Measurement and evaluation of percolation drainage systems' capacity in real conditions

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Abstract. The drainage system must ensure a safe disposal of the surface water without endangering the buildings and safety of people. Despite the common use of rainwater infiltration facilities, there is still only limited data available evaluating the long-term capacity of such systems especially for underground infiltration facilities. This study presents experimental measurements and evaluation of long-term infiltration efficiency in real conditions and emphasizes the importance of hydrogeological survey. The measurements of infiltration efficiency were applied to an existing percolation drainage system – infiltration shafts. Infiltration shafts were made in year 2007 so that its drainage operation takes more than 8 years. This study was started in 2011 and still continues and presents 5 years measurements of infiltration efficiency for this infiltration facility.

1. Introduction

Urban drainage systems can be divided into two most commonly used; a combined sewer system and a separate sewer system. Combined sewer systems convey storm water and waste water away in a single pipe. Where the combined systems are used, the risk of combined sewer overflows appears (CSO) represented by transfers of untreated waste water into receiving waters [1]. On the other hand, separate sewer system carry storm water and waste water in the separate pipes, usually laid side-by-side [2].

A serious problem in recent years of waterworks praxis has appeared to be the one with growing necessity for surface water detention. Continuous growth of natural terrain coverage for building construction, industry, free time activities and transport reasons leads to widening of the area of build surface and lack of natural terrain with capability of natural rainfall water infiltration. This causes serious damage to natural water cycle.

Waste-water disposal system is very often overloaded with water coming from heavy rainfall which means that it cannot be used for the purpose of rainwater management. Higher disposition of manhole covers helps to keep sewerage water within safe level and minimize the risk of endangering sensitive ecosystems. Waste-water disposal systems, sewage treatment plants and recipients of water flows are overloaded and the risk of floods grows. This represents another reason for waterworks companies to have the possibility of forbidding the disposal of rainfall water from surface detention into the waste-water disposal system already during the creation and fulfilment of the development plan. This leads to the necessity of using rainwater infiltration systems or capturing rainwater for further reuse [3].
Infiltration capacity of soil mainly depends on two factors; the particle size and the moisture content of the soil [4]. The permeability of infiltration zone is an essential qualitative and quantitative prerequisite for infiltration of rainwater. Permeability is represented by a filtration coefficient $k_f$, which represents the effectiveness of infiltration facilities, respectively ability of subsoil infiltrate incoming rainwater. Therefore, the most important design parameter of the infiltration facilities is to determine the filtration coefficient $k_f$ on-site. Another important parameter for design of infiltration facilities is level of groundwater. The Mangangka’s research shows the decline of soil infiltration capacity due to high elevation groundwater [4]. For aboveground facilities, designer have to consider with influence of rainfall patterns on the instability of slopes [5].

Of course there is another very important factor for right operation of infiltration facilities – maintenance. According to Lindsey, Roberts and Page research, analysis of field inspections reveals that the condition of facilities declined significantly in four years [6]. Without maintenance of infiltration facilities, especially above-ground facilities, decrease of performance of infiltration facilities have been identified [7].

The primary threat to the long-term hydraulic performance of stormwater infiltration systems is their inclination to become clogged due to the accumulation and deposition of sediments on the system surface during its operation [8]. One main reason for clogging is a demonstrable lack of regular maintenance [6]. Balades et al. showed that coping effectively with this problem requires regular maintenance as a preventive measure to sustain the infiltration capacity of porous pavements.

2. Materials and Methods

2.1 Site description

The article describes experimental measurements and evaluation of the infiltration efficiency in the real conditions.

Our research and own measurements in the field of storm water quantity and quality parameters has been started in the campus of Technical University of Košice as a part of the management of storm water project. The objects of our research are two infiltration shafts in TU campus in Kosice, already existing prior to our research. These infiltration shafts were designed as a drainage solution for a real school building PK6. Two vertical shafts are located next to the PK6 building. All run-off rainwater collected on the roof flows into the underground pipes (figure 1) [3].

![Figure 1. The location of drainage shafts near the PK6 building [3].](image)

The initial measurement started in March 2011 and has continued in the infiltration shaft A so far, followed by the measurement of the inflow of rainwater runoff from the roof of the building PK6. The research was extended of measurements for second shaft (shaft B) in March 2012. It should be noted that the project of building drainage and project of design and realization of infiltration shafts is not available. These infiltration shafts were made before the start of the research and measurements in year 2007.
3. Results and discussion

The fills of the area of interest consist mostly of gravel clays, building waste and natural gravels. The exploratory bores were used to verify the thickness of these fills from 0.5 to 0.6 meters. Under the fills, the sediments of Hornád River were identified. Right under the backfill the continuous layer of clay with a thickness of 4.0 to 4.5 meters was identified. Under the flood sediments the fluvial gravel sediments of thickness 5.0 to 7.0 meters were identified and the gravels blended with fine-grained soil. The bottom layer consists of clay-gravel with a thickness of 0.7 to 2.7 m (The final report of geological survey for object Technicom, 2010).

