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THE SHAFT PERCOLATION AS SUSTAINABLE CONCEPT FOR SAFETY DRAINAGE OF RAINWATER RUNOFF

Gabriel Markovič[1]*, Daniela Kaposztásová[1], Zuzana Vranayová[1]

[1] Technical University of Kosice, Faculty of Civil Engineering, Vyskoskolska 4, 04200 Kosice

Abstract

The main goal of this paper is to provide the analysis of the measured data from infiltration system (infiltration shafts) at university campus in real conditions and to describe the effectiveness of infiltration facility depending on required local conditions. Infiltration shafts are located at campus of the Technical University of Kosice. All rainwater runoff from roof of PK6 building flowed into the two infiltration shafts. The permeability of infiltration area is an essential qualitative and quantitative prerequisite for infiltration of rainwater. Filtration coefficient k_f of the soil in explored infiltration shafts near the PK6 building was determined by taking samples of soil from the bottom of the infiltration shafts. Through the laboratory tests, the samples were evaluated as gravel blended with a fine-grained soil and infiltration coefficient set at 10^{-3} m/s. Therefore, the most important design parameter of the infiltration facilities is to determine the filtration coefficient k_f on-site. The results from the overall measured data during the research indicated that infiltration process of the total volume of rainwater runoff inflow into the infiltration shafts, took place at the time of termination of rainfall events, respectively short-time after. Therefore, despite the smaller surface for percolation of infiltration shafts compared 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. With the correct design, realization and maintenance of infiltration facilities, it should be operation of this device safe, fluent and without complications and real estated damages.

Key words

Efficiency; infiltration; rainwater; runoff; shaft; soil

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*Corresponding author: Tel.: +421556024143
E-mail address: gabriel.markovic@tuke.sk

1 INTRODUCTION

As a consequence of a continuous growth of building construction and urban development, natural terrain is replaced by compact soil for example roofs of industrial, residential, commercial or other buildings, road network, car parks etc. [1]. When rainfall water reaches these surfaces almost 80% of this water flows to waste-water disposal system or rivers and only 20% soaks to the soil. This leads to ecological damages as floods, torrential rain, decline of subsoil water level, local soil dehydration and endangering of sensitive ecosystems [2]. It is necessary to build and develop not only urban constructions but also artificial regulation of water circulation in nature, which contribute to maintenance of ecological stability of chosen location [3].

2 SHAFT PERCOLATION

One of the types of infiltration facilities are percolation/infiltration shafts. It is a vertical underground infiltration facility which is usually made from concrete rings with the filter layer on the bottom (figure 1).

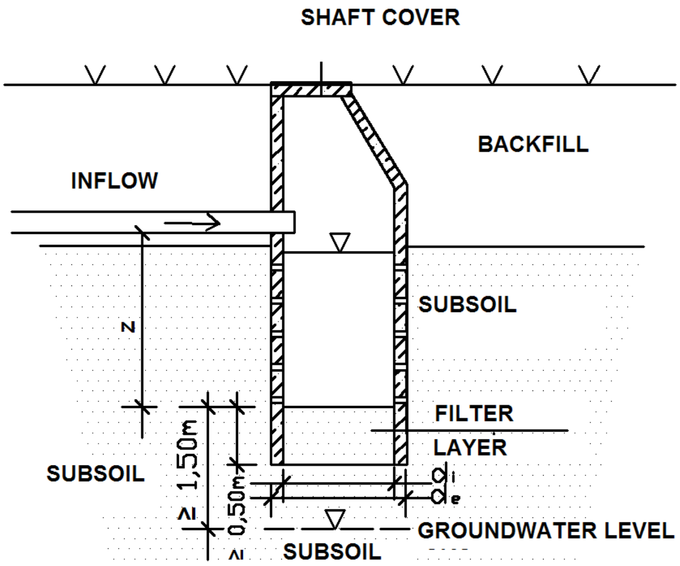

Fig. 1: Infiltration shaft

Rainwater from the catchment area is transported with system of vertical and horizontal rain pipes in underground space for infiltration.

Infiltration shaft is a facility where the largest dimension is depth, so that design of this shaft depends of the highest water level in the shaft and also of the groundwater level in the interest area. The design of shafts must take into the account protection of groundwater and infiltration capability of shaft which is represents by infiltration coefficient on site.

The design of shafts must take into the account protection of groundwater and infiltration capability of shaft. German standard DWA-A 138 indicates that it is necessary to place the bottom of the infiltration shaft a filter sack which is located above the filter layer. The total volume of inflow rainwater must pass through the filter sack before infiltration into the soil. The filter sack is absorbing all of the settle able and filterable solids and filter sack should be flushed or replaced [4]. Czech standard for infiltration indicates that on the bottom layer is placed layer of gravel at least 300 mm. On this layer is placed geo-textile, which is recommended to protect with the gravel-sand layer [5][6][7].

