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Experience of geosentetic materials use in drainage system device

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At present, objects of responsibility (consequences) construction various classes, including SS-3 occurs in areas with possible manifestations of dangerous engineering-geological processes. One of such processes types is flooding. Based on the world experience, the main possibilities of using geosynthetic materials in various fields of construction are considered. Requirements for such materials and the conditions for their use are set out in European norms. An analysis of the program that is used to calculate drainage systems to meet force requirements in Ukraine is performed. These materials have good prospects for building in Ukraine with appropriate justification, considering the normative documents in force in our country.

Keywords: drainage, filtration, geotextile, filtration coefficient, Darcy law

Досвід застосування геосинтетичних матеріалів при влаштуванні дренажних систем

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Відомо, що на сьогоднішній день будівництво об’єктів різних класів відповідальності (наслідків), у тому числі СС-3, відбувається на територіях, на яких можливі прояви небезпечних інженерно-геологічних процесів. Зазначено, що одним із видів таких процесів є підтоплення. При зведенні нових об’єктів на таких ділянках необхідно виконувати спеціальні заходи щодо захисту заглиблених частин будівель та споруд від дії ґрунтових вод та збереження існуючого гідрогеологічного режиму. При цьому слід виконувати вимоги діючих в Україні нормативних документів щодо інженерного захисту територій. Ґрунтуючись на світовому досвіді, розглянуто основні можливості застосування геосинтетичних матеріалів у різних галузях будівництва. Як приклад наведені сучасні матеріали, які можуть замінити традиційні рішення при проектуванні пластового дренажу. Зазначено, що геосинтетичні матеріали використовують у світі більше двадцяти років при будівництві цивільних та промислових доріг, спортивних майданчиків, полігонів твердих побутових відходів, парків, тунелів. Вимоги до таких матеріалів і умови їх використання викладено в Європейських нормах. Наведено характеристики матеріалів та їх складових частин, а також умови їх використання. Розглянуто переваги використання сучасних геосинтетичних матеріалів порівняно з традиційними рішеннями, пов’язаними з проблемами підтоплення територій, будівель і споруд. Виконано аналіз програми, яка використовується для розрахунку дренажних систем на відповідність вимогам, що діють в Україні. Показано, що ці матеріали мають гарну перспективу при будівництві в Україні при відповідному обґрунтуванні з урахуванням діючих у нашій країні нормативних документів.

Ключові слова: фільтрація, геотекстиль, коефіцієнт фільтрації, закон Дарсі

Introduction. At present, objects of responsibility (consequences) various classes construction, including CC-3, takes place at the sites where dangerous engineering and geological processes are possible. This is predetermined by the fact that the sites, relatively simple in terms of engineering-geological and hydrogeological conditions, have already been developed. The phenomenon of flooding is one of the dangerous geological processes types. This is due to the fact that considerable areas of Ukraine are located in the zone where the hydrogeological regime with high groundwater levels has already been formed, or the flood has an anthropogenic character associated with human activity. These conditions require the implementation of special measures that must protect the underground parts of erected constructions from groundwater, as well as compliance with the requirements of regulatory documents being in force in Ukraine required for engineering protection of territories.

Analysis of the latest sources of research and publications. Requirements for engineering protection of territories from flooding are set out in DBN A.2.1-1-2008 [1], DBN B.1.1-24: 2009 [2], DBN B.1.1-25-2009 [3]. However, the solutions proposed in these standards for the protection of buildings and constructions from flooding offer mainly traditional solutions, without consideration positive experience of using up-to-date materials, popular in the world. Abroad, geosynthetic materials as drainage have been widely used for more than twenty years. The conditions for such materials use are set out in European norms [4, 5, 6]. A large number of articles published in foreign scientific publications and reports made at international scientific conferences has been devoted to the application of drainage made of geosynthetic materials [7, 8].

In our country, these materials are not widely spread yet, although in the world practice, drainage systems made of geosynthetic materials are widely used in the performance of the following tasks:
– drainage of underground structures and parts of buildings located below the ground (vertical and horizontal);
– drainage of roads (including railway infrastructure);
– drainage of sports grounds;
– drainage of roofs and terraces;
– drainage of gardens and parks;
– drainage (gas) of landfills of solid household waste;
– waterproofing and drainage of tunnels.

