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RELIABILITY OF STRUCTURES DURING THE CONSTRUCTION DEWATERING AS A BIM TASK

Abstract. Determination of the dynamics of the groundwater level is one of the most important tasks, without the solution of which it is impossible to reliably estimate the reliability and durability of the projected building. In this article, the concept of applying information modeling technologies for obtaining a reliable "building-ground" system is proposed, which allows modeling the position of the groundwater level.

Key words: depression surface, smart city, construction dewatering, BIM technology, soil information model.

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НАДЕЖНОСТЬ КОНСТРУКЦИЙ ПРИ СТРОИТЕЛЬНОМ ВОДОПОНИЖЕНИИ КАК BIM ЗАДАЧА

Abstract. Определение динамики уровня грунтовых вод является одной из важнейших задач, без решения которой невозможно достоверно оценить надежность и долговечность проектируемого здания. В данной статье предложена концепция применения технологий информационного моделирования для получения надежной модели "здание-грунт", позволяющая моделировать положение уровня грунтовых вод.

Ключевые слова: поверхность депрессии, умный город, водопонижение при строительстве, технология BIM, информационная модель грунта.

1 Introduction

The application of information modeling technologies at all stages of the life cycle of the constructional project is one of the goals of innovative development of the construction industry in many countries at the present time. It is necessary to think about prospects for the development of this direction. Modern trends in the development of science and technology show a particularly effective result in the synthesis of knowledge and experience in ranges of a science. In this article the synthesis of experience in information modeling of buildings, the development of modern geoinformation systems and mathematical modeling of changes in the hydrogeological regime of urban areas is considered.

Variations of the groundwater level significantly affect the reliability of the constructional project and surrounding buildings, these risks are difficult to assess during the design process of the building. In the modern scientific and technical literature, the problem of raised water table of modern cities is much-publicized [1], however, it is necessary to take into account the risks that arise also in the process of lowering the groundwater level too. Given that earlier watered soils give additional settlement, compacting under their own weight.

Depression of groundwater surface level is possible with the drainage device, as a result of the damming effect resulting from the development of the underground space of cities [2-4], and also during construction dewatering.

As is known, when the groundwater is pumped out, the surface of the water in the soil changes in some area, becomes funnel-shaped, while decreasing with a slope to the pumping site. A similar effect is achieved with the installation of drainage of groundwater. The funnel-shaped surface of groundwater is called the depression surface, and the drained space between the original surface of the subterranean stream and the depression surface is the depression funnel [9]. At a constant pumping rate, steady-state regime sets in, with which the depression surface does not change. When pumping is stopped, the groundwater level is restored, and their surface gradually acquires its original (natural) form.

The purpose of building unwatering is the development and maintenance, during the required time, of a depression funnel in aquifers cut through the foundation pit, which makes it possible to erect all underground construction dry.

It is necessary to take into account the fact that the density of the soil above the depression surface increases by about two times due to the loss of the Archimede's buoyant force (Fig.1), and therefore both the drained layer and the layers below are further compacted under their own weight [5].

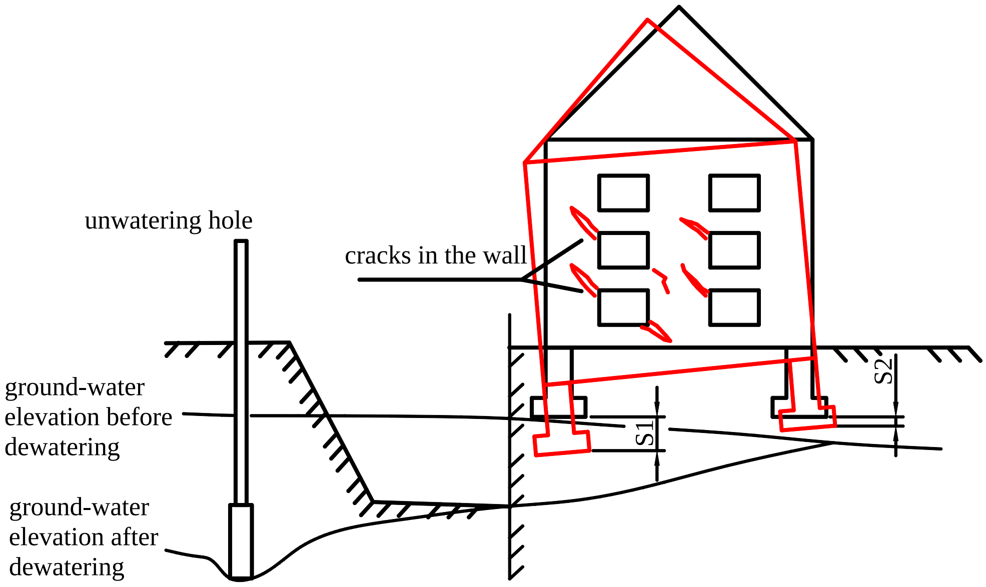

Figure 1. Deformations of the building due to the dewatering

In this case, the additional load P_{ds} can be determined by the formula (1).

