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Using pipes from various materials for sewage network: theoretical analysis

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Abstract. The paper presents the analysis of data on Russian settlements sewage networks as of 2014-2018, published in the public domain. All the settlements are divided into six groups depending on the population size. For each group, the distribution of sewage networks depending on the material of the pipes is established. In this country, the most widespread pipes are ceramic and cast-iron pipes, which have been widely used in the last 100 years. Asbestos-cement, reinforced concrete and steel pipes were used much less frequently. Active construction of sewage networks from plastic pipes began only in the last 20 years, so their share in the total volume does not exceed 6%. The authors believe that there will be a significant increase in the number of plastic pipes in the total length of sewage networks in the next few years.

1. Introduction

In the design and construction of sewage networks, the choice of pipe material is of great importance. It has a great effect on pipe capacity, depth of laying and durability of underground constructions which have a direct impact on trouble-free and uninterrupted functioning of the sewage system in general. It means that capital and operating costs for ensuring sanitary and hygienic conditions in a settlement depend on the correct choice of pipe material.

The following requirements are taken into account when the pipe material is being chosen:

– good long-term hydraulic performance;
– high corrosion and chemical resistance as well as abrasion resistance;
– low overgrowth capacity with different types of deposits;
– resistance to external loads;
– long-term tightness of connections;
– ease of installation;
– low cost.

With these requirements taking into account, ceramic, asbestos-cement, reinforced concrete, cast iron, steel, plastic pipes, as well as brick and pre-cast concrete pipes were used for external sewage networks construction at different stages the building industry development.

2. Materials and research

Paper 1 [1] gives information on Samara municipal wastewater sewage network as of 2011. This paper summarizes the information on sewage networks of 60 Russian settlements located in 30 administrative regions of the country (see Table 1) as of 2014-2018.

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Table 1. Settlements statistics

Inhabitants in the settlement	Number of settlements	Name of the administrative district
less than 5000 people	12	Republic of Kalmykia Komi Republic Republic of Tatarstan Kamchatka Region Krasnodar Territory Krasnoyarsk Region Khabarovsk Territory Astrakhan Region Vladimir Region Ivanovo Region Irkutsk Region Kaliningrad Region
from 5 000 to 10 000 people	6	
from 10 000 to 50 000 people	22	Kaluga Region Kemerovo Region Kirov Region Kostroma Region Leningrad Region Moscow Region Murmansk Region Nizhny Novgorod Region Novosibirsk Region Omsk Region Rostov Region Samara Region Sverdlovsk Region Smolensk Region Tambov Region Tver Region Chelyabinsk Region Yaroslavl Region
from 50 000 to 100 000 people	5	
from 100 000 to 500 000 people	8	
over 500 000 people	7	

3. Data analysis

Table 2 presents data on the average length of sewage networks and distribution of pipes made of different materials used.

The analysis of data presented in Table 2 shows that small settlements (up to 10 thousand inhabitants) are characterized by greater irregularity of application of pipes from different materials. There might be sewage networks made of only one type of pipe material (ceramic, cast iron, steel or plastic). This is due to the fact that sewage networks in such settlements were built throughout all the territory for a relatively short period of time and, in the future, these networks were not subjected to any expansion or reconstruction. At the same time, pipes with the best technical and economic indicators for the given locality were used for these networks construction. In larger settlements, there are pipes made from all materials. E.g., brick collectors which are more than 100 years old are still used at present in the cities of Samara and Yaroslavl.

The analysis revealed that ceramic pipes, which are used for sewage networks from the first half of the XX century, are still most widespread in Russia. In general, the share of ceramic pipes is 21.2-46.0% for cities with different numbers of inhabitants. Cast-iron pipes, which also were actively used in the last century, amount to 15.5-54.0%. Later, asbestos cement (5.4-14.5%) and reinforced concrete pipes (0.0-12.5%) came into use. Reinforced concrete pipes are more frequently used in large cities.