Drainage systems made with the use of geosynthetic materials can be used both for diverting of ground water and for removing gases from landfills of solid household waste.

The following objects can serve as the examples of their use: the third tramway line in Nantes (France), the National Library in Beirut (Lebanon), sports complexes in Toulon (France), Quebec (Canada), construction of a microdistrict in Ore (France), the South Hospital in Marseille (France), the construction of solid waste landfills in France.

The main geosynthetic material for drainage, considered in this work, is Draintube produced by the company Afitex (France).

Distinguishing of previously unresolved parts of a common problem. When designing horizontal drainage (bed and combined) in civil engineering, usually a layer of crushed stone is used as a water-permeable layer through which water is diverted outside the protected area. Typically, layer thickness of crushed stone is at least 0.5 m when applying traditional solutions. The volume of crushed stone used as drainage is determined by the engineering-geological and hydrogeological conditions, as well as the need to lower the groundwater level to the required level. In such cases, the amount of work associated with the excavation of pit increases, the bottom of the excavation pit is additionally lowered, which may lead to complications of its work, or the performance of additional measures for the construction of water depression, the costs for the transportation of the worked out soil, and the purchase and delivery of crushed stone. The use of up-to-date drainage materials such as Draintube enables to minimize the volume of ground works, soil transportation (removal/delivery) and crushed stone, application of special measures related to water depression.

Task specification. The main task is to show the perspective of using up-to-date geosynthetic materials in the construction of buildings and constructions under flood conditions, as these materials allow solving the problems of groundwater drainage from the construction site and protecting the parts of buildings and constructions that are below the ground from the groundwater, as well as reducing the costs associated with ground works and soil transportation in the excavation of pits. The evaluation of the calculation method applied in the world in the design of drainage, as well as of the approaches to the solution of this problem applied in Ukraine, were carried out.

The basic material and the results. In the late 90s of the 20th century, a new type of flat drainage geocomposite Draintube was developed. This material consists of two components:
– two or three layers of non-woven geotextiles that act as a back filter, that is, they allow the passage of water through them, while preventing the entry of ground particles from the base. At the same time, on the side that is in contact with the structure, a waterproof layer in the form of a membrane, which is a waterproofing, can be made;
– built-in corrugated polypropylene perforated pipes, located at regular intervals. The distance between the pipes can vary from one pipe for every two meters of width to four per meter. The number of pipes depends on the operating conditions. Usually the following distances between them are acceptable: 0.25 m; 0.5 m, 1.0 m, 2.0 m. The following diameters of the pipes are acceptable: 0.16 mm, 0.20 mm, 0.25 mm. Perforated pipes in this material provide the basic function of drainage to ensure the transit of groundwater beyond the area under consideration. Figure 1 shows the gen-

eral view of the Draintube material. Figure 2 shows the main dimensions acceptable for drainage using the Draintube material.

