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HYDRAULIC CHARACTERISTICS OF THE PLASTIC PIPES OF DRAINAGE COLLETORS

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Abstract. In Lithuania, plastic drain pipes are being used when building new land reclamation systems or reconstructing already existing. It is connected with the better constructions and technological characteristics of plastic pipes in comparison with the tile clay drainage pipes. Various factories produce a wide assortment of plastic pipes, which differ not only in the sizes of their inside diameters, but in their constructional characteristics as well. It has a significant impact upon the water flow of pipes or upon their hydraulic characteristics. Applying theoretical formulas, which were received following the results of experimental investigations carried out for the pipes of particular types, the errors (up to 30 per cent) of the water flow of pipes were received.

Results of the hydraulic investigations of plastic drain pipes of constructions and diameters used in Lithuania are presented in the article. Following the created water flow dependencies of smooth and corrugated plastic drainage pipes (for the drainage collectors) with various diameters, mathematical and graphical dependencies of water flow, pipe diameters and pipe slope, which are recommended to be applied when carrying out hydraulic calculations of plastic drainpipes, were made.

Keywords: *Drainage systems, plastic drain pipes, hydraulic calculations.*

1. Introduction

When replacing clay drainage tile with plastic pipes during the reconstruction of old drainage systems (widely carried out in Lithuania in recent years) or when building the new drainage, plastic drain pipes of various constructions and of various factories are being used. Hydraulic characteristics of these pipes are not determined and rather significant differences are received using calculation formulas.

Accepted standard are made for the fitting of constructions of plastic drain pipes (Melioracijos 2006). Corrugated perforated plastic pipes (the area of perforations ≥24 cm^2/m) with external diameters of 75-200 mm and inside diameters of 65-180 mm (wrapped with filter material) as well as smooth non-perforated drain pipes with external diameters of 250-400 mm or inside diameters of 234.8-375.6 mm were used for drainage collectors. It is indicated that collectors should not only derive water gathered by laterals, but should fulfil the draining function as well.

A very significant parameter of hydraulic characteristics of pipes is the roughness of the inside walls of pipes, which is being often estimated by the dimensionless friction factor λ. Theoretical formulas are ideal (by their physical meaning) for the determination of this coefficient. The most widely known is the Darcy-Weisbach formula (Эггельсман, 1978):

$$\lambda = \frac{2g \cdot d \cdot h}{v^2 l}, \quad (1)$$

where: g- acceleration due to the gravity (m/s^2); d - inside pipe diameter (m); h – hydraulic head loss over pipe length l (m), v - average flow velocity (m/s).

However, their practical application is limited, because the water average flow velocities v in pipes (which are different in the pipes of different constructions) should be determined. Many authors suggest formulas for the determination of flow velocity while applying these formulas for the pipes of various constructions and types.

The most widely known are empirical formulas. One of the most popular is the Chézy formula (Эггельсман, 1978):

$$v = C\sqrt{R \cdot i} \quad (2)$$

where: v - average flow velocity (m/s); R - hydraulic radius (m); i - drain slope (m/m);

C is the Chézy coefficient depending upon the raughness coefficient and the diameter of pipe.

There are formulas for the determination of the Chézy coefficient, however, they are made with reference to the investigation results of the pipes of particular constructions and diameters. Therefore, in every other case (the pipes of new construction) additional hydraulic investigations of pipes should be carried out.

For the determination of the water flow velocity the Kutter's formula is rather widely used at present (Gurklys 1981):

$$v = \frac{100\sqrt{R}}{n + \sqrt{R}} \sqrt{R \cdot i} \quad (3)$$

where: n – hydraulic raughness coefficient (for clay drainage pipes – 0.27-0,30).

A.I. Murashko (Мурашко, 1997) formula for smooth pipes is as follows:

$$v = 220.5 \alpha R^{0.745} i^{0.573}, \quad (4)$$

Where α is the perforation coefficient.

