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A NEW DRAINAGE SYSTEM TO DIVERT THE GROUND WATER FOR THE SAFETY OF THE FOUNDATION OF HIGH-RISE BUILDINGS

One of the problems with improving the stability of the structure during the construction of high-rise buildings on the territories adjacent to the sea or a river bed is to draw down the ground and seepage waters in the foundation, and solving this problem will help improve the stability of the structure in the final run. Aiming at solving this problem, a new structure of a three-stage combined drainage system was designed at Ts. Mirtskhulava Water Management Institute of Georgian Technical University (Georgian Patent #GE P2005, 3573 P) ensuring not only drawing down the ground water, but also regulating the surface and seepage waters in the building foundation. The goal of the study is to examine the water conductivity of the three-stage combined drainage system to improve the building stability and develop the methods of its hydraulic calculations.

Keywords: **high-rise building, foundation, ground water, three-stage combined drainage**

INTRODUCTION

Tbilisi, the capital of Georgia, with a 1500-year-long history, is located in the river Mtkvari canyon, with its mountainous relief naturally fragmented with numerous watersheds and catchment areas.

For many hundreds of years, at different times, on this territory, a city was built with one- and many-storey and high-rise buildings, with their reliability diminishing over the years. As a result, the buildings were hazardous well before the expiration of their service life [1].

The scientific-research works proved that one of the major reasons for the accidents of high-rise buildings was a washout of their foundations, suffusion with ground and filtration water currents formed with the surface water currents originated as a result of intense rains and filtration water currents flowing out of the Tbilisi Sea (so-called Tbilisi water reservoir). Figure 1 shows the contours of accommodation of the city of Tbilisi.

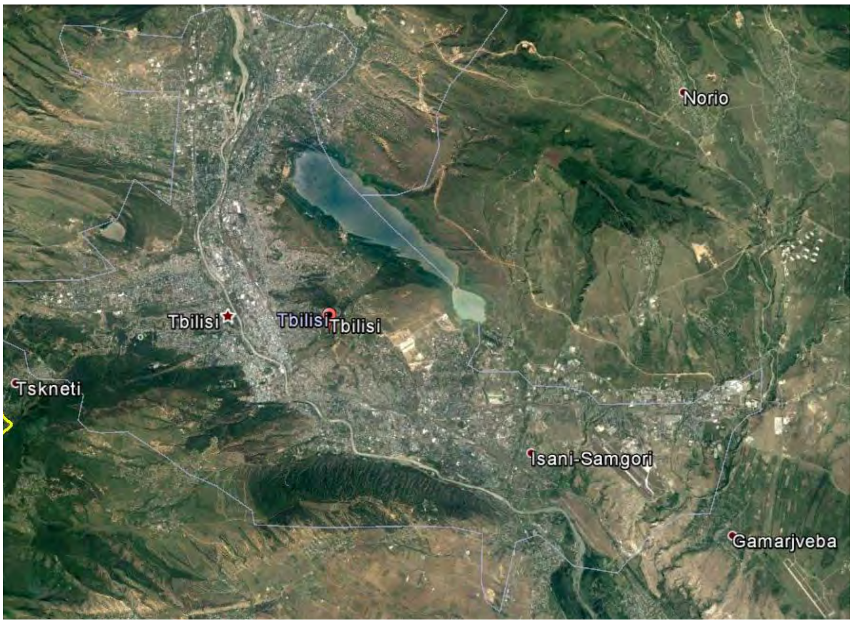

Fig. 1. Contours of accommodation of the city of Tbilisi

If considering the geographical location of Tbilisi and analyzing the contours of its accommodation, we will see that the location of the natural landscape of Tbilisi, the capital of Georgia, does not support the construction of high-rise buildings much [4]. The situation is aggravated by steep mountain slopes making the area very sensitive due to the formation of surface waters and subsequent water erosion of the surface of the relief.