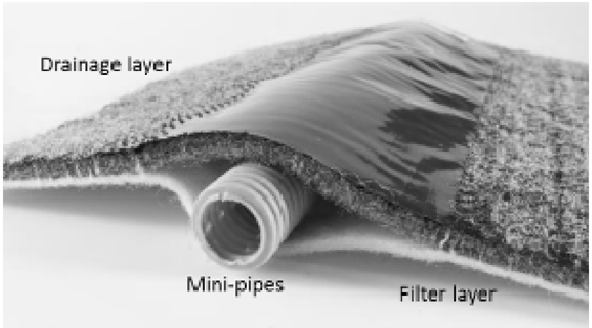

Figure 1 – General view of the Draintube material

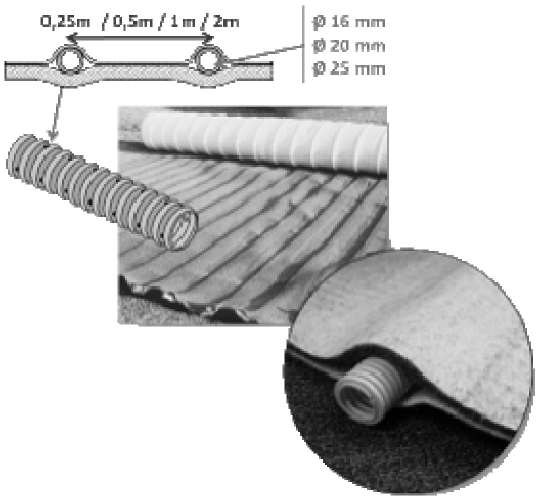

Figure 2 – Main dimensions acceptable for Draintube material

Depending on the task set, similar materials may be used, but considering the conditions where they are to be used. For example, if it is necessary to perform vertical drainage, the Alveodrain EV material can be used, which example is shown in Fig. 3. For this type of drainage, a special material made of thermoformed geotextile is used, through which water filters to the base of the vertical element and then enters to the polypropylene pipe, through which it is further drained outside the site.

To drain water out of drainage, the drainage pipes are connected to an interceptor through which water is drained outside the site. To connect the drainage pipes to the collector, a special connection (coupling) called Quick Connect is used, which enables to perform this work within a very short time. Figure 4 shows the Quick connect system for connecting drain mini-pipes to a collector.

Figure 5 shows examples of using up-to-date geosynthetic drainage materials at various sites.

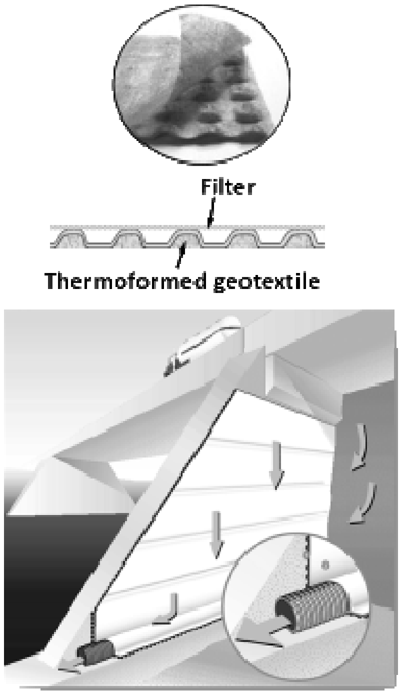

Figure 3 – An example of using Alveodrain EV material

Figure 4 – Quick connect system connecting drain mini-pipes to a collector

Figure 5 – Examples of using drainages made of geosynthetic materials

Compared with the traditional methods used in construction, the use of geosynthetic materials has several advantages. The main advantage is volume decrease of crushed stone and sand use as filtering materials. Depending on the conditions of drainages made of geosynthetic materials application, the economy of crushed stone reaches 60...70%, and under certain conditions it can reach 100%. At the same time, the pit depth is reduced (due to the reduction in the volume of used crushed stone), transportation cost of the worked-out soil and the delivery of crushed stone are reduced. In addition, the scope of works related to the construction of water depression is reduced. In certain cases, it is possible to use material where the sodium bentonite is used as the top layer (on contact with the construction), in such case this material can also serve as drainage and waterproofing.

On Figure 6 the options for using traditional solutions and drainage made of geosynthetic materials are compared.

To substantiate the possibility of using up-to-date geosynthetic materials as drainage and determine its parameters in the world, a number of specially developed software packages are used. One of such packages is the Lymphea software package, used by the company Afitex (France).