The perforation coefficient of perforated drains is equal to 0.93-0.98, the perforation coefficient of non-perforated drains is equal to 1.0.

For corrugated pipes:

$$v = 77.5 R^{0.665} i^{0.493} \quad (5)$$

For the hydraulic calculations of drainage, empirical formulas of Gurklys-Blažys (Gurklys, 1981) are widely used in Lithuania at present and are applied for good (6) and complicated (7) conditions of drainage building:

$$v = (1.76 \cdot 10^{-4} + \frac{4.1 \cdot 10^{-7}}{d^{1.476}} \nu^{-1.132} e^{-1.414\nu})^{-0.5} i^{0.573} d^{0.745} \quad (6)$$

$$v = (1.02 \cdot 10^{-3} + \frac{3.24 \cdot 10^{-9}}{d^{2.620}} \nu^{1.2} e^{-9.09\nu})^{-0.5} i^{0.52} d^{0.667} \quad (7)$$

where e is the base of natural logarithm (e = 2.72).

So, many formulas for the hydraulic calculation exist. These formulas can be applied with sufficient accuracy only for particular types of pipes.

The aim of the investigation is to determine hydraulic characteristics of the plastic pipes used in Lithuania for the building of drainage collectors and to work out the method of hydraulic calculation for plastic drainage collectors.

2. Investigation method

On the basis of laboratory experiments hydraulic characteristics of various diameters, constructions and of various slopes plastic drainage pipes had to be determined. The main aim of the determination of hydraulic investigations and hydraulic characteristics of pipes is the finding of dependencies:

$$Q = f(i; d) \quad (8)$$

where: Q - water flow 1/s; i - drain slope in percent; d - inside pipe diameter (dm).

Specific requirements for the hydraulic calculations of drainage collectors should be applied, i.e. water should flow through the full cross-sectional area, but without the pressure.

The main hydraulic characteristics of the pipes were determined during the laboratory experiments (λ; v; i), according to which the water flow of pipes was calculated. Laboratory experiments were carried out using the laboratory device (Blažys and Gurklys 1985).

Laboratory investigations were carried out with the following plastic drain pipes (Company "Plasta", Vilnius):

- corrugated $d_{iš}$ (inside pipe diameter ($d_{iš}$/d): 1.10/0.916 dm; 1.60/1.45 dm; 2.37/2.002 dm;
- smooth $d_{iš}/d$: 1.10/1.02 dm; 1.60/1.502 dm; 2.00/1.877 dm; 2.00/1.882 dm; 2.50/2.348 dm;
- corrugated with a nipple $d_{iš}/d$: 1.10/0.916 dm;2.37/2.002 dm.

3. Results

The results of the laboratory investigations are presented in the curves of the dependencies of the slope and the discharge of water flowing through pipes. These curves are created for all pipes used for the investigations. The dependence of water flow and slope as well as the results of the laboratory investigations of smooth non-perforated plastic pipes with the inside diameter of 1.878 dm are presented in figure 1 (as an example).

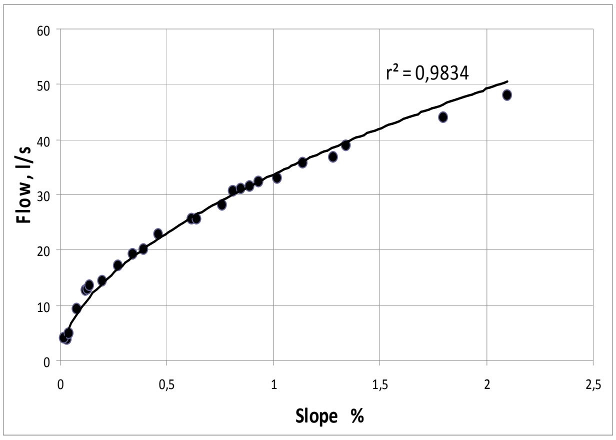

Fig 1. Dependencies water flow of slope of smooth non perforated plastic pipes $d_{iš}$/d =2.00/1.878 dm

The common mathematical expression of the drainage pipe flow and slope is made on the basis of the determined dependencies. The appropriate dependencies of different d drainage pipes can be calculated according to the mathematical expression. Using the dependencies Q (of the pipes of various diameters) from the mathematical expression i, the hydraulic calculation nomograms for smooth plastic drain pipes were made using the logarithm net (Fig. 2) allowing to more precisely determine the small values of appropriate parameters (*Q, i, v*).

