is paid to the development of optimal solutions for waterproofing the foundations of buildings, reliable protection of structures from aggressive underground influences and thereby increasing the life expectancy of buildings, structures. Currently, the protection of brick buildings from the effects of capillary moisture rising from under the ground is carried out in a simple way. In this case, it was recommended that waterproofing be formed between the foundation and the brick wall for brick buildings to be built in seismic areas using a cement-sandy mixture with a thickness of 30 mm. This article presents the result of a scientific research work carried out to protect the foundations and walls of low-and medium-rise residential, public buildings, which are being built in our republic today, from underground moisture.

KEYWORDS: *Waterproofing, moisture, foundation-wall, capillary*

1. Introduction

Particular importance is attached to the issues of increasing the operational reliability of buildings in the world, ensuring the viability of underground structures and assessing their technical condition, and, if necessary, strengthening them. Currently, in developed countries, about 75% of construction structures are exposed to the harmful effects of an aggressive environment. In underground construction, however, this number can reach 80-90%. In the US, for example, more than $ 20 billion was allocated for the repair and restoration of buildings in the 90s, and these costs then increased every year. In this regard, particular attention is paid to the development of optimal solutions for waterproofing the foundations of buildings, reliable protection of structures from aggressive underground influences and thereby increasing the life expectancy of buildings, structures.

2. Materials and methods. Capillary water rises in the grunt through free tubes formed by the interconnection of the pores, or is trapped in them in a suspended state.

The rise of fluid in the capillary continues until the force of gravity acting on the fluid column in the capillary is equal to the force obtained by the module.

Moisture entering the body of building structures is a serious cause of their breakdown. In conditions of high humidity, wooden structures rot and break in 2-3 years, steel structures lose their strength after 10-12 years due to corrosion, and stone, concrete and reinforced concrete structures break after 40-50 years of operation. Therefore, the formation of waterproofing of the foundation body and the foundation-wall junction is an important factor in the integrity and strength of buildings [1].

With Capillary absorption in water-unsaturated concrete, water can rise over relatively large distances (theoretically up to a height of 4-15 m) through very small capillaries as a result of diffusion processes that help moisten the capillary surface. However, in practice, water in concrete does not rise to such a height. This is because Concrete does not have ideal capillaries, their shape and size are constantly changing and, therefore, the capillary forces that cause water to be absorbed and moved are also changing. The complete saturation of concrete samples with water does not occur due to the step of the air in the pores of the concrete, which creates pressure against capillary forces, even when storing them in water for a long time [2].

The ingress of water (especially mineralized water) into the pores of the concrete, its variable humidification and drying, freezing and melting are the main causes of the erosion of concrete structures. For this reason, a decrease in water absorption into concrete contributes to an increase in its long durability [3].

The mechanism of wet transition from concrete is a complex and poorly studied process. This moisture penetration depends on many factors acting together with various pores, under the influence of which it passes through the concrete.

At the same time, the mechanism of moisture transfer in the pores of the gel is not clear. Both our and foreign scientists believe that the size of the pores of the gel is very small, so capillary forces do not play a big role in them. In the studies, it is believed that the main role of the mechanism of moisture transfer in the pores of the gel is played by the mechanism of diffuse transfer of moisture [4, 5].

3. Result.

In concrete, the size of air pores is much larger than the size of capillaries, and the mechanism of capillary suction cannot be used in this case. Air ports act as a barrier to moisture transfer [6, 7].

Therefore, during the research, we were faced with the task of developing a model for predicting the movement of water in concrete under various types of effects and creating a mechanism for reducing the capillary saturation of concrete materials. Therefore, we are limited to considering the movement of liquid flow due to capillary suction.

The height of the elevation of the liquid along the capillary can be determined by the Juren formula as follows, through the simplest theoretical model in which the pore radius in concrete for a two-component system depends on r (Laplace's formula was used to determine the lifting force of the meniscus):

$$H_k = \frac{2\sigma}{\rho \cdot g \cdot r} \cos \theta \qquad (1)$$

where r is the capillary radius;

σ - The surface tension of the fluid (equal to $t = 20\,^oC$, when $\sigma = 72{,}8\,din\ /\ sm$ for water);

θ - Marginal angle of wetting;

g - Free fall acceleration;

ρ - Water density.