The complex analysis of the natural landscape of Tbilisi and its assessment as of the principal polygon of the population accommodation reveal that one of the sensitive challenges of constructing high-rise buildings is the provision of the foundation stability against the ground and filtration water currents leading to the suffusion of the foundation and reducing the reliability of the premises.

1. CALCULATION OF WATER-CONDUCTIVITY OF THE COMBINE THREE-TIER DRAINAGE FOR THE STABILITY OF THE BUILDING FOUNDATION

Aiming at identifying the degree of hazard of the apartments of five-storey and high-rise buildings in Tbilisi, some hazardous buildings were selected in Vake-Saburtalo district and Varketili-3 massif of Tbilisi, and geological pits were drilled along their foundations with the depth of 5.0 m for continuous footings and 10÷30 m for pile foundations (see Fig. 2). Figure 3 shows the general views of a five-storey hazardous house in Moseshvili street (Tbilisi) and tall hazardous house in Varketili-3 massif. Figure 3 shows the general view of the geological pit drilled along the foundation of the five-storey building.

Fig. 2. Cross section of the geological pits

Fig. 3. The pit drilled in the house foundation in Moseshvili street (Tbilisi): a) hazardous house in Moseshvili street (Tbilisi), b) view of the hazardous house in Varketili-3 massif (Tbilisi)

The studies revealed that the foundation of the house in Moseshvili street in Tbilisi with its depth of 5.0 m, is filled with ground water and as a result, the five-storey building is hazardous, while the hazardous state of the houses in Varketili-3 massif is mostly the result of the Tbilisi Sea water filtration. The buildings in Varketili-3 massif are built at low levels resulting in the suffusion of their foundations.

Thus, one of the major issues with improving the stability of the five-storey and high-rise buildings in Tbilisi is the diversion of ground waters from the foundation and currents of filtration waters from the Tbilisi Sea water area.

2. CALCULATION OF WATER-CONDUCTIVITY OF THE COMBINE THREE-TIER DRAINAGE FOR THE STABILITY OF THE BUILDING FOUNDATION

Following the detailed study of the landscape for the purpose of accommodation of the city of Tbilisi, aiming at improving the stability of the foundations of the five-storey and high-rise buildings, a new device of the combine three-tier drainage was developed at Ts. Mirtskhulava Water Management Institute of Georgian Technical University, with the priority of its scientific-technical novelty certified by Georgian Patent Certificate No. 3573 B) [2, 3].

Figure 4 shows the design model of the combine three-tier drainage.

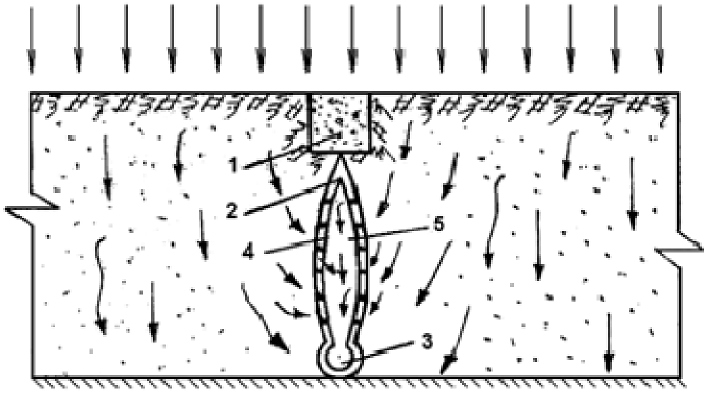

Fig. 4. Cross section of the combine three-tier drainage

The combined drainage is made up of underground fracture drains (1), with the pipes of the water intake made of the super-strong polyethylene material (2) with perforated elliptic nods (4) under them. The water intake connects up to the pipeline connected to the water pipeline collector (5).

- The purpose of the first tier (1) is to regulate the surface runoff water to avoid its delay in the building foundation longer than admissible.
- The second tier is an elliptic perforated polyethylene structure (2) absorbing excess humidity in the foundation and transforming it into water currents.

