Theoretical and Experimental Aspects of Sustainable Rainwater Management in a Residential Area

Aspecte teoretice și experimentale privind gestionarea sustenabilă a apelor meteorice într-un ansamblu rezidențial

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Abstract. *In the paper, the authors address the issue of rainwater management, which represents a renewable, clean, and cost-free resource. However, currently, the way to reintroduce it into the environment is not sustainable because it is done with high energy consumption and at significant expenses. The case study presents a solution whereby, with a small investment, rainwater is returned to the natural water cycle in nature.*

Keywords: rainwater, rainwater management, circular economy

1. Introduction

Rainfall collection has been used historically to conserve water, especially in areas with little or difficult access to alternative water sources.

Rising water demand, greater interest in conservation of water and energy, and increased regulatory emphasis on reducing stormwater runoff volumes and related pollutant loads have all led to a renewed interest in water use techniques among researchers and policymakers in recent years [1].

Understanding the importance of rain and making the most use of both the rain and the place where it falls are important aspects of rainwater harvesting and conservation [2].

Urban stormwater management practices in place today are meant to quickly collect, transport, and evacuate excessive runoff outside the urban areas. This can lead to flash floods, downstream flooding in significant stream channels, costly property damage, and washout of structures. The problem is made even more complicated by the unpredictability of the climate in the future. For localities with existing infrastructure, the change in precipitation in the future may have very serious ramifications for managing and controlling flooding.

With the application of best practices management within the watershed, stormwater quantity can be decreased, and stormwater quality can be increased. Detention/retention basins, infiltration basins or trenches, dry wells, sediment traps, vegetated swells, bioretention, and artificial wetlands are a few examples of structural best management techniques. By containing peak flows, eliminating pollutants via physical and biological processes, and allowing stormwater to seep in to recharge aquifers, the placement of these structures within a watershed has the potential to lessen flooding [3].

Due to climate change, there is a general increase in rainfall and especially an increase in extreme events such as 'cloudbursts', which, due to the high intensity of rainfall in a short period of time, cause flooding with negative effects on the quality of life. In this context, the sustainable management of stormwater is a highly topical issue, especially as it is found in very large quantities in short periods of time. The technical solution of using stormwater retention tanks and subsequent controlled discharge into sewerage networks is not a sustainable solution in terms of recycling, infiltration, and reuse.

One solution is the use of storage tanks and the gradual infiltration of water into the ground, thus returning the water to its natural circuit and at the same time relieving the sewage network of these quantities of stormwater and, perhaps more importantly, relieving municipal wastewater treatment plants of the need to process these flows of water. In this respect, the concept of circular water economy is becoming increasingly important [4].

In other locations around the world, considering the climatic zone, it may be important to collect rainwater for later use, especially if we do not have an even distribution of rainfall throughout the year [5], [6]. The collected rainwater can be used for gardening, watering green areas, washing driveways and so on. However, care should be taken to avoid collecting rainwater from heavily polluted areas in the immediate vicinity of industrial areas that release pollutants into the environment if reuse is intended.

With this paper, the authors aim to present a case study of stormwater storage in a residential development using retention and infiltration tanks.

2. Case study

The solution chosen to be implemented in this particular case is to store stormwater collected from the built-up areas of a residential area in a retention and infiltration tank that can be placed either in the green area, under the alleys or in the traffic zone with a maximum speed of 60 km/h. The material used for this kind of tanks is tested for high load resistance. Another point to note is that new technologies on the manufacturing lines can produce these tanks from recyclable materials, the one used in this case being made from PP-B polypropylene.

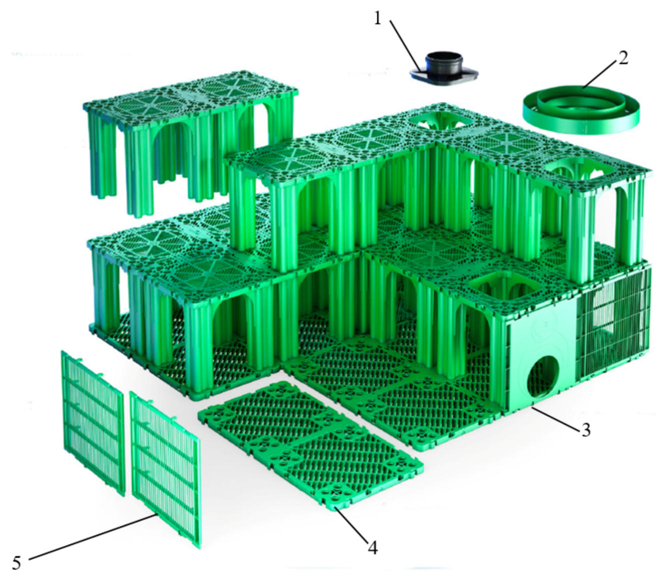

Fig. 1. Retention and infiltration tank [4]
1 and 2 - adapters, 3 - connection plate, 4 - bottom plate, 5 - side wall.