$$P_{ds} = (d_w - d_{ds})(\rho - \rho_{sb}) \quad (1)$$

d_w – the depth of location of groundwater before dewatering;
d_{ds} – the depth of groundwater distribution at a given point after dewatering, the depth of the point on the depression surface;
ρ – the density of the soil;

ρ_{sb} – the density of soil taking into account the weighing action of water can be determined by the formula (2).

$$\rho_{sb} = (\rho_s - 1)/(1 - n) = (\rho_s - 1)/(1 + e) \quad (2)$$

ρ_s– the specific gravity of solid ground particles;
n – the porosity of the soil;
e – coefficient of soil porosity.

The additional settlement is calculated from the condition that the additional load is applied at the elevation h_{ws} within the area under the influence of water depletion, and the compressible strata includes all soil layers to the top of the bedrock. To calculate the total bank of a building that is close to the dewatering wells, it is necessary to sum the settlement from the dewatering with the settlement caused by the interference of the existing and new building (structures). It should be noted that long-term or permanent dewatering first causes only uniform setting of buildings and structures that have entered this zone, which, as a rule, do not significantly affect their operational usability. However, long-term consequences can be dangerous, especially where the structures are erected on such soils, where the flattening of the depression surface from the level at the site of pumping water to its natural level is the most dramatic. Thus, in order to quantify the risk of possible deformations of the foundation, it is necessary to determine the reliable position of the depression groundwater surface. This difficult-to-forecast phenomenon is a threat to existing buildings and structures that are situated into the zone of depression funnel. For measure such risks it is necessary to have a reliable information model of the soil.

2 Information model of soil

The modern system for data storage about front end engineering design in most of Russian cities is represented such a way that the geodetic survey archive is an on-line electronic map of the city, which is continuously updated with new information after the report on the survey is submitted. The archive of geological surveys in most cases is a set of uncoordinated copies of reports on geological surveys carried out by different companies at different times. The storage and actualization of geological information is the area that requires digitalization as soon as possible. The semantics of each borehole should contain complete information about it, in accordance with the borehole log from the geological survey report. Thus, the geological survey archive will become a soil information model (SIM), which will be constantly updated with new information. It is necessary that the SIM contain not only data on the situation of soil units, but also the physical and mechanical characteristics of soils, as well as information on the level of groundwater. A reliable soil information model can be used to model the dynamics of the groundwater table.

3 Modeling the flow of groundwater

From the point of view of filtration theory [6], the soils lying at the base of building objects are a porous medium, the most important characteristic of which is their porosity n. Its definition is closely related to the basic law of fluid motion in a porous medium, called the Darcy's law (filtration law).

If we consider the problem of inflow to a well – a narrow cylindrical hole that is drilled in a reservoir for water evacuation, in the vicinity of the well, symmetry of the streamlines is directed radially to the well, and the area of the cross section of the current tubes is proportional to the distance from the well axis (r, $r+\Delta r$). The filtration rate is defined as:

$$u = Q/2\pi rh. \tag{3}$$

A small section of the current tube between the sections at distances r and $r + \Delta r$ is an analog of the sample in the Darcy experiment, so that for the pressure drop on it we have:

$$\Delta p = \frac{\mu}{k} u\Delta r = \frac{\mu Q}{2\pi kh} \frac{r}{\Delta r}. \tag{4}$$

Thus, for the pressure distribution p (r), we obtain the simplest differential equation, whose solution has the form:

$$p(r) = \frac{\mu Q}{2\pi kh} ln \frac{r}{r_{hole}} + p_{hole}, \tag{5}$$

r_{hole} – borehole radius,
p_{hole} – pressure of the water into the borehole.

