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IMPLEMENTING CIRCULAR ECONOMY PRINCIPLES THROUGH A MODULAR TANK DESIGN APPROACH

Abstract: *In the context of the new directions concerning resource reuse and energy efficiency, the use of meteoric waters represents a sustainable solution in urban development. This paper presents modular tanks designed for the retention and infiltration of meteoric waters. These modular elements not only fulfil the requirements of circular water economy, but also enhance efficiency during implementation. The paper highlights the applicability of modular tanks in both residential and commercial complexes, demonstrating their sustainability in diverse settings. Additionally, the authors stress how important it is to be skilled in manipulating 2D and 3D spatial structures for realizing the geometric design of these modular tanks.*

Keywords: *modular tanks design, rainwater, circular economy, reuse, rainwater management*

1. INTRODUCTION

Water is one of the most valuable resources. It is an essential natural resource for the world's rapidly growing population. [1] It is also a basic right and a fundamental public good for life and development. [2] The scarcity of water produces negative effects in agriculture, in many industrial sectors, and overall quality of life. Climate change, increased agricultural activities and urban population growth have disrupted the hydrological balance, leading to an uneven distribution of rainfall. [3] The hydrological cycle illustrates water's circular nature, yet the evolution of the last hundred years has disrupted this cycle. [4] Thus, there is a pressing need to develop and implement the concept of circular water economy. In 2015, the United Nations (UN) established objective 6 with the theme of clean water and sanitation, which emphasizes the need to improve water quality and make its use more efficient, but also integrate water resources management. In 2019, the World Economic Forum ranked the water crisis fourth in terms of impact risk and ninth in likelihood. [5] At the onset of development, the industry followed the three stages take-make-dispose, which can be defined in the water sector as take-use-discharge. Over time, these three stages have proven to be unsustainable in line with climate change. In this context, in 1990, Pearce and Turner first introduced the concept of circular economy, and since 2010 it has been developed by the Ellen MacArthur Foundation across different sectors. Subsequently, the 6R strategy was developed: reduce, reuse, recycle, reclaim, recover, and restore, by which water is kept in circulation for a longer time to reduce the pressure on natural systems and to promote regeneration.

Mitigating the water stress to which our planet is subjected can be done by implementing the concept of circular economy. This theoretical solution can be integrated into practical application by incorporating the knowledge of descriptive geometry and graphics with elements of equipment sizing that serve the circular water economy.

According to the latest revisions, introduced in October 2023 to the European Directive 91, climate change will increase the probability of water overload because of storms and urban runoff. Thus, urban wastewater management infrastructures are particularly vulnerable to climate change. One of the new objectives is to reduce the water overload from stormwater to about 1% of the annual load of wastewater collected at the entrance to the treatment plant. At the same time, better management of water quantities in urban areas will contribute to adaptation to climate change. [6]

The idea of modular construction solutions is adopted both in civil construction, through modular houses, but also in building services through the design of modular tanks to make sustainable and efficient use of the available space. [7]

In this paper, we propose to present the solutions implemented in the context of reusing stormwater, water that we receive at no cost, but we spend important resources to reintroduce it into the natural water circuit.

The optimization of tank shapes played an important role in designing these solutions, enabling efficient utilization of space within the premises.

2. CIRCULAR ECONOMY OF WATER

The path to a circular water economy can take many forms. In this work, our approach is guided by the principles of reduce, reuse, recycle, reclaim, recover, and restore. Through the circular economy, we aim to reduce the amount of water consumed from the water supply network by harvesting rainwater that has fallen on-site.

This water is then stored, reused, and recycled for various purposes. Additionally, any excess rainwater that cannot be stored using the designed systems will be returned to the soil to restore the water balance.

In recent years, global warming and human activities have exacerbated water scarcity worldwide, leading to severe consequences in regions experiencing water stress, such as ecosystem destruction, food insecurity, and inadequate hygiene and health conditions. As the global population grows, so does the demand for water. According to the UNICEF report "Reimagining WASH - Water Security for All," the increase in water demand is directly correlated with population growth, urbanization, and improved living standards, further exacerbating water stress. [8] For this reason, protecting resources from water is fundamental. Sustainable water consumption can ensure the satisfaction of the basic human needs of the next generations, regardless of the geographical area.

Water - concept of sustainability, is one of the 17 objectives of sustainable development of the UN. In this context, sustainable management can be defined as the totality of activities that ensure the reduction of drinking water consumption, recycling, and reuse, so that wastewater and meteoric water are transformed into a valuable asset. Studies highlight the fact that up to 6.6 billion cubic meters of water could be reused per year. At the moment, we only reuse 1.1 billion. Due to the multiple possibilities of reuse, meteoric waters represent the most essential and effective way to ensure a sustainable development of buildings.

For such applications of the circular water economy, solutions can be implemented to collect meteoric water and reuse it for different purposes. However, an observed effect of climate change is the increase in the intensity of rainfall, resulting in a larger volume of water over a shorter period of time. One solution involves using tanks for accumulating and gradually infiltrating water into the soil. This process reintroduces water into its natural cycle, relieving both the sewerage network from excess rainwater and, more importantly, municipal treatment stations from processing these water flows. In this regard, the concept of circular water economy is becoming increasingly important. [2] We will further develop these ideas by presenting the solution with modular tanks in two designed and implemented applications.

3. APPLICATIONS WITH MODULAR TANKS

To meet the goals set by various international and European bodies, one solution is to store and utilize rainwater. This can be achieved using modular tanks for both accumulation and infiltration.

They can be placed on the premises with a buried mounting in the ground, allowing the land surface to be used for various purposes after covering, such as parking lots, green space, or playgrounds.

The constructive forms of the modular tanks can be adapted based on the available space at the location and the situations encountered during execution.

The constructive elements of the tanks are PP-B polypropylene plates equipped with holes to allow water to penetrate inside the tank. Figure 1 shows the components of modular tanks. The tanks are made of recyclable materials that can take the shape of the space available for placement in the ground.

For situations where the retention capacity is insufficient, several tanks can be interconnected, even with different geometric shapes, to create a tank capable of collecting the volume of rainwater. The modular boards are designed to facilitate tank maintenance and allow for video inspection when necessary.

Depending on the nature of the soil where the tank is located and the subsequent uses of the stored water, the installation of such a system will be done on a layer of compacted gravel with a granulation adapted to the situation. As can be seen in figure 2, such modular tanks can also be placed beneath heavy traffic roadways, being made of resistant materials. In this image, the solution of accumulating the water collected by the gutters was adopted.