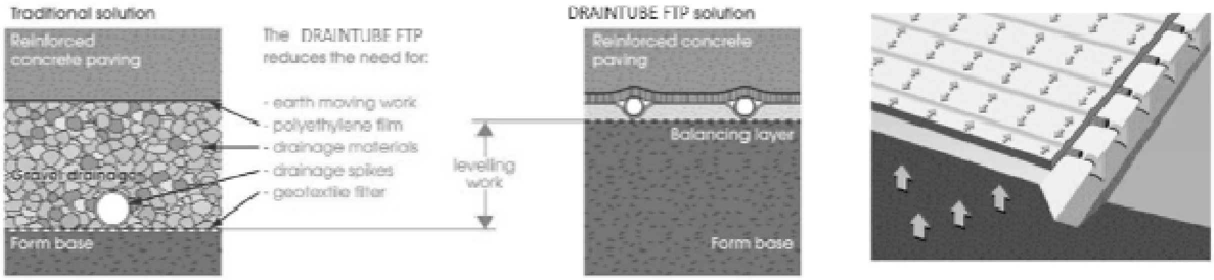

Figure 6 – Comparison of the traditional drainage design and drainage made of geosynthetic materials

The Lymphea software package is designed for performing hydraulic calculations to determine the parameters of drainage systems made of geosynthetic materials (geocomposites). This program is used in France. This complex is joint development of the Laboratory product of Regional Roads and Bridges from Nancy (France) and research laboratory in the field of geology and soils mechanics from Grenoble (France).

The software complex for solving the problems of determining the parameters of a drainage system made of geosynthetic materials is based on the application of the main law of filtration – Darcy's law.

The main parameters that are considered in this software package are the following:
– filtration coefficient of the drainage layer, taking into account the loads acting on it;
– length of drainage (dimensions);
– drainage slope;
– type of flow (complete flooding or pipe operation of partial cross section).

In the model that is formed for the calculation, the following prerequisites are used:
– the filtration flow is assumed constant (uniform), flowing from one side;
– two flow directions are taken: into the drain mat and into the mini-pipes.

The following parameters are considered in the calculation:
– pressure loss when water enters filter from the geotextile is acceptable;
– pressure loss when passing through the filter (geotextile) is acceptable;
– pressure loss when water enters the mini-pipe is acceptable;
– pressure loss when water flows through mini-pipes is acceptable.

During the calculation the pressure loss when passing from the ground to the filter is not considered. The drainage layer is water-saturated.

The specific consumption is assumed to be equal to

$$q = v_1 \cdot e_1 = k_{gf} \cdot i ,$$

where q is the specific consumption, m^2/sec;
v_1 is the velocity of flow entering the drainage mat, m/sec;
k_{gf} is the geotextile filtration coefficient, m/sec;
i is the pressure gradient.

According to laboratory studies, which are consistent with the theory of filtration, pressure loss after water entering the mini-pipes is reduced. It is assumed that the mini-pipes are oriented in the direction of the pressure drop.

According to the results of laboratory studies, the expenditure that a mini-pipe can be calculated according to the formula

$$Q = q_d \cdot i = \alpha \cdot i^{n+1} ,$$

where q_d is specific discharges of mini-pipes;
i is hydraulic gradient;
α, n are the values obtained experimentally.

Figure 7 shows the calculation scheme for determining the characteristics of hydraulic drainage made of Draintube material.

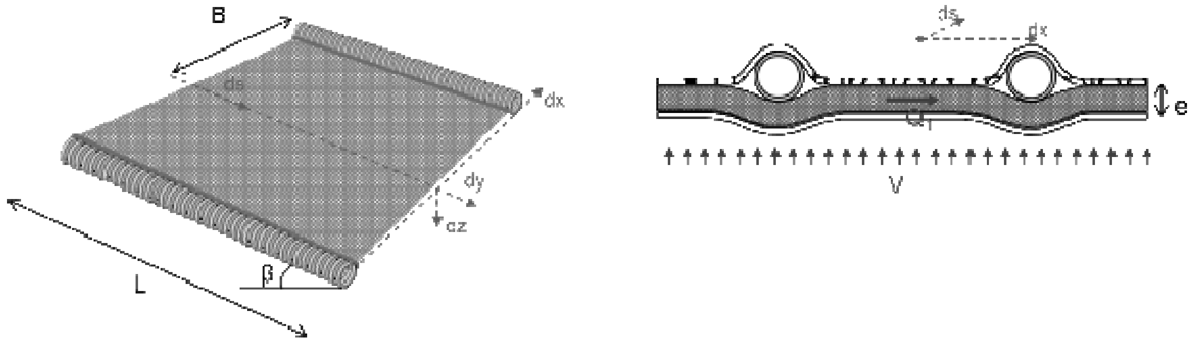

Figure 7 – Calculation scheme for drainage made of Draintube material

The maximum pressure in the drainage for the case when the mini-pipes work with the full cross-section is calculated according to the formulas:

$$h_{\max} = h_{geotextile} + \Delta_{hentransofm-p} + \Delta h_{m-p} ;$$

$$h_{\max} = \frac{VB^2}{2k_{geitextile}} + C(VB)^b + \frac{n+1}{n+2} L^{\frac{n+2}{n+1}} \left(\frac{2VB}{\alpha}\right)^{\frac{1}{n+1}} + L \sin\beta .$$

For drainage, when the mini-pipes are operated with a partial section, the maximum pressure is calculated according to a formula

$$h_{\max} = \frac{VB^2}{2k_{geitextile}} + C(VB)^b ,$$

where $h_{geotextile}$ is the loss of pressure;
$h_{hentransofm-p}$ is the loss of pressure at the inlet to the mini-pipe;
Δh_{m-p} is the loss of pressure on the length of mini-pipes;
V is the velocity of flow in the ground base;
B is half distance between the mini-pipes;
$k_{geotextile}$ is filtration coefficient of drainage layer (geotextile);
c, b, α, n are the values obtained experimentally.

For the case in which the mini-pipes are partially cross-sectional, the loss of pressure throughout their length is not considered.

Based on these equations, it is possible to determine the pressure in mini-pipes or the maximum drainage length. The solution of the equations is performed by selection, while different diameters of the pipes and the distances between them are taken into account in the calculations.

Figure 8 shows the results of comparing the experimental data obtained and the results of modelling (calculations). As a result of the comparison, we can conclude that the results of the calculations do not differ significantly from the experimental data. Figure 9 shows an example of visualization of calculation results.

The basis of the Lymphea software package contains the main provisions of the filtration theory, which are based on the Darcy's law (the filtration law).

The theory of filtration studies the laws of motion of fluid, gas, or mixtures of these. The theory of filtration provides an opportunity to develop methods of filtration calculations of various kinds of structures during their design, construction and operation.

In the field of design, filtration calculations play an extremely important role, when solving issues related to flooding and filtration, it is possible to determine the structure and dimensions of constructions, as well as the construction of drains and various activities related to the protection of underground structures from flooding.