The design of an infiltration tank can be adapted to the available space because it has a modular design. A parallelepiped module measures 1200×600×600 mm and occupies a volume of 432 l, which can store 412.6 l of water. For situations where the holding capacity is too low, several interconnected reservoirs could be provided, thus forming a larger capacity reservoir. Three horizontal tunnels 295 mm wide and 500 mm high are provided inside the infiltration tank according to the components to facilitate cleaning and video inspection when needed.

A geotextile or geomembrane membrane shall be provided on the entire outer surface of the tank to prevent soil particles from infiltrating into the tank, depending on the role of the tank. The arrangement of the perforations in the tank elements are designed to ensure protection of the geotextile/geomembrane during the pressure cleaning process. The bottom plate is designed to facilitate the cleaning direction.

a b c

Fig. 2. Examples of tank intervention [5].
a - video inspection camera, b and c - pressure water cleaning.

A compacted gravel layer is required when installing the system. Its grain size depends on the use to which the water accumulating in the tank will be put and on the nature of the soil in which it is placed.

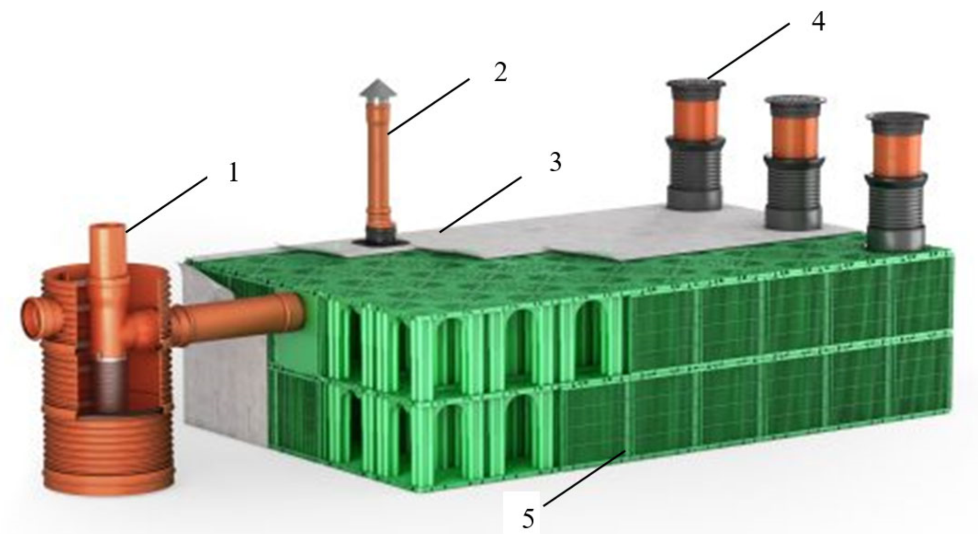

Fig. 3. Tank component elements in final form [5].
1 - sand trap, 2 - vent pipe, 3 - geotextile or geomembrane, 4 - manhole, 5 - tank itself

Thus, in the following we present an application of the system described above, in the case of a residential complex in the Cluj - Napoca area.

The residential complex consists of four buildings A, B, C and D with a height of D+P+7E+R. The total roof terrace area of the four buildings completed so far is 3600 sq m. The residential complex was developed in successive stages: the A building with a terrace area of 732 sqm was completed in 2018, the B building with a terrace area of 1290 sqm was completed in 2019, the D building with a terrace area of 853 sqm was completed in 2020 and the C building with a terrace area of 725 sqm was completed in 2022. Construction work is currently underway on buildings E and F, whose terraces total 1450 square metres. The total area of the terraces will be 5050 sqm.

For the above situation, a retention and infiltration tank with a volume of 48 m^3 was used. The installation was carried out in parallel with the construction of the first two buildings in the complex. After the land was cleared and the site for the tank was excavated, the geomembrane was spread to cover all six outer sides of the parallelepiped tank (see fig. 5). In the next step, the bottom plate was assembled (see fig.5). After the base of the tank was made, it was mounted vertically and the four corners were provided with double-walled polypropylene manholes of DN 400 (see Figs. 6 and 7) to ensure ventilation of the tank.

