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Construction norms in the field of storm sewer system calculation

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ABSTRACT

A requirements analysis of construction norms of Russia in the field of storm sewer system calculation is presented in this paper. The analysis was done by comparing the results obtained from the calculations of the two storm collectors. The calculations were performed in accordance with the requirements of Russian Building Norms and Regulations SNIP 2.04.03-85 and its updated version – Russian Set of Rules SP 32.13330.2012. An appreciable continuity of the basic calculation formulas and values was noted. The increase in the value of storm water design flow in the case of the calculation in accordance with Russian Set of Rules SP 32.13330.2012 was amounted to about 79%. The increase in the price of several sections of storm sewer system project was amounted to about 15%.

Content

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1. Introduction

Storm sewer system, which protects the area from flooding by rainwater, is a substantial part of the territory improvement [1-4]. Damage and obstructions as well as insufficient capacity of the storm sewer system, lead to its partial or complete failure. The competent calculation of the storm sewer system along with the high-quality execution of the construction and installation works monitoring and timely executing of overhaul is one of the main factors ensuring the smooth operation of the storm sewer system during the whole period of its operation.

At the same time, the construction industry dictates its own terms. With a view to economy, simplify and cut down the design and construction time, the developer tends to choose the simplest and most cost-effective (in this case - an appropriate to the minimum of the lump sum investment) version of the storm sewer system project [5]. That, in turn, leads to frequent breakdowns of the storm sewer system and unplanned costs of the breakdowns [6]. Moreover, the failure of storm sewer system can lead to the more serious consequences than just the difficulty of pedestrians and vehicles movement [2].

Thus, the direct running off of the surface flow from the territory of the major cities to the water reservoirs leads to the serious environmental consequences [3, 4, 7–18]. The retention of the surface flow on the cover of roads not only increases the risk of the aquaplaning effect occurrence [19] and traffic accident [20], but also leads to the wetting of the pavement and subgrade soil that reduces the surface strength and leads to the rapid destruction of the coating [3, 4, 21]. The accumulation of water in the emerging potholes and gullies leads to the decline of the general sanitation conditions, and the renovation of the road surface is a regular object of expenditure of the city budget [3]. The retention of the surface flow in the immediate neighbourhood of the buildings has a negative impact not only on the state of the soil, but also on the overall condition of the foundations [2]. In some cases, the lack of the storm sewer system leads to the landslides, scouring, removal of the soil and the deterioration of the appearance of the area [4, 22, 23]. Sudden and serious consequence of the storm sewer system failure could also be flood [24].

In order to minimize the risk of the occurrence of such situations, at the same time ensuring an adequate level of the economic feasibility, storm sewer system should be designed correctly and efficiently. Since the results of the calculation of the storm sewer system are directly influenced by cliffhanging factors such as the duration and intensity of the rain [25], the rationality of the project is provided mainly by professional experience of the designer and, in addition, by the requirements, guidelines and procedures contained in the construction norms. Thus, it is extremely important that the regulations provide literacy and rationality of the construction projects, as well as meet the requirements of the time.

However, the rationality of the construction norms requirements, as well as the economic feasibility of the projects carried out in the strict compliance with these requirements, may be questioned. In the field of the storm sewer system hydraulic calculation, the economic feasibility of the projects carried out in accordance with the requirements of Russian Set of Rules SP 32.13330.2012 raise some doubts. For this reason, the main objective of the work is to analyse the requirements of the document.

2. Methods

Initial data

To analyze Russian Set of Rules SP 32.13330.2012 requirements it was decided to perform a calculation of storm sewer system according to the document and according to the requirements of the previous version of the document - SNIP 2.04.03-85. The project of the closed gravity storm sewer system with two main collectors was chosen for the calculation. The storm sewer system was designed on the territory of a cottage settlement in the Leningrad Region. The cottage settlement has the total area of 18.72 ha and includes the 61 private housing construction sites.

Two versions of the storm sewer system were designed. Version 1 was chosen to calculation in accordance to Russian Building Norms and Regulations SNIP 2.04.03-85 requirements and Version 2 was chosen to calculation in accordance to Russian Set of Rules SP 32.13330.2012 requirements.

Both versions have the similar structure, which consists of two independent collectors. The minimum of the collectors laying depth was dictated by the depth of soil freezing and taken as 1 m. The calculation also takes into account the topography, climate, soil characteristics and the features of the surface coating [26, 27]. The calculation assumed that the development of the cottage settlement is represented by the same type of buildings. The water catchment area of the typical private housing construction site includes areas with different coatings that are shown in Table 1.

