Infiltration efficiency of percolation facility for its safety operation

Gabriel Markovič, Daniela Kaposztásová, Zuzana Vranayová

Abstract— Facilities for percolation of rainwater are devices designed for fluent and natural infiltration of rainwater from the roofs of buildings and other paved surfaces. The basic principle and function of all types of infiltration facilities as quickly as possible to divert rainwater to infiltration zone and there it infiltrates into the surrounding soil. Every construction should be secure with a drainage system to remove rainwater from the roof, or other paved surfaces without causing damage to the construction or endangering the health and safety of people in and around the building. Infiltration facilities must be designed correctly. There are a number of cases, when from the incorrect design of infiltration facilities insufficiently or only partly fulfill their function, and in many cases there has been damage of property.

Keywords— percolation, rainwater, runoff, safety, shaft.

I. INTRODUCTION

Every building and paved surfaces must be designed and constructed with a surface water drainage system. This drainage system must ensure the disposal of surface water without threatening the building and safety of the people [12]. Suitability of choice of type of infiltration facility is dependent on local conditions. It is necessary to take into account the principles of design of these facilities, for example separation distance from buildings, groundwater level, infiltration coefficient etc. Therefore, in each case, it is to be considered carefully, which drainage concept in combination with the percolation of precipitation is ecologically sensible, technically possible and economically justifiable.

II. IMPORTANT DESIGN PRINCIPLES FOR CORRECT DESIGN

A. Distance from buildings

It always should be respected a minimum distance from buildings, basement of the buildings and the average amount of groundwater levels. These dimensions can vary from a few decimetres to several meters. Figure 1 and 2 represent minimum distance from buildings. The same rules apply for underground infiltration facilities.

Fig. 1. The minimum distance of the decentralized infiltration facilities from building without waterproofing [6]

Fig. 2. Required separation distance from buildings [13]

Recommended minimum distances from the infiltration facility:
- 5 m from residential buildings without waterproof
- 2 m from residential buildings with waterproof
- 3 m from local vegetation (trees, bush etc.)
- 2 m from the property line, public communication, etc
- 1,5 m from gas pipelines and water pipelines
- 0,8 m from power lines

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• 0,5 from telecommunication lines
• 1 m from ground water level

B. The permeability of infiltration area

The most important design parameter of infiltration facilities is to determine the infiltration coefficient \( k_f \) in the interest area, respectively infiltration coefficient of the soil where is planned to place an infiltration facility. Infiltration coefficient \( k_f \) generally represents an efficiency of infiltration facilities, respectively infiltration capability of the soil to absorb inflow water.

Permeability of the infiltration zone is a main qualitative and quantitative requirement for rainwater infiltration. Permeability of loose rock depends primarily on the size and distribution of the particles and compactness, in soils is critical soil structure and water temperature and is given by the infiltration coefficient. Permeability of loose rock varies in general between 1.10-2 and 1.10-10 m/s (figure 3). The \( k_f \) values apply to the process of infiltration water in the saturated zone. The range of values for the filtration coefficient for technical drainage ranges from 1.10-3 and 1.10-6 m/s [14].

The \( k_f \) values greater than 1.10-3 m/s cannot be reached for rainwater runoff and low depth of groundwater level the sufficient pretreatment through chemical and biological processes. If the \( k_f \) values are smaller than 1.10-6 m/s, the percolation facilities are loaded very long time. For this reason, anaerobic processes in the unsaturated soil, which resulting in adverse effects on retention and capacity capabilities of the soil can occur.

Therefore, the most important design parameter of the infiltration facilities is to determine the filtration coefficient \( k_f \) on-site.

Tab. 1 Required time for rainwater infiltration in shaft depending of the infiltration coefficients from theoretical calculation

<table>
<thead>
<tr>
<th>Infiltration coefficient</th>
<th>Rainfall periodicity</th>
<th>( V ) (required accumulation volume in m(^3))</th>
<th>( t ) (time of infiltration in hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_f = 10^{-2} )</td>
<td>( r_D(0,5) )</td>
<td>0,16 m(^3)</td>
<td>( t = 0,05 ) h</td>
</tr>
<tr>
<td>( k_f = 10^{-3} )</td>
<td>( r_D(0,5) )</td>
<td>1,49 m(^3)</td>
<td>( t = 0,13 ) h</td>
</tr>
<tr>
<td>( k_f = 10^{-4} )</td>
<td>( r_D(0,5) )</td>
<td>3,77 m(^3)</td>
<td>( t = 1,4 ) h</td>
</tr>
<tr>
<td>( k_f = 10^{-5} )</td>
<td>( r_D(0,5) )</td>
<td>6,26 m(^3)</td>
<td>( t = 14 ) h</td>
</tr>
<tr>
<td>( k_f = 10^{-6} )</td>
<td>( r_D(0,5) )</td>
<td>7,27m(^3)</td>
<td>( t = 143 ) h (6 days)</td>
</tr>
<tr>
<td>( k_f = 10^{-7} )</td>
<td>( r_D(0,5) )</td>
<td>7,40 m(^3)</td>
<td>( t = 1432 ) h (60 days)</td>
</tr>
</tbody>
</table>

III. RESEARCH OF INFILTRATION EFFICIENCY IN REAL CONDITIONS

A. Experimental research in the campus of TU Košice-city

We have started our research and own measurements in scope of stormwater quantity and quality parameters at the campus of Technical University of Košice within the project relating to the management of stormwater. The objects of research represent two infiltration shafts in the campus of TU Kosice that were made before the start of our research. These infiltration shafts represent drainage solution for real school building PK6 and All of the runoff rainwater falling onto the roof flows into these underground shafts (figure 4) [1].
The measuring devices for information about volume of incoming rainwater from the roof of the building PK6 and also information about the quality of rainwater are located in both infiltration shafts [1]. All devices are connected with registration and control unit M4016. Unit M4016 automatically sent measured and archived data into the server database (data hosting) via GPRS in regular intervals [8]. Under inflow, respectively rain outlet pipe in the shaft, there are measurement flumes for metering of inflow rainwater from the roof of a building PK6 in both of infiltration shafts. Rainwater from the roof of the building PK6 is fed by rainwater pipes directly into measurement flumes, which are placed under the ultrasonic level sensor which transmitting data of the water level in the measurement flumes to the data unit M4016 (figure 5). Water level at the bottom of shafts is measured by pressure sensors type LMP307 (figure 5) [2].