If the pressure p_0 is known at a distance r_0 from the borehole (such a line of equal pressure is called the external reservoir boundary), then using (5), we can find the formula for the flow (rate):

$$= 2\pi kh\ (p_0 - p_{hole})/\mu\ ln(r_0\ /\ (r_{hole}). \tag{6}$$

This formula (6), called the Dupuit equation, is the most important in hydrogeology. Dupuit equation in the formula refers to deep seams under high pressure. In particular, for a water borehole in a non-pressure regime, the analogue of the Dupuit formula has the form:

$$Q = \frac{\pi k\rho g\ ({h^2}_0 - {h^2}_{hole})}{\mu\, ln\left({r_0}/{r_{hole}}\right)}. \tag{7}$$

h_{hole} – hydrostatic level in the borehole;
h_0 – hydrostatic level on the external reservoir boundary.

Thus, have known the amount of pumping out of the well and the discharge capacity of the soil, from this expression it is possible to determine the depth of occurrence of groundwater anywhere in the depression zone. Similar calculations must be carried out regularly on the construction site.

To solve the equations of moisture transfer for given initial and boundary conditions, numerical methods are used, namely: the finite-element method and the finite-difference method, which are implemented in modern software such as MODFLOW and others [7-12]. The researcher is able to obtain a series of successive values of pressure or head of groundwater in the nodes of the spatial grid. However, in order to obtain reliable results, it is necessary to take into account the influence of building objects on the filtration properties of soils that occurs in connection with the change in the stress-strain state of the base. The authors see the solution of this problem in the application of BIM technologies for getting flow of groundwater model.

4 BIM

Information modelling of a building or structure is the process of creating and managing information about a building or structure, which forms the basis for decision-making throughout its full life cycle [13].

In the course of modelling, a 3D model is created, and in the course of information modelling, a model is created where each component has parameters, properties, and other semantic data. The third component of the BIM concept is a building, which means that a totality of simulated elements will be a model of some building.

The information from the model of the projected object can be transformed into different types: a 3D model, plans and sectional views of a building with the marking and dimensions that are similar to the drawings familiar to us, in the form of tables, lists, diagrams, graphs, etc. But the model remains unified. Information model of the building is a database saturated with data about the object, which can give an idea of the space planning decisions, the structural scheme, building services systems, all the materials, economic performances, etc.

It should be noted that at present in Russia the introduction of BIM technologies in design practice enjoys broad government support: a working group has been created, pilot projects are launched, and a normative framework is being developed. So, the need to develop a BIM model is prescribed in the contract for the design of all objects financed by the municipal budget in Yekaterinburg from the beginning of 2017 year.

Modern technologies provide new perspectives for processing information, open wide horizons for the math modelling of various complex processes, which previously was either impossible or impractical, due to its labor intensity. At the present time, we can look at the solution of already known problems in a new way.

5 Prospects for the development of the use of mathematical modeling in construction

According to the authors, as the database of BIM models of building objects expands, it becomes necessary to link them to each other in a geoinformation system of new generation. This system will be a collection of information model of the soil automatically built and continuously updated according to geological survey data, a digital map of the city where the mutual arrangement of objects is shown, and BIM-models of these objects, the level of detail of which is sufficient to perform the tasks. There is quite a logical question, how to get the BIM model of long-built objects, for which the design documentation might not have survived. Here, the latest technology for 3D scanning of buildings comes to the rescue [14]. The result of such scanning is an information model containing information on space-planning solutions and materials used during the building erection. The proposed new generation of geoinformation system can be implemented on the basis of the popular concept of "Smart City" today, significantly expanding its functionality.

Such information system will make it possible to assess the consequences of the impact of construction projects on the existing buildings arising from the change in the hydrogeological regime during construction or operation, due to a change in the stress-strain state of the base. This will allow modeling the position of the groundwater surface with minimal errors. The result of this work will be the information about the permissible variations of the groundwater table taking into account the safety margin of the existing building, which will allow the most reliable assessment of risks in the design of the construction dewatering, calculation of the barrage effect, forecasting possible flooding of the territory. The prospects for using this information are such that we can subsequently obtain a model of not only individual objects, but also entire blocks, districts, cities.

In conclusion, it should be noted that using the concept of "Smart City" you can solve a large number of other tasks that were not available at the previous stages of technology development. There are some examples in the field of architecture, construction and operation of the city. We are able to simulate the impact of wind loads on complex structures, to monitor the fulfillment of insolation requirements, to organize monitoring of the construction process, to use "Smart City" as a visual model of the architectural appearance of the city, to improve the operation of operating services, to simulate emergencies, to use new technologies for environmental design, correctly form traffic flows and much more.

"Smart City" is a concept that needs to be developed in cooperation with specialists in completely different areas, only this will give an opportunity to get a truly working system worth the investment, time and money.

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