Table 2. Distribution of pipelines by material used

Number of inhabitants	Average length of sewage network, km	Distribution of pipelines by material used, %		
		material	average value	value variation
less than 5000 people.	3.66	asbestos cement	8.4	0.0 – 61.4
		reinforced concrete	0.0	not used
		ceramics	21.2	0.0 – 100
		brick	0.0	not used
		plastic	5.0	0.0 – 20.6
		steel	11.4	0.0 – 100
		cast iron	54.0	0.0 – 100
from 5 000 to 10 000 people	13.81	asbestos cement	5.4	0.0 – 18.9
		reinforced concrete	0.0	not used
		ceramics	46.0	0.0 – 100
		brick	0.0	not used
		plastic	27.0	0.0 – 100
		steel	2.5	0.0 – 9.6
		cast iron	19.0	0.0 – 43.5
from 10 000 to 50 000 people	40.78	asbestos cement	13.3	0.0 – 36.8
		reinforced concrete	7.9	0.0 – 36.8
		ceramics	30.7	0.0 – 77.5
		brick	0.0	not used
		plastic	3.7	0.0 – 44.7
		steel	12.5	0.0 – 76.6
		cast iron	31.9	9.4 – 85.8
from 50 000 to 100 000 people	133.79	asbestos cement	8,4	2.0 – 13.2
		reinforced concrete	11,8	4.3 – 17.5
		ceramics	46,0	32.8 – 56.3
		brick	0,0	not used
		plastic	1,8	0.9 – 3.9
		steel	16,5	1.8 – 31.5
		cast iron	15,5	3.4 – 44.8
from 100 000 to 500 000 people.	297.66	asbestos cement	14.5	0.0 – 64.5
		reinforced concrete	11.9	3.3 – 18.0
		ceramics	42.4	0.8 – 69.7
		brick	0.0	not used
		plastic	5.2	0.0 – 14.9
		steel	2.8	0.0 – 7.0
		cast iron	23.2	2.0 – 45.4
over 500 000 people	1058.27	asbestos cement	11.7	1.7 – 24.2
		reinforced concrete	12.5	0.0 – 30.0
		ceramics	40.9	10.8 – 66.4
		brick	0.4	0.0 – 1.9
		plastic	5.3	3.5 – 8.8
		steel	5.1	0.0 – 16.8
		cast iron	24.1	14.1 – 41.3

This is due to the fact that the range of reinforced concrete pipes in the period when they came into use started with a diameter of 400mm.

Steel pipes due to their low corrosion resistance were used only with appropriate justification, but their number is comparable to asbestos-cement and reinforced concrete pipes and ranges between 2.5% and 16.5%. There are also settlements where the share of steel pipes in the total length of their sewage networks exceeds 50%. E.g. in the urban-type settlement of Kamskiye Polyany (Tatarstan) this figure goes up to 55.8% (with steel sections length of 25.27 km), in the town of Zima (Irkutsk region) it is 76.6% (31.58 km), and in the settlement of Glebychevo (Leningrad region) it is 100% (5.0 km).

4. Discussion

All of the pipes mentioned above are characterised with both advantages and drawbacks, limiting their scope. These drawbacks are:

– for ceramic pipes: the length of standard elements is small, which increases the labour intensity for their installation;

– for cast iron pipes (from gray cast iron): fragility and, as a consequence, high metal content (they are thick-walled and heavy);

– for asbestos cement pipes: both fragility and low resistance to abrasion, which leads to the lowest lifetime of all the pipes;

– for reinforced concrete pipes: susceptibility to corrosion, high weight, assortment begins with large diameters.

Since the 80s of the last century, plastic pipes became popular, but in Russia they began to be used only in the last 20 years, so their share in the total volume does not exceed 6.0%. The exception here is the urban-type settlement of Aksubaevo (Tatarstan), where the sewage network was built completely from polyethylene pipes with a total length of 18.38 km (in the period from 2000 to 2014). These sewage network characteristics affected the average values of the sample of settlements with the number of inhabitants from 5 to 10 thousand people.

5. Conclusions

Currently, plastic pipes offer the best potential for the construction of sewage networks [2-8], as their main drawback is a slightly higher cost compared to other pipes, as well as increased requirements for their trench base construction and the material used for backfilling (lack of large inclusions). In all other respects, they exceed previously used materials by far. Pipes made of high-strength cast iron with spherical graphite are not used for sewage networks construction because of their high cost.

As the service life of most sewage networks exceeds the normative values (asbestos cement pipes – 30 years, reinforced concrete and cast iron pipes – 40 years, ceramic pipes – 50 years), in the near future we should expect a significant increase in the share of plastic pipes in the total length of sewage networks.

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