3 RESEARCH OF SHAFT PERCOLATION AS SUSTAINABLE CONCEPT FOR SAFETY DRAINAGE OF RAINWATER RUNOFF

The research of infiltration facility effectiveness takes place at the Faculty of Civil Engineering in Kosice-city. The source tested is located in the premises of TUKE (Technical University of Kosice). The resources that provide us information about the quality and quantity of rainwater are real school building PK6 and two infiltration shafts for rainwater runoff drainage (firuge 2). Roof area of the PK6 building is 548,55 m^2.

Fig. 2: Location of infiltration shafts near building PK6

Infiltration shafts are situated at the east side of the building PK6. The shafts consist from concrete rings with the outer diameter of 1000 mm. Parameters of infiltration shafts are shown in table 1.

It should be noted that the project of building drainage and project of design and realization of infiltration shafts is not available. All data, whether the parameters of infiltration shafts or a drainage concept of rainwater from the building, were investigate on site (figure 3).

Fig. 3: Drainage of rainwater from roof of building PK6 [1].

Tab. 1: Parameters of infiltration shafts

	SHAFT A	SHAFT B
The outer diameter of shaft	1000 mm	1000 mm
The inner diameter of shaft	800 mm	800 mm
Shaft depth	6,0 m	5,9 m
Depth of inflow	1,65 m	1,5 m
DN of inlet pipe	DN 150	DN 125
Infiltration coefficient at the bottom	1.10^{-3} m/s	1.10^{-3} m/s
Drainage area of roof	212 m^2	336 m^2
Accumulation volume	2,11 m^3	2,18 m^3

The measuring devices for information about volume of incoming rainwater from the roof of the building PK6 are located in both infiltration shafts [8]. All devices are connected with registration and control unit M4016 (figure 4).

Fig. 4: Drainage of rainwater from roof of building PK6

Unit M4016 automatically sent measured and archived data into the server database (data hosting) via GPRS in regular intervals [9]. 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 (figure 5). 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 Water level at the bottom of shafts is measured by pressure sensors type LMP307 (figure 6) [10].

Fig. 5: Drainage of rainwater from roof of building PK6

Fig. 6: Drainage of rainwater from roof of building PK6

4 RESULTS AND DISCUSSION

As resulting not only from figures 7 to 8, but also from the overall measured data during the research, the total infiltration of rainwater runoff inflow into the infiltration shaft, take place at the time of termination of rainfall events, respectively short-time after, which represent a high infiltration efficiency of this infiltration shaft, given by the coefficient of infiltration of soil at the bottom of shaft.

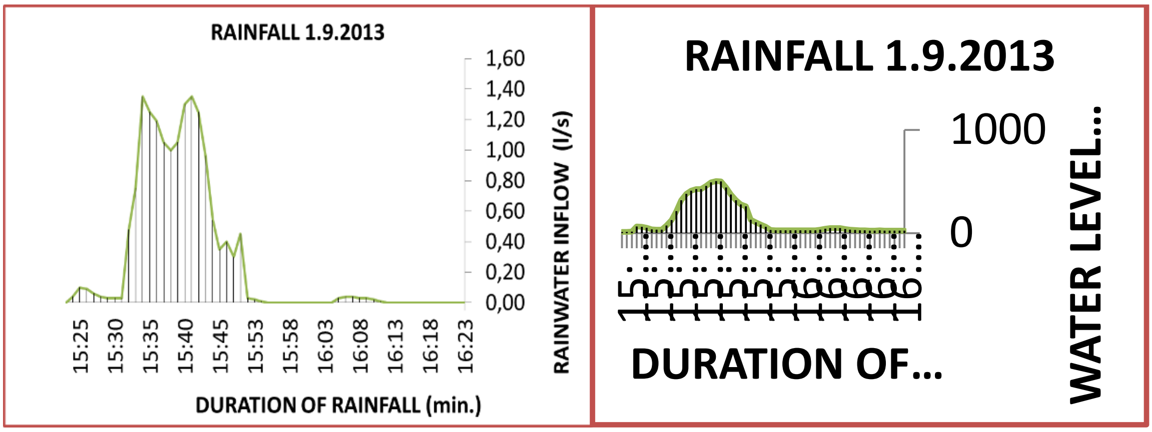

Fig. 7: Example of rainwater infiltration process (water level changes at the bottom of the shaft A) depending on rainwater inflow – rainfall 1.9.2013