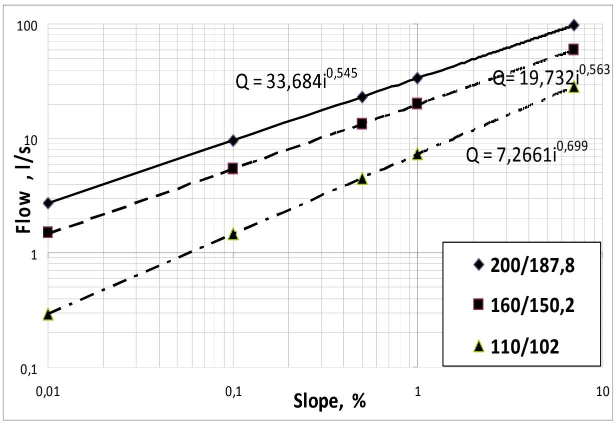

Fig 2. Hydraulic calculation nomogram for smooth non-perforated plastic drains

Analogically the nomogram for corrugated plastic pipes is being done (Fig. 3).

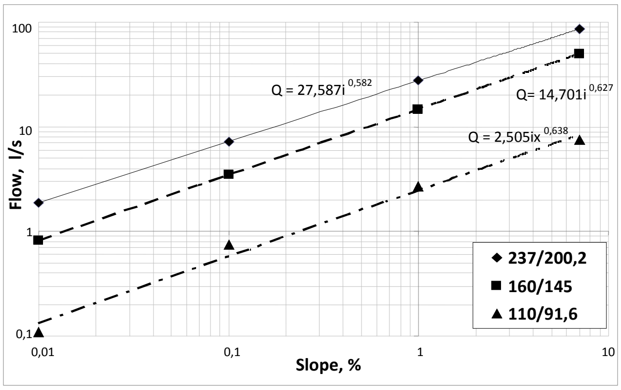

Fig 3. Hydraulic calculation nomogram of corrugated plastic pipes

Following the results of the laboratory investigations and applying mathematical methods the common water flow formulas, which evaluate (when calculating water flow (*Q*)) not only the slope of drainage pipes (*i*), but their inside diameters (*d*) as well, were made.

The formula of the hydraulic calculation for smooth (and corrugated with a nipple) plastic pipes, allowing calculating the water flow of the pipes of various diameters, was received:

$$Q = 6.19\, i^{0.602} d^{2.85}. \qquad (9)$$

The formula of the hydraulic calculation for corrugated plastic pipes, allowing calculating the water flow of corrugated plastic pipes of various diameters, was received

$$Q = 3.87\, i^{0.588} d^{2.99}. \qquad (10)$$

Received formulas can be applied (with sufficient accuracy) for the hydraulic calculations of all types of smooth and corrugated plastic pipes' collectors.

In Figure 4 presented water flow dependencies of smooth plastic pipes (*d* = 1.02 dm) calculated according to different hydraulic calculation formulas – the Kutter's formula (3), the Murashko formula (4), good conditions (6) and according to the new formula (9) received after the laboratory investigations of this study.