Table 1. Water catchment area of a typical private housing construction site

Type of the coating [26, 27]	Area, m^2
Roofing of the building and structures	364.3
Asphalt concrete pavement	9.6
Block pavement and black macadam pavement	189.4
Gravel landscape path	110.5
Graded area	219.1
Lawn	647.9
Total area	1540.8

The territory occupied by the streets and thoroughfares includes water catchment areas with different coatings that shown in Table 2 The recreational zone area was not included in the calculated area.

Table 2. Water catchment areas of the territory occupied by the streets and thoroughfares

Type of the coating [26, 27]	Area, m^2
Asphalt concrete pavement	20558.0
Lawn	6820.0
Total area	27378.0

Determination of the storm water design flow value

Storm water design flow value q_{cal} in l/s for the hydraulic calculation of the storm sewer system was determined by the method of limit intensities. Basic calculation formulas are shown in Table 3, wherein:

- z_{mid} – the average value of the coefficient characterizing the surface of the water catchment area;
- ψ_{mid} – the average value of the coefficient of surface flow;
- A, n – the dimensionless parameters characterizing respectively the intensity and duration of the rain for a particular area;
- F – the designed area of the water catchment in ha;
- t_r – the designed duration of the rain equal to the duration of the flow of the surface water on the surface and in pipes to the calculated segment in min;
- P – the period of the single exceeding of the estimated intensity of rain in years;
- q_{20} – the intensity of the rain in l/s per 1 ha, for the given area and with the duration equal to 20 min while *P* equal to 1 year;
- m_r – the average number of rains for the year;
- γ – the exponent;
- β – the coefficient which takes into account the filling of the free volume at the moment of the forced flow initiation.

Table 3. Basic calculation formulas

Calculated value, unit	Version 1 [26]	Version 2 [27]
Storm water flow, l/s	$q_r = (z_{mid} \cdot A^{1.2} \cdot F) / t_r^{1.2n - 0.1}$	$Q_r = (\psi_{mid} \cdot A \cdot F) / t_r^n$
The average value of the coefficient of surface flow	-	$\psi_{mid} = z_{mid} \cdot q_{20} \cdot t_r$
Parameter *A*	$A = q_{20} \cdot 20^n \cdot [1 + (\lg P / \lg m_r)]^{\gamma}$	
Storm water design flow, l/s	$q_{cal} = \beta \cdot q_r$	$Q_{cal} = \beta \cdot Q_r$

Hydraulic calculation

To determine the diameter, slope and depth of the collector pipes of the two storm sewer system versions, the hydraulic calculation was done. The hydraulic calculation took into account the requirements for the minimum diameter of the pipes, the estimated value of their filling, flow rate and minimum slope. The requirements, which have been given above are the same in both documents [26, 27].

Thus, 7 ‰ is the assumed minimum slope and 200 mm is the assumed minimum diameter of the pipes. The calculation was performed using [28]. The storm water design flow in the different pipes was calculated on the basis of the growing water catchment area and the time of the surface flow movement on the trays and in pipes. The time between the beginning of the rain and the first appearance of the water in the calculated segment was not taken into account. The impact of this factor on the results is insignificant due to the small slopes of the pipes [29].

Economic assessment

The economic assessment of the storm sewer system project was also done. Parameters which are mostly dependent on the requirements of the construction norms were selected. There are following parameters:

- The total cost of the pipes;
- The total cost of excavation.

The reinforced concrete pipes were chosen for ease of assessment. To determine the total cost of the excavation, the calculation of the tranches volume was carried out. In determining the estimated cost of the excavation, all types of work were taken into account. The cost of the delivery and installation of pipes, wells and other elements of the storm sewer system were not taken into account. The cost of the excavation and pipes ware assumed equal to the average market value in St. Petersburg in the autumn 2016. Results are provisional and may vary for different regions.

3. Results and Discussion

Results

The necessary values to determine the storm water design flow value for two variants of the storm sewer system project are shown in Table 4.

