Plastic Pipes and Their Use in Rainwater Drainage Systems

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Abstract. This paper studies the conditions for the use of plastic pipes in rainwater drainage systems. In this research, the author undertakes a literature review and finds out that the share of plastic pipes in the construction of gravity sewage network has significantly increased over the past 20 years. Plastic pipes low roughness ensures higher flow rates of wastewater. The peculiarity of rainwater drainage calculating methodology leads to the fact that an increase in the speed of wastewater movement leads to the formation of larger wastewater discharge in the design section of the pipeline with the same rainfall intensity. It is established that at present the cost of rainwater drainage systems construction from polypropylene pipes is 80-100% higher than from reinforced concrete (excluding the construction of pumping stations and wastewater treatment facilities).

1. Introduction

Papers [1-4] report that in the last 20 years plastic pipes have been widely used in the Russian Federation for the construction of sewage networks carrying municipal wastewater. About 50% of new sewage networks commissioned during this period are made of plastic pipes.

Such a radical shift towards the use of plastic pipes can be explained by the fact that these pipes have several advantages compared to their competitors, e.g.

- Distinguishing hydraulic characteristics.
- High corrosion and chemical resistance as well as abrasion resistance.
- Low overgrowth capacity with different types of deposits.
- Long-term tightness of connections.
- Ease of installation [5].

Special attention should be paid to the first indicator, distinguishing hydraulic characteristics. Papers [6-8] analysis shows that wastewater flow rate, and accordingly, plastic pipes discharge capacity is 30-60 % higher compared to other types of pipes (asbestos-cement, reinforced concrete, ceramic, cast iron). This factor is undoubtedly a strong argument for plastic pipes when they are used for the transportation of household and fecal and industrial wastewater, since it makes possible to use pipes of a smaller diameter. However, this factor can adversely affect rainwater drainage systems under certain conditions.
2. Research calculations
As is well known, the main characteristic of rainwater is the fact that it doesn't fall evenly over the catchment area. Rainwater flow rate for the design section of the pipeline is determined by the method of limiting intensities and depends, among other things, on the duration of rainwater flow time to the design section.

\[ Q_r = \frac{z_{\text{mid}} \cdot A^{1.2} \cdot F}{t_r^{1.2n-0.1}} \]

where \( z_{\text{mid}} \) is the average value of the coefficient that characterizes runoff surface type (the cover coefficient),

\( F \) is an estimated runoff area for the design network section, ha,

\( A, n \) are hydrological parameters determined by the results of processing long-term records of self-recording rain gauges for a given region of the country, the value of the parameter \( n \) can be in the range of 0.26-0.74,

\( t_r \) is an estimated duration of rain, min, equal to the duration of rainwater flow over the surface and through pipes to the design cross-section of the pipeline.

The duration of the flow consists of the time of the flow over the surface to the trench drain, the time of the water run through the trench drain and the time of the run through the pipes of the rainwater drainage system.

\[ t_r = t_{\text{con}} + t_{\text{can}} + t_p \]

\( t_{\text{con}} \) is a duration of rainwater flow to the trench drain,

\( t_{\text{can}} \) is a duration of rainwater flow through trench drains,

\( t_p \) is a duration of rainwater flow through the pipes to the design cross-section.

Formula 1 shows that the shorter the rainwater flow time is, the greater the wastewater discharge will be formed in the design section of the pipeline. Thus, it should be expected that the construction of a rainwater drainage system from plastic pipes will result in heavy expenses and, as a result, will increase capital and operating costs.

Calculation done according to Formulae 1 and 2 shows that an increase in the speed of rainwater flow in pipelines by 40-70 % can lead to an increase in the flow rate for the design cross-section by 10-200%. Such a large spread of the total values is explained by the fact that the calculation takes into account a large number of factors that have mutual influence on each other.

Thus, it is necessary to identify the elements of the rainwater drainage system (pipelines and surface structures above), which may be affected by this increase in wastewater consumption.

1. Pipeline diameter
As it has been mentioned above, plastic pipes discharge capacity is 30-60% higher compared to other pipes, so this increase in the discharge will not affect the pipeline itself. In other cases, you will need to increase the pipeline diameter.

2. Pipeline laying depth.
Hydraulic calculation of sewage networks is performed on the basis of maintaining the flow rate of wastewater, preventing the deposition of solid mineral impurities in the pipeline tray. This requirement is met by laying a pipe with an appropriate slope.

In this study, calculations were performed for three cases: when the surface slope is less than 0.01; when the surface slope is from 0.01 to 0.03; when the surface slope is more than 0.03. As a result, it was found that when the surface slope is less than 0.01, the use of plastic pipes increases the flow rate and diameter, but, at the same time, the pipeline laying depth decreases (see Fig. 1).
If the surface slope is more than 0.01, there is also an increase in the flow rate of drainage and the diameter of the plastic pipeline, but the laying depth of the pipelines made of different materials stays the same and is equal to the surface slope.

3. Technical parameters of surface structures built above the sewage network.

Increasing the plastic pipeline diameter will require increasing the size of wells and separation chambers.

![Figure 1. Sewage pipeline profile with a surface slope less than 0.01.](image)

- polypropylene pipes
- reinforced concrete pipes

There will also be a significant increase in the productivity of flow-through wastewater treatment facilities. In general, the estimated capacity of flow-through wastewater treatment facilities is already 20 to 100 times higher than the same value for storage-type facilities [9-14]. The additional water consumption will lead to a further decrease in the economic performance of the treatment system.

In addition, there will be a corresponding increase in the productivity of pumping stations designed both for pumping unregulated rain runoff directly from the gravity pipeline [15], and for pumping excess flow of rain runoff diverted from the separation chamber to a storage tank or a water body.

The research also produces technical and economic comparison of options for the use of polypropylene and reinforced concrete pipes for different surface slopes (up to 0.01 and more than 0.01). The economic calculation is made in the form of local resource estimates with the same construction conditions: the soil is diverted to the dump; the construction of wells is taken into account. The estimates do not consider the cost of delivery of materials, as well as the construction of pumping stations and flow-through treatment facilities.

3. Results

The results of pipelines with different lengths comparison are as follows:

- For the surface slope less than 0.01, the costs of excavation work in the trench, of laying the foundation for pipelines, laying pipelines for polypropylene pipes is less than for reinforced concrete.
- For the surface slope more than 0.01, the costs of excavation work in the trench and of laying the foundation for pipelines are the same, and the costs of laying pipelines for polypropylene pipes is less than for reinforced concrete.

Considering the fact that the costs of polypropylene pipes are higher than reinforced concrete, it was determined that the costs of building a rainwater drainage system from polypropylene pipes is 80-100% higher (a higher value applies to areas with a surface slope of more than 0.01). In the case of the
installation of pumping stations and sewage treatment plants of the flow-through type above the sewage network, this indicator will increase even more.

4. Conclusion
The performed calculations show that:

- Rainwater flow higher speed in plastic pipelines leads to an increase in the discharge for the design cross-section up to 200%.
- An increase in wastewater consumption will lead to a proportional increase in the productivity of pumping stations if they are installed without a storage tank and flow-through type treatment facilities.
- Plastic pipelines high discharge capacity will reduce the laying depth of the rainwater drainage system at the surface slope to 0.01.
- Capital costs of rainwater drainage systems construction from plastic pipes is 80-100% higher than from reinforced concrete (excluding the construction of pumping stations and wastewater treatment facilities).
- The feasibility of using plastic pipes for the construction of a rainwater drainage system should be justified by a technical and economic comparison of the options.

5. References
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