When all the particles of the capillary material are completely wetted, that is, when $(\theta = 0)$, putting the numerical values of σ and g in expression (1), we get the following expression:

$$H_k = 0{,}15\ /\ r, \qquad (2)$$

It follows that the height of the liquid rising through the capillaries is inversely proportional to the capillary radius. At the same time, the height of the liquid rising in the capillary porous material is also affected by the exposure time of the liquid. In this case, the time dependence of the liquid rise height is determined by the following expression:

$$H_t = \sqrt{r \cdot m \cdot \frac{\cos \theta}{2} \cdot \mu \cdot \sqrt{t}}, \qquad (3)$$

where H_t is the height of capillary rise of water in concrete;

μ - dynamic viscosity of liquid;

m - porosity environment in concrete.

It can be seen from the expression (3) that the height of the capillary rise of water in concrete is proportional to the square root of the exposure time of the liquid. (3) the expression describes a model of a pipe (capillary) made of concrete, representing a porous medium, and roughly calculates the rise in water.

In general, the rise of liquid from concrete occurs through pores, microcracks and voids in concrete. Under normal conditions with moderate humidity and moderate temperature, the main driving force for moisture migration in porous media is moisture and temperature gradients. When the moisture content is low or the pores are in contact with liquid, the main mechanism for moisture transport is vapor diffusion or capillary absorption.

In recent years, most of the mixture used for horizontal waterproofing has low capillary porosity. This is due to the transition from traditional mixtures to highly effective mixtures with very fine porosity. In these mixtures, the transformation of the rheological matrix takes place, providing a rational rheology [8, 9]. At the same time, micro-dispersed stone flour, fine-grained and fine sands, which make up the biological matrix, act as active components affecting the formation of the pore space of the mixture [9].

Despite the reduction of the capillary pore size, at lower values of the C/S/P=8/16/0.08 ratio, such concretes show water saturation characteristic of conventional concretes after initial drying. That is, it is determined by the one-way absorption of liquid through capillaries, which is calculated by expression (3).

The water molecule is a dipole, equal in size, but at its opposite ends it differs by a hint of electrical charges, and the particles of the binding filler on their surface, depending on what materials the particle consists of, acquire positive and negative electrical charges.

Under the influence of particle charges, the direction of water dipoles appears. The location of the water molecules in the capillary can be shown in the process between two parallel glass plates partially immersed in water. The water in the narrow slit of the capillary is in a strained state caused by the interaction of the charges of the capillary-water system.

According to LaPlace's theory, the surface film of a liquid is in a state of tension [8]. The rest of the liquid is not bound to the capillary walls. In addition to electrical forces, water molecules in the capillary are also affected by gravitational forces. From the condition of static balance between the electric and gravitational forces, it follows that the height of the rise of water in the capillary is equal to h_o:

$$h_o = \frac{q_C \cdot q_B}{\rho_B \cdot \varepsilon \cdot r^2} \qquad (4)$$

in this h_o - the height of the liquid column in the capillary crack;

q_C - the total electric charge passing through the surface of the crack wall equal to 1 cm^2;

q_B - the total electric charge of a water molecule located in the middle plane of 1 cm^2;

ε - dielectric constant;

r^2 - the distance between the crack planes;

ρ_B - water density.

In concrete, capillaries look like a thin tube, not a crack. As a result, the pull on the walls is greater than in a flat crack.

$$h_{mp} = \frac{2 q_C \cdot q_B}{\rho_B \cdot \varepsilon \cdot r^2} \qquad (5)$$

4. Conclusion.

The results of the study of the rise of capillary water showed that this process lasts for a long time. In all components of composite materials - concrete has varying degrees of porosity. Due to the complexity of creating an approximate model of moisture transfer in concrete samples, phenomena related to moisture absorption and transfer were investigated. At the same time, movement along large-diameter capillaries and due to direct diffusion was considered.

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