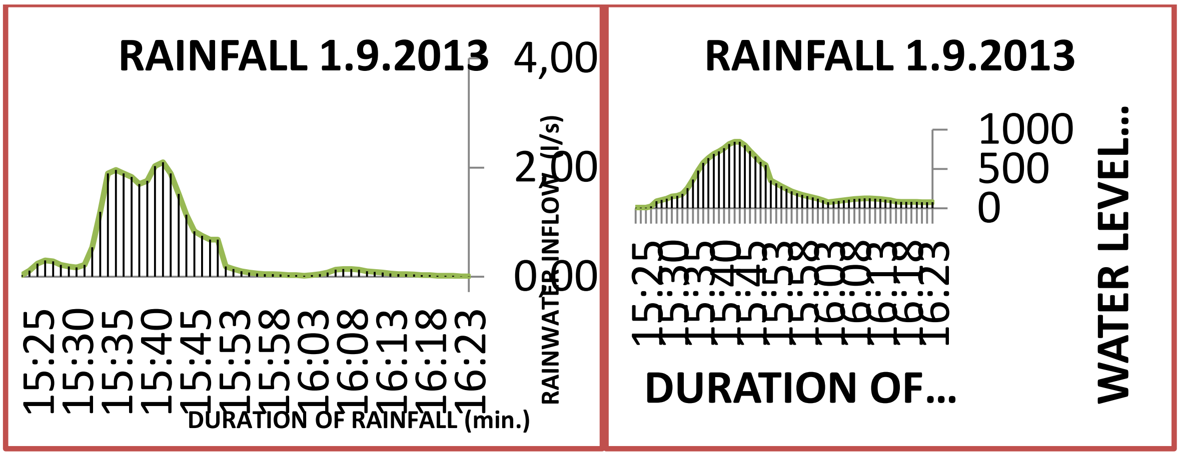

Fig. 8: Example of rainwater infiltration process (water level changes at the bottom of the shaft B) depending on rainwater inflow – rainfall 1.9.2013

Morphology of the interest area is formed by alluvial plains of the river Hornád. The surface of the site is formed from anthropogenic sediments (fills). Under this layer are located fluvial sediments of river Hornád and under this layer are sediments of neogene age. The fills of the interest area consist mostly of gravel clays, a building waste and natural gravels. Through the exploratory bores was to verify the thickness of these fills from 0.5 to 0.6 meters. Under the fills were verified fluvial sediments of the river Hornád. Immediately under the backfill was verified continuous layer of clay with a thickness of 4.0 to 4.5 meters. Under flood sediments were verified fluvial gravel sediments with a thickness of 5.0 to 7.0 meters, and its gravels blended with fine-grained soil. The bottom layer consists of clay-gravel with a thickness of 0.7 to 2.7 m [11].

Validation of the hydrogeological survey of the site, respectively verify the infiltration coefficient k_f of the soil in studied infiltration shafts near the PK6 building was made by taking samples of soil from the bottom of the infiltration shafts. Through the laboratory tests, the samples were evaluated as gravel blended with a fine-grained soil and infiltration coefficient set at 10^{-3} m/s, what confirming the hydrogeological survey of the site made for object Technicom in the campus of TU Košice [12].

Therefore, despite the smaller surface for infiltration of infiltration shafts with compared to other types of infiltration facilities (for example infiltration boxes) 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 shaft A, measured during the research period 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.

As was already mentioned above, the most important parameter of design not only for infiltration shafts, but in general infiltration facilities, is to determine the infiltration coefficient k_f in the interest area. Results from theoretical calculation (table 2) show importance of infiltration coefficient. The most suitable values for the filtration coefficient for technical drainage ranges from 1.10^{-3} and 1.10^{-5} m/s .

(Note: Theoretical analysis of infiltration shaft efficiency respectively of the time required for infiltration of inflow rainwater from the roof of the building was processed for the studied infiltration shaft A and its real dimensions and local conditions in TUKE campus)

Tab. 2: Required time for rainwater infiltration in shaft A depending of the infiltration coefficients from theoretical calculation

Infiltration coefficient	Rainfall intensity	z (shaft depth in m)	V (accumulation volume in m^3)	t (time of infiltration in hours)
$k_f = 10^{-2}$	$r_D(0,5)$	0,32 m	0,16 m^3	t = 0,05 h
$k_f = 10^{-3}$	**$r_D(0,5)$**	**2,97 m**	**1,49 m^3**	**t = 0,13 h**
$k_f = 10^{-4}$	$r_D(0,5)$	7,51 m	3,77 m^3	t = 1,4 h
$k_f = 10^{-5}$	$r_D(0,5)$	12,47 m	6,26 m^3	t = 14 h
$k_f = 10^{-6}$	$r_D(0,5)$	14,46 m	7,27m^3	t = 143 h (6 days)
$k_f = 10^{-7}$	$r_D(0,5)$	14,73 m	7,40 m^3	t = 1432 h (60days)

5 CONCLUSION

It is always necessary to consider from the view of local conditions about suitability of rainwater infiltration solutions [13]. 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 [14][15]. As resulting not only 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 at the bottom of shaft. Infiltration facilities must be designed correctly. There are a number of cases, when from the incorrect design of infiltration facilities insufficiently or only partly fulfil their function, and in many cases there has been damage of property. With the correct design, realization and maintenance of infiltration facilities, it should be operation of this device fluent and without complications. It is therefore necessary that the designer of the infiltration facilities known hydrogeological conditions at the interest area.

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