Table 4. Necessary values to determine the storm water design flow value

Calculated value, unit	Description	Version 1 [26]	Version 2 [27]
q_{20}, l/s per 1 ha	The intensity of the rain for the given area and with the duration equal to 20 min. while $\mathrm{P} = 1\ \mathrm{year}$	60	60
P, years	The period of the single exceeding of the estimated intensity of rain	0.5	1
n	the dimensionless parameter characterizing the duration of the rain for a particular area	0.48	0.62
m_r	The average number of rains for the year	120	120
γ	-	1.33	1.33
A	The dimensionless parameter characterizing the intensity of the rain for a particular area	205.3	384.4
β	The coefficient which takes into account the filling of the free volume. at the moment of the forced flow initiation	0.76	0.69

The results of the storm water design flow value and storm water flow value in the pipes determination are shown in Table 5.

Table 5. Storm water flow values

Calculated value, unit	Description	Collector 1		Collector 2		Average increase in the value (V. 2 relative to V. 1)
		Version 1	Version 2	Version 1	Version 2	
$Q_{cal}^{mid\ spec}$, l/(s·m^2)	The average specific value of the storm water design flow	0.007	0.012	0.008	0.014	78.6%
$Q_{cal\ pipes}^{mid}$, l/s	The average value of the storm water flow in the pipes	126.0	193.3	108.0	166.6	53.8%
$Q_{cal\ end}$, l/s	The value of the storm water flow in the end of the collector	229.4	356.6	344.6	533.3	55.1%

As a result of the hydraulic calculation, the diameters of the pipes were chosen. The total lengths of the pipes of each of the selected diameters are shown in Figure 1 and Figure 2 for the Collector 1 and Collector 2 respectively.

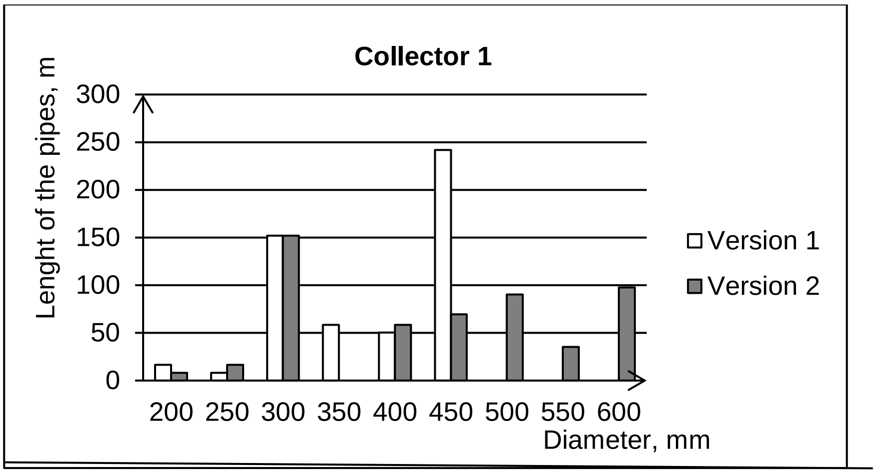

Figure 1. Total lengths of the pipes of Collector 1

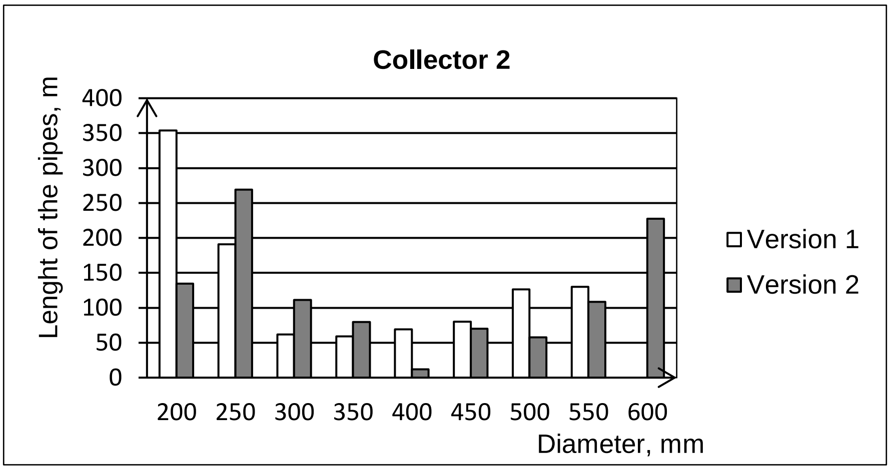

Figure 2. Total lengths of the pipes of Collector 2

The results of the scope of work calculation and the economic assessment are shown in Table 6.