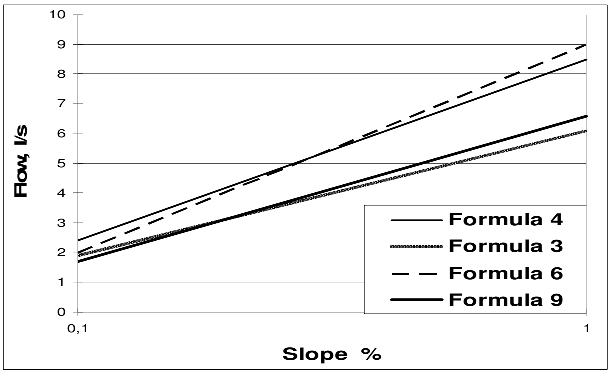

Fig 4. Comparison of water flow of smooth plastic pipes of d =1.02 dm, calculated according to different formulas

The character of the change (when the slope is changing) of the water flow curves made according to the received new formula (9) corresponds to the slope character calculated according to the Murashko formula. The difference is that water flow, calculated according to the Murashko formula, has increased on the average by 23-25 per cent in comparison with the water capacity, calculated according to formula (9). This difference could be conditioned by the technical characteristic of the plastic pipes used for the investigations. In his experiments A.I. Murashko (Мурашко, 1997) used simple length smooth plastic pipes of smaller diameter (up to 97 mm of the inside diameter). Our experiments were carried out with large diameter plastic pipes the length of which is limited (3 m) or the characteristics (diameter, ovality) of the cross-sectional area of pipes are different. Water flow values, calculated according to the formula (9), best of all correspond to the capacity values, calculated according to the Kutter's formula (3), however, the character of the change is different, i.e. with the decreased slope values (up to 0.5 per cent) formula 3 gives the increased values (up to 30 per cent), and when slope values are increased – values decrease up to 25 per cent.

The comparison of water flow of corrugated plastic pipes, calculated according to different formulas, is presented in figure 5.

The character of the change of curves is very similar, however, the values of water flow are different. Comparing the water flow of pipes, calculated according to the formula (9), we get that the Murashko formula gives values, which increased from 20 up to 35 per cent. The formula, used for good drainage building conditions, gives water flow values, which decreased approx. by 20 per cent. The closest are water flow values, calculated according to the Kutter's formula (3), however, here we also get values, which increased up to 15 per cent.

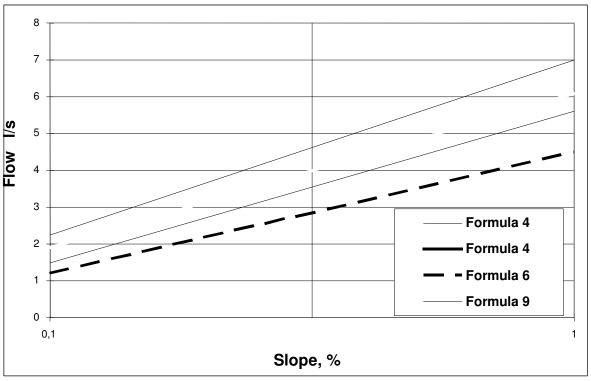

Fig 5. Comparison of water flow of corrugated plastic pipes of d = 1.13 dm, calculated according to different formulas

The differences of the water flow of pipes between the calculated according to the formula used for good drainage building conditions (6) and according to the differences received during the laboratory investigations (9; 10), can be explained by the changes in the drainage building technologies, which have improved the quality of the building of drainage collectors and especially the quality of the maintenance of the drain slope (Gurklys *at al.* 2008).

The comparison of water flow is presented following the example of the same-diameter pipes, however, the above-mentioned regularities and water flow characteristics are specific to the plastic pipes with other diameters as well.

4. Conclusions

The hydraulic laboratory investigations of plastic drain pipes (used in Lithuania) of various constructions and diameters were carried out when determining water flow of these pipes. It was determined that the application of existing formulas for hydraulic calculations gives up to 30 per cent of inaccuracies of water flow of pipes, since the changes in the diameters and the constructions of plastic pipes (used at present) as well as in the drainage building technologies of drainage collectors are not estimated.

The mathematical-graphical dependencies (according to which the water flow of plastic pipes of various diameters can be calculated) of smooth and corrugated plastic drain pipes are made when evaluating the slope and the inside diameter of pipes.

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