![Fig. 5. Measurement devices - Data unit M4016 in shaft A, Measurement flume with ultrasonic level sensor, Pressure sensor LMP307](image)

**B. Experimental research in peripheral part of Prešov-city**

Second experimental research of infiltration efficiency is located in Šarišské Lúky near Prešov-city. Rainwater infiltration as a drainage solution is from bridge road after its reconstruction. The infiltration gallery from infiltration units was designed in the monitored area by theoretical calculation.

Bridge object (Figure 6) is located on road 1/8 between Prešov and Kapušany. Approached two-way road on the bridge contains 4 lanes. It is bridge road over the train and local road MK Sekčov and road III/06815. Roadway on the bridge has one-sided slope 1,5% [7].

![Fig. 6. Bridge object](image)

Figure 7 shows the location of measuring equipment and objects for research. Rainwater from the bridge flows into filter shaft (1), which serves for capture and sedimentation of coarse and fine impurities. The rainwater subsequently flows into the infiltration gallery (2), where the water is filtered during infiltration to the soil. Measuring devices for volume of rainwater are the same as in infiltration shaft in campus of TU Kosice. A flow meter is located in the filter shaft, which record incoming rainwater in l/s. The water level in the infiltration gallery can be monitored by means of the float-gauge which is located in inspection shaft (3). Near this infiltration gallery is located rain-gauge (4).

![Fig. 7. Infiltration gallery – situation [9]](image)

**IV. MEASUREMENT AND EVALUATION**

**A. Experimental research in the campus of TU Košice-city**

Figures 8-11 represent typical process of flow rate and next percolation of rainwater during rainfall events in percolation shafts [3,10]. Figures 8-11 shows 2 selected rainfall events from year 2013 and 2014 with high rainfall intensity. All data from research show, the total infiltration of runoff inflow into the infiltration shafts from roof of PK6 building take place at the same time of duration of rainfall events, respectively very short-time after. This represents a high infiltration rate of this infiltration shafts. It is given by the coefficient of infiltration of soil at the bottom of shaft determined as $k_f = 1.10^{-3}$ m/s.

The maximum water level at the infiltration shaft A, measured during the research period 2011-2014 is 1,28 m, which is less than 1/3 filling depth of infiltration shaft A and maximum water level at the infiltration shaft B, measured during the research period is 1,31 m, which is less than 1/3 filling depth of infiltration shaft B too.

If we compared size of area for infiltration of runoff with other types of infiltration facilities (for example infiltration units) this size is several times smaller against another types of infiltration facilities. But the infiltration coefficient of surveyed infiltration shafts $k_f = 1.10^{-3}$ m/s ensures percolation of rainwater in required time so represents safe disposal of surface runoff for the object PK6 [11].
B. Experimental research in peripheral part of Prešov-city

The percolation gallery is formed by plastic units. The percolation area of the infiltration gallery is 46,08 m². Its surface is rectangular. The volume of rainwater draining into infiltration gallery and water level changes at the bottom are monitored with devices in the filter shaft.

During the design phase of the infiltration gallery the infiltration coefficient was estimated by designer as 8,2.10⁻⁵ m/s. All parameters of infiltration gallery were calculated with this infiltration rate which should ensure a sufficient and suitable percolation characteristics for this facility.

But results from laboratory test set infiltration coefficient in area of interest as 4,84.10⁻⁷ m/s! It means about 100 times lower infiltration efficiency and also lower accumulation volume of infiltration gallery as was design for safe disposal of rainwater runoff. This results to insufficient infiltration rate of this percolation gallery. Infiltration coefficient 4,84.10⁻⁷ m/s represents practically impermeable type of soil not suitable for infiltration facilities. Unfortunately this inaccurate design caused flooding and silting all infiltration gallery and result to failure of installed devices for research – figure 12.

Figures 13-14 represent typical process of rainwater percolation in infiltration gallery respectively water level in gallery during the month. Data from research showed that there was continuously high water level in percolation gallery. This represents a very low infiltration rate of this infiltration gallery what is given by the coefficient of infiltration of soil at the bottom of gallery determined as kᵢ = 4,84.10⁻⁷ m/s and also means overfill of percolation gallery (figure 13-14).
V. CONCLUSION

Percolation of rainwater as a part of stormwater management is quite a new topic in Slovakia. There is no legal framework as well as standards or guidelines how to apply sustainable stormwater management techniques especially in field of percolation of rainwater. Percolation drainage systems are technical solutions that provide an alternative to the traditional direct channelling of surface water through networks of pipes and sewers to wastewater treatment plant or watercourses. But these systems must be designed with regard of threatening the building and safety of the people.

As was mentioned above, suitability of type of infiltration facility is dependent on local conditions. Of course, it is necessary to take into account the principles of design of these facilities, for example separation distance from buildings, groundwater level, infiltration coefficient etc. In this study, the results obtained through the research on the percolation facilities, demonstrated how coefficient of infiltration depend to efficiency of percolation facility in real conditions. So for correct operation of these facilities its necessary has knowledge of hydrogeological conditions in site of design.

REFERENCES