Table 6. Results of the scope of work calculation and the economic assessment

Calculated value, unit	Description	Collector 1		Collector 2		Average increase in the value (V. 2 relative to V. 1)
		Version 1	Version 2	Version 1	Version 2	
h_{pipes}^{mid}, m	Average collector pipes depths	2.46	2.62	2.82	3.04	7.2%
V_{tran}^{sum}, m^3	Total volume of tranches	3150.5	3579.2	7920.6	9206.5	14.9%
c_{pipes}, thousand RUB	Cost of the pipes	866.9	1008.5	1742.05	1984.5	15.1%
c_{exc}, thousand RUB	Cost of the excavation	5833.5	6596.2	14532.5	16808.7	14.4%

Discussion

In this part of the article an appreciable continuity of the basic calculation formulas and values is noted (see Table 3 and Table 4). An immutability of the main requirements for hydraulic calculation of storm sewer system (for example, the minimum diameter of the pipes, the estimated value of their filling, flow rate and minimum slope) also can be noted.

At the same time, a significant divergence of the values of the storm water design flow was received. The increase in the value of storm water design flow in the case of the calculation in accordance with SP 32.13330.2012 was amounted to about 79%. It can be noted from Table 4 that the main parameters affecting the results are the following:

- P - the period of the single exceeding of the estimated intensity of rain in years;
- n - the dimensionless parameter characterizing the duration of the rain for a particular area.

The increase in the storm water design flow value had a direct impact on the value of the storm water flow in the pipes that increased on average about 53.8% (see Table 5). This led to a change in the results of the hydraulic calculation (see Figure 1-2). There are following changes:

- The average diameter of the pipes increased.
- There is a need to use a larger diameter pipes.
- The average depth of the pipes increased on average about 7.2% due to an increase in the required slope in some areas (see Table 6).

The changes in the used pipes and the depth of their inception led to increase the total volume of excavation. Thus, an increase in the total volume of trenches is about 14.9% (see Table 6). This in turn led to increase in the cost of the overall project.

The increase in the price of several sections of storm sewer system project was amounted to about 15% (see Table 6). To determine the changes in the total cost of the project a more precise assessment is required.

It can be noted that the project of the storm sewer system which is designed in accordance with the requirements of SP 32.13330.2012 will cost more than the project implemented in accordance with the requirements of SNIP 2.04.03-85. The obvious is the fact that the increase in cost is not due to the more stringent requirements for the storm sewer system or to the quality of the installation works. The increase in the cost basis is changing the values of parameters that characterize the period of the single exceeding of the estimated intensity of rain and the duration of the rain for a particular area.

Due to the fact that these parameters are difficult to predict, the final conclusion about the appropriateness of the increase in these parameters can be done only during the operation periods of the sufficient number of the storm sewer systems, which would be designed in accordance with the requirements of the different construction norms.

4. Conclusions

1. The analysis of the requirements of SP 32.13330.2012 to the hydraulic calculation of the storm sewer system was done.
2. To analyse the requirements, the hydraulic and economic calculations of the storm sewer system of the cottage settlement in the Leningrad region were performed. Calculations were done in accordance to the requirements of SNIP 2.04.03-85 and its updated version - SP 32.13330.2012.
3. The result was an undoubted increase in the storm water design flow value and the cost of the overall project.
4. The main parameters affecting the results were identified.
5. The final conclusion about the appropriateness of the increase in these parameters can be done during the operation periods of the different storm sewer systems.

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Строительные нормы в области расчёта ливневой канализации

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КЛЮЧЕВЫЕ СЛОВА

строительные нормы;
ливневая канализация;
гидравлический расчёт;
коллектор ливневой канализации;
сток дождевых вод

АННОТАЦИЯ

В статье представлен анализ требований строительных норм России в области расчёта ливневой канализации. Анализ проведен путем сопоставления и анализа результатов, полученных при гидравлическом расчёте двух коллекторов ливневой канализации. Расчёты выполнены в соответствии с требованиями СНиП 2.04.03-85 и его актуализированной редакции – СП 32.13330.2012. Отмечена преемственность основных расчетных формул и значений. Увеличение расчётного расхода ливневых вод в случае расчёта в соответствии с требованиями СП 32.13330.2012 составило около 79%. Увеличение соответствующих расходов на реализацию ряда разделов проекта ливневой канализации составило около 15%.

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