Fig. 5. Geomembrane preparation and tank bottom plate installation stage

Fig. 6. Details from the tank assembly stage

Once the assembly of the tank components was completed, the tank was covered with geomembrane (see fig. 8). All around the tank, an 80 cm compacted gravel fill was made and covered with soil. (see fig. 9).

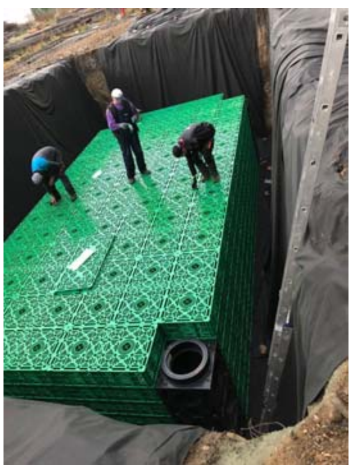

Fig. 7. Preparation for geomembrane coating

Fig. 8. Covering the tank with geomembrane

Fig. 9. Preparing the soil for final landscaping

For the built-up areas shown above, we will determine the stormwater flows collected from the buildings. According to current regulations and standards, the design flow rate for stormwater collected from the surfaces of terraces is determined with the relation below [9]:

$$V_{ci} = 0.0001 \cdot i \cdot \Sigma\phi \cdot S_c \qquad [l/s] \quad (1)$$

where i is the design rainfall intensity in [l/s-ha];

ϕ - the coefficient of stormwater water runoff from the design surface;

S_c - design area, in [m^2], corresponding to the drainage coefficient ϕ.

A design rainfall intensity of 320 l/s-ha for a design rainfall duration of 5 minutes with a rainfall frequency of ½ was used to determine these flows collecting from the walkable terraces of the buildings and a design surface runoff coefficient of stormwater, $\phi = 0.85$, was applied.

Table 1

Stormwater flow per building

Building	S_c	t	f	i	ϕ	V_{ci}
	[m^2]	[min]	[-]	[l/s-ha]	[-]	[l/s]
A	732,00	5	1/2	320	0.85	19.91
B	1290.00	5	1/2	320	0.85	35.09
C	725.00	5	1/2	320	0.85	19.72
D	853.00	5	1/2	320	0.85	23.20
E	600.00	5	1/2	320	0.85	16.32
F	850.00	5	1/2	320	0.85	23.12
TOTAL	5050.00	5	1/2	320	0.85	137.36

According to the phased implementation of the building complex, in 2018 a flow of 19.91 l/s was collected from the built-up areas, in 2019 a flow of 55.00 l/s was collected, in 2020 and 2021 78.20 l/s and in 2022 97.92 l/s.

Reviewing the statistical data on the average amount of precipitation that fell in the years 2018-2022, in the following we will examine how much water accumulated in the reservoir.

Table 2

Monthly precipitation amount in Cluj - Napoca [10]

Month	2018	2019	2020	2021	2022
January	9.90	59.00	8.80	30.30	16.70
February	27.10	19.40	39.30	23.60	11.40
March	40.90	18.00	48.60	41.60	9.90
April	23.00	73.20	30.70	41.70	49.30
May	36.40	136.20	56.90	74.30	97.40
June	173.40	36.40	109.30	33.60	19.90
July	68.60	37.80	60.20	130.60	25.20
August	22.00	57.20	88.30	70.60	87.80
September	48.80	18.40	42.60	31.10	91.70
October	61.60	18.10	50.70	12.10	29.20
November	32.00	18.90	21.00	23.00	20.10
December	74.80	16.40	37.20	73.70	24.20

Table 3

Annual rainfall amounts collected in the case study

Year	Collecting surface	Amount of precipitation accumulated in the tank annually	
	m^2	l	m^3
2018	732	452742	452.7
2019	2022	1029198	1029.2
2020	2875	1706600	1706.6
2021	2875	1685325	1685.3
2022	3600	1143360	1143.4

These volumes of water infiltrated back into the ground during the non-rainfall period and were returned to the natural water cycle without the need for additional costs associated with disposal. Since the collecting surface is represented by the walkable terraces of the buildings, the water quality is considered conventionally clean and can therefore be returned to the soil.

3. Conclusions

According to the data presented above, there is a continuous increase in the volume of water discharged into the reservoir, reaching a significant volume of 1143.40 m^3 of stormwater in 2022, exceeding the reservoir capacity by 23.81 times. From periodic visual checks of the tank, it was found that the water level in the tank never reached the level of the overflow pipe, so the amount of water reaching the tank was fully infiltrated into the soil, indicating the functionality of the proposed technical solution.

In this context, the use of storage and infiltration tanks is a sustainable solution as a first step in "Turning stormwater into a valuable asset".

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