The validation of the hydrogeological survey of the site, respectively verification of the infiltration coefficient $k_f$ of the soil in studied infiltration shafts near the PK6 building, was performed by taking the samples of soil from the bottom of the infiltration shafts. With the use of laboratory tests, the samples were evaluated as gravel blended with a fine-grained soil and infiltration coefficient set at $10^{-3}$ m/s which confirms the hydrogeological survey of the site conducted for the object of Technicom in the campus of TU Košice.

Figures 2-5 represent a typical process of flow rate and subsequent percolation of rainwater during the rainfall events in the percolation shafts [3]. Figures 2-5 show 2 selected rainfall events from the period of 2012 to 2013 with high rainfall intensity. All data from the research show that the total infiltration of runoff inflow into the infiltration shafts from the roof of PK6 building takes place at the same time within the duration of rainfall events, respectively very short-time after. This represents a high infiltration rate of these infiltration shafts determined by the coefficient of infiltration of soil at the bottom of the shaft $k_f = 1.10^{-3}$ m/s.

![Figure 2-3. Volume flow rate and water level changes at the bottom of the shaft A on a rainfall of 24 April, 2012.](image1)

![Figure 4-5. Volume flow rate and water level changes at the bottom of the shaft A on a rainfall of 30 July, 2013.](image2)

As resulting not only from figures 2-5, but also from the overall measured data during the research, the total infiltration of rainwater in the infiltration shaft, take place at the time of termination of rainfall events, respectively short-time after, which represent a high infiltration rate of this shaft, given by the coefficient of infiltration of soil at the bottom of shaft. Therefore, despite the smaller surface for infiltration of infiltration shafts with comparison to other types of infiltration facilities, the infiltration coefficient of surveyed infiltration shafts $k_f = 1.10^{-3}$ m/s ensures safe disposal of surface runoff. The maximum water level at the infiltration shafts are shown in figures 6 and 7 [3].
Figure 6-7. Values of maximum water level at the bottom of the shaft A from August 2011 to December 2015 and of the shaft B from March 2012 to December 2015. The test of the infiltration capacity in both of infiltration shafts was done in 2014 - in shaft A where was used volume 1000 liters of water and second experiment in both of infiltration shafts (A,B) where was used volume 2000 liters of water.

Figure 8-9. The experimental infiltration measurements of infiltration capacity in shaft A – volume of water used for the test - 2000 liters.

Figure 10-11. The experimental infiltration measurements of infiltration capacity in shaft B – volume of water used for the test - 2000 liters.

Table 1. Measured infiltration capacity from infiltration test.

| Infiltration shaft | Volume of water used for the test (l) | Date | Year of infiltration facility operation | Infiltration capacity (l/min) |
|--------------------|----------------------------------------|------|-----------------------------------------|-----------------------------|
| Shaft A            | 1000                                   | 2014 | 7                                       | 18.51                       |
| Shaft A            | 2000                                   | 2014 | 7                                       | 23.52                       |
| Shaft B            | 2000                                   | 2014 | 7                                       | 22.98                       |
The course of infiltration capacity test is depicted on figures 8-11. Values of measured infiltration capacity are shown in table 1 and also were selected 5 rainfall events from every year of research and calculated the mean infiltration capacity for these infiltration shafts – table 2.

| Infiltration shaft | Year of facility operation | Date | Mean infiltration capacity (l/min) |
|--------------------|---------------------------|------|-----------------------------------|
| Shaft A            | 4                         | 2011 | 11.9                              |
| Shaft A            | 4                         | 2012 | 23.57                             |
| Shaft B            | 5                         | 2012 | 35.26                             |
| Shaft A            | 6                         | 2013 | 17.91                             |
| Shaft B            | 6                         | 2013 | 32.64                             |
| Shaft A            | 7                         | 2014 | 24.36                             |
| Shaft B            | 7                         | 2014 | 18.99                             |
| Shaft A            | 8                         | 2015 | 49.57                             |
| Shaft B            | 8                         | 2015 | 24.93                             |

4. Conclusion
Results from calculated data of selected rainfall events and from field test of infiltration capacity of our research show specific and various trend of infiltration capacity during operation of these infiltration shafts. The important fact is that there are no significant decreasing of infiltration capacity after 8 years of operation of these infiltration facilities and the operation of the facilities are fluent and free from complications. Of course, it should be noted that the infiltration shafts are underground infiltration facilities and inflow to these shaft was only from roof construction what represents less risk of contamination with high suspended solids in runoff.

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