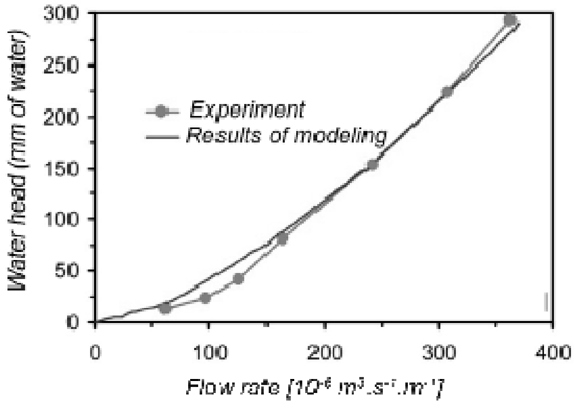

Figure 8 – Results of comparison of experimental data and modelling results

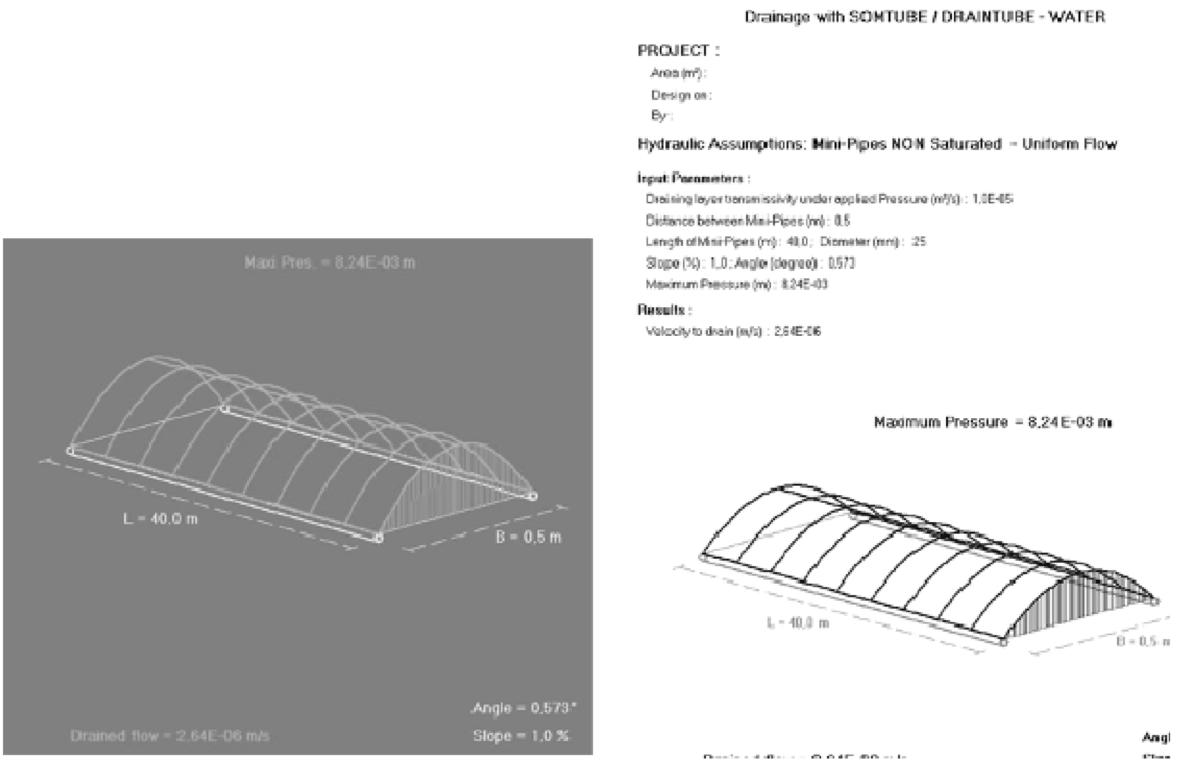

Figure 9 – Example of visualization of calculation results

The theory of filtration, which has wide practical application, has emerged relatively recently. The active development of the theory of filtration began in the second half of the twentieth century. The basis for the scientific development of filtration issues was the law of resistance in the fluid filtration.

In 1852–1855, the French engineer A. Darcy, having conducted a research on the study of filtration in sandy soils, established a linear relationship between the velocity of water filtration and the loss of pressure, which is called the law of filtration or the Darcy's law. According to the Darcy law, the pressure loss during filtration depends linearly on the filtration velocity. The presence of such a connection, as well as the development of hydraulics and hydromechanics, enables in the second half of the nineteenth century to develop theoretical dependency that can be used in filtration calculations.

The first theoretical studies of filtration, based on the linear law of filtration, were begun by J. Dupuis. However, the foundations of the filtration general theory were laid only in 1889 by M.E. Zhukovsky.

He derived differential equations of filtration. M.E. Zhukovsky introduced the concept of resistance force in filtration. In 1922, the theory of filtration was given a new boost owing to the work of M.M. Pavlovsky.

Further, the scientists of the world considerably expanded the theory of filtration in all directions and brought it to the level necessary for the design of modern constructions and their elements.

Conclusions. As a result of the approaches analysis used to determine the parameters of drainage made of modem geosynthetic materials (Draintube) manufactured by Afitex (France) in the Lymphea software package, it can be concluded that the theory of filtration applied throughout the world, including in Ukraine, are used in it. This software package enables to evaluate correctly the parameters of drainage, made of up-to-date materials, and to perform their design. The use of such drainage has become quite widespread throughout the world. There is a positive experience in their designing, construction and operation under different engineering and geological conditions on different continents. The requirements for such materials and the conditions for their application are described in the European norms.

These materials have good perspective of application in Ukraine with the appropriate justifying calculations, considering the normative documents in force in our country.

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