- The third tier is an intake pipe (3) located below the foundation level ensuring the water supply to the conducting channels (pipes 5) and swift ground water diversion in the foundation (Fig. 5).

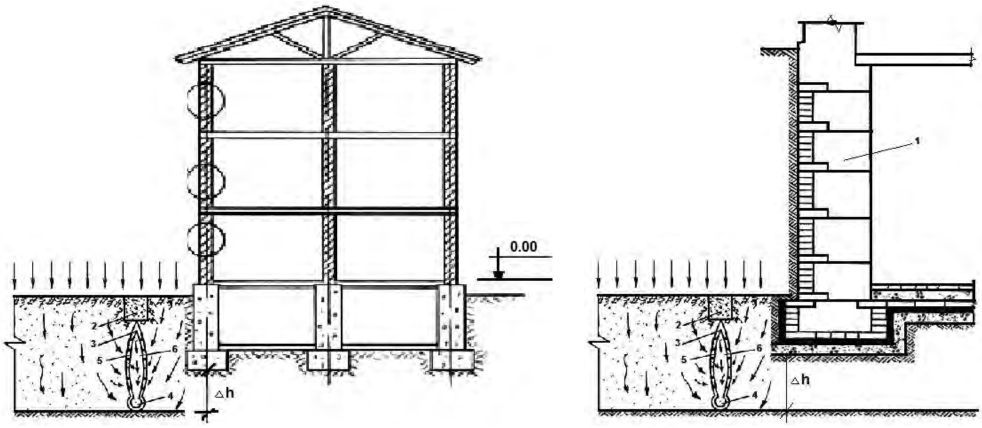

Fig. 5. Plan of the combined three-tier drainage in the building foundation

3. HYDRAULIC CALCULATION OF THE COMBINED THREE-TIER DRAINAGE

For the hydraulic calculation of the combined three-tier drainage, let us consider the calculation plan given in Figure 6. The ground water discharge flown into the prism will equal [5]:

$$Q = 2xyk\frac{dy}{dx} \tag{1}$$

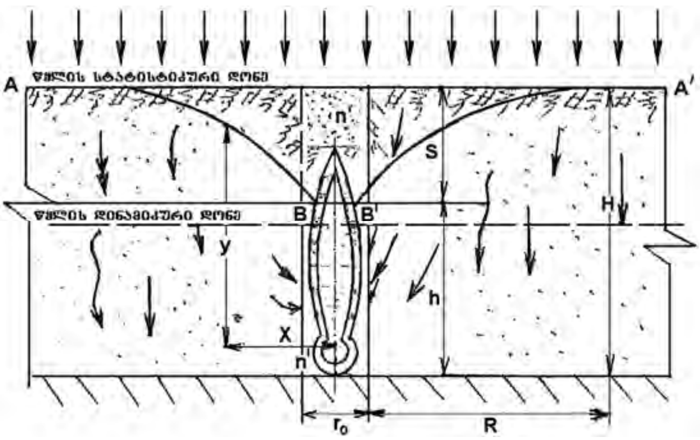

Fig. 6. Calculation plan of the combined three-tier drainage

By using the method of separation of variables, expression (1) will be as follows:

$$ydy = \frac{Q}{2k}\frac{dx}{x} \tag{2}$$

By integrating (2), we obtain:

$$y^2 = \frac{Q}{k}\ln x + c \tag{3}$$

To find the integration constant (*c*), we use the boundary condition, when $x = R_0$, then $y = h$, and we obtain: In order to calculate the output along 1 linear meter of the combine three-tier drainage, let us consider so called prism presented with the length of $2x$ and depth of y. The velocity of the ground water current flown into the prism will be proportional:

$$h^2 = \frac{Q}{k}\ln r_0 + c \tag{4}$$

Integration constant (*c*) from expression (4) equals:

$$c = h^2 - \frac{Q}{k}\ln r_0 \tag{5}$$

As the cylinder with radius r_0 does not coincide with the surface of the combine three-tier drainage of an elliptic shape (Fig. 6), let us introduce a new value as a form coefficient (η). Then, let us introduce ηr_0 instead of r_0 in equations (4) and (5). By considering the above-mentioned, if considering expression (5), equation (3) will be as follows:

$$y^2 - h^2 = \frac{Q}{k}\ln\frac{x}{\eta r_0} \tag{6}$$

Let us insert the boundary condition in equation (6), when $x = R$, then $y = H$ (Fig. 5), and we will obtain:

$$H^2 - h^2 = \frac{Q}{k}\ln\frac{R}{\eta r_0} \tag{7}$$

If using equation (7) and transform it, we will obtain the equation to calculate the ground water discharge flown into the prism:

$$Q = \frac{k\left(H^2 - h^2\right)}{\ln \frac{R}{\eta\, r_0}} \text{ [cm}^3\text{/sec]} \tag{8}$$

If designing the combine three-tier drainage with length L, then expression (8) will be as follows:

$$Q = \frac{Lk\left(H^2 - h^2\right)}{\ln \frac{R}{\eta\, r_0}} \text{ [cm}^3\text{/sec]} \tag{9}$$

where: η, as mentioned above, is the form coefficient of the elliptic nod of the combine three-tier drainage, whose value depends on the radius of curvature of the elliptic nod of the three-tier perforated drainage, with its numerical value equaling:

$$\frac{\text{nn}\left(\text{Length of the horizontal curve}\right)}{\text{nn}\left(\text{Length of the vertical curve}\right)} > 1 \tag{10}$$

During the operation of the combine three-tier drainage, when the level of ground water falls to level $h = (H - S)$ (Fig. 5), the ground water dynamic level is established:

$$h^2 = H^2 - 2HS + S^2 \tag{11}$$

Let us simplify expression (11) to obtain:

$$H^2 - h^2 = 2HS\left(1 - \frac{S}{2H}\right) \approx 2HS \tag{12}$$

By considering that $S << 2H$ and expression (12), expression (8) will be as follows:

$$Q_{max} = \frac{2kHS}{\ln \frac{R}{\eta \cdot r_0}} \text{ [cm}^3\text{/sec]} \tag{13}$$

So, expression (13) is used to calculate the water conductivity of the combine three-tier drainage ensuring efficient diversion of the ground and surface waters from the building foundation what is one of the solid guarantees for the stability of the five-storey and high-rise buildings in Tbilisi.

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NOWY SYSTEM DRENAŻU ZAPEWNIAJĄCY ZRÓWNOWAŻONY PRZEPŁYW WODY GRUNTOWEJ W STREFIE FUNDAMENTÓW BUDYNKÓW WYSOŚCIOWYCH

Jednym z problemów związanych z posadowieniem konstrukcji budynków wysokościowych na terenach przylegających do morza lub koryta rzeki jest przesiąkanie wody w strefę fundamentów. Rozwiązaniem tego problemu, które może poprawić stateczność danych konstrukcji w całym cyklu funkcjonowania budynku, jest odprowadzenie wody z gruntu, z otoczenia fundamentów. Mając na celu rozwiązanie tego problemu, w Gruzińskim Uniwersytecie Technicznym (GUT) zaprojektowano nową konstrukcję trójfazowego kombinowanego systemu drenażowego. Instytut Gospodarki Wodnej im. Mirtskhulavy GUT opatentował konstrukcję zapewniającą nie tylko odprowadzenie wód gruntowych, ale także regulację wód powierzchniowych i przesiąkowych do fundamentów budynku (gruziński patent GE P2005, 3573 P). Celem badania było zbadanie przepływu wody w trójfazowym kombinowanym systemie drenażowym w celu poprawy stabilności budynku i opracowanie metody jego obliczeń hydraulicznych.

Słowa kluczowe: **budynek wyskościowy, fundament, woda gruntowa, trójfazowy drenaż kombinowany**