Method of Gravity-Flowing Sewage Network Drainage as a Way to Increase its Durability and Maintainability

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Abstract. High-quality maintenance extends the service life of costly pass-through collectors. Maintenance of a collector requires its inspection and diagnostics, it is repaired if necessary. Thorough collector maintenance is possible only after its drainage. The most frequently used method of a collector drainage consists in its overlapping with plugs with further pumping of sewage via temporary branches, bypassing drainage rehabilitating sections. This method involves considerable technical and material difficulties and can be used mainly for drainage networks with diameter up to 400 mm. It also requires electrical energy to connect pumping units. This paper describes alternative methods of gravity sewage network drainage for the purposes of its inspection and repair, which provide high-quality maintenance of gravity sewer networks. These methods extend the network service life, as well as minimize the costs of diagnosis and repair works.

1. Introduction
Nowadays, sewage collectors are often inspected to diagnose the most vulnerable areas for blockages and structural accidents. Most maintenance methods of comprehensive diagnostics of gravity sewage network require its pre-draining and cleaning.

The problem of drainage is also essential when sewerage network needs repairing. It is not difficult to disconnect a part of an extensive water supply ring by means of stop valves. There are some difficulties, though, connected with gravity sewer networks cutout. Thus, it is necessary to block pipes with plugs and to pump wastewater through temporary branches, bypassing rehabilitating sections of the network. This process involves considerable technical and material difficulties and can be used mainly for drainage networks with diameter up to 400 mm. With larger diameters of gravity networks this method is not efficient enough. In this situation it is more efficient to arrange temporary duplicating lines, though it makes repair and rehabilitation operations more expensive. According to this method, wastewater from the upper chamber is transported to the bottom, i.e. bypassing the site. Another, a more complex, method to reserve drainage networks, involves making nets providing the transfer of sewage between two allied sewer drainages by laying additional collectors crossing the watershed of both basins [1, 2]. Sometimes this method is the only possible one.

Both variants suggest either delivery pressure for water flow made by pumps installation, or water flowing, if possible according to local conditions.
2. Problem

Wastewater Paper 3 [3] describes such complex and expensive works on renovation of drainage collectors with a large collector in Naberezhnye Chelny as an example. Its laying depth is 4-6 m, its diameter is 2500-3000 mm and the maximum water discharges varies from 5.8 to 6.0 m³/s. Drainage of this collector was carried out with the use of internal bypass, as well as by pumping water into the lower well. The collector renovation expenses were to 70-75% of its re-laying.

Offers of services analyses on collector drainage shows that draining is made with use of pumping equipment. Automatic suction pumps and submersible water pumps with electric drives are usually used as electric pumps do not produce exhaust gas. Still, there is not always a possibility of power supply for pumping units, therefore pumps with internal combustion engines are also used.

Pumping of wastewater with the use of pumps with internal combustion engines is a dangerous factor as there is a risk of carbon monoxide poisoning. Therefore, there are special requirements to the safety of such works. Exhausts are carried out through a special high-temperature collector to a surface without risk of carbon monoxide poisoning. This design is imperfect, so such pumping units with internal combustion engines are used only when there is no access to electricity.

It should also be noted that wastewater pumping is a very costly process, especially if the disconnection of the site takes a relatively long time. Besides, according to the existing requirements, sewage handling of residential area can be limited or terminated only for 8 hours within a period of a month or for 4 hours at any one time [4, Appendix 1].

Therefore, when a network segment is disconnected, the charge for energy resources (electricity, fuels) should also be taken into account, as well as the charge for the negative impact on the environment (when using the pump units with internal combustion engines).

Thus, it is necessary to minimize the charge for energy resources at drainage of a site of gravity sewage network.

3. Possible Solutions

Paper 5 [5] proposes a constructive decision on drainage of large collectors. It offers several constructions of a constant bypass line for collector drainage.

As the question of allocating the land for underground structures is actual for modern cities, such a bypass can be built directly above the serviced collector by it, in one vertical plane. Figure 1 demonstrates the principle design of such a bypass.

In the upper shaft of the drainage section, Gate 2 is open and Gate 3 is closed. In the lower shaft of the drainage section, Shutter 2 is closed and shutter 3 is open.

Let us consider the following drainage scheme (see Figure 2)

When the section is being drained, Gate 2 in the upper chamber and Gate 3 in the lower chamber are closed. Wastewater flows into the bypass line chamber. When it reaches the highest point, the Air Feed Pipe Valve 6 opens and at the same moment the displacer opens Valve 5. Wastewater from the bypass-line chamber is transferred to the bypass line. The it flows by gravity to the lower chamber. Further wastewater comes from the upper chamber to the bypass line because of vacuum.

It is necessary to consider sizes of chambers for creating vacuum in the system. Let us note that the volume of the upper (lower) chamber is accepted constructively. The question of the volume of the bypass line chamber will be considered from the point of view of Boyle-Mariotte \((PV = \text{const})\) law.

At the initial moment of time the system is under atmospheric pressure, therefore:
Figure 1. Bypass line above collector: 1 – straight-way collector; 2, 3 – gates; 4 – bypass.

\[ PV = P_{atm} \cdot V_{free} \]  
(1)

- \( P_{atm} \) - atmospheric pressure
- \( V_{free} \) - liquid volume free of wastewater (see Figure 2). 20\% of the volume of the bypass line chamber is accepted.

\[ V_{free} = 0.2V_b \]  
(2)

Then, wastewater comes from the upper chamber to the bypass line because of vacuum.

\[ PV = P_{vac} \cdot \left( V_b + \frac{2}{3}V_p + \frac{\pi d^2}{4}h + \frac{\pi d^2}{4}L \right) \]  
(3)

- \( P_{vac} \) - vacuum pressure
- \( V_b \) - the bypass line chamber volume

**Note:**

The 2/3 coefficient is based on the fact that during the drainage, the upper chamber is not fully filled, as Gate is closed.

- \( V_{up} \) - the upper chamber volume
- \( \frac{\pi d^2}{4}h \) - the volume of the pipeline between the upper chamber and the bypass line chamber
\[
\frac{\pi d^2}{4} L \quad \text{the volume of bypass line pipeline}
\]

Taking into account \( PV = \text{const} \), we have:

\[
P_{atm} \cdot 0.2V_b = P_{vac} \cdot \left( V_b + \frac{2}{3} V_{up} + \frac{\pi d^2}{4} h + \frac{\pi d^2}{4} L \right)
\]  \( (4) \)

Therefore, the vacuum pressure should be:

\[
P_{vac} = \frac{P_{atm} \cdot 0.2V_b}{\left( V_b + \frac{2}{3} V_{up} + \frac{\pi d^2}{4} h + \frac{\pi d^2}{4} L \right)}
\]  \( (5) \)

\[\text{Figure 2. Scheme of drainage of a gravity sewage network section; 1, 2, 3, 4, 5, 6, 7 – gates.}\]

On the other hand, the vacuum pressure should be sufficient to lift the sewage to \( h \) height and overcome the loss of pressure \( \Sigma H_{lp} \)

\[
P_{vac} = h + \sum h_{tp}
\]  \( (6) \)

That is:

\[
P_{atm} \cdot 0.2V_b \left/ \left( V_b + \frac{2}{3} V_{up} + \frac{\pi d^2}{4} h + \frac{\pi d^2}{4} L \right) \right. \geq h + \sum h_{tp}
\]  \( (7) \)
We solve this equation as regard to $V_b$ and see that the volume of the bypass line chamber should be not less than:

$$V_b \geq \frac{(h + \sum h_{ip}) \left( \frac{2}{3} V_B + \frac{\pi d^2}{4} (h + L) \right)}{0.2 P_{atm} - h - \sum h_{ip}} \tag{8}$$

It should also be noted that in order to avoid sewerage network smell, it is necessary to install a cartridge with sorption-filtering loading.

4. Conclusions
The advantage of this method of drainage in comparison with those described above is that, according to this method, backwater in the system stays only from time to time, while in other structures it is constant.

It should be noted that the increase of the collector service should compensate the construction costs for a constant bypass.

The proposed constructions do not require electric power or fuel supply. Therefore, constant costs will be minimized in the process of operation though they usually increase over time. Taking into account the fact that sewage collectors have rather a long life span, and during the service life it is often necessary to drain them for an inspection or repair, it can be concluded that additional investment during the construction process would be economically justifiable in terms of saving the resources of wastewater disposal organizations.

Constant bypass lines described in this paper provide better maintenance, which in the end extends the service life of the structures, therefore, increases the durability of gravity pipelines and significantly increases sewerage network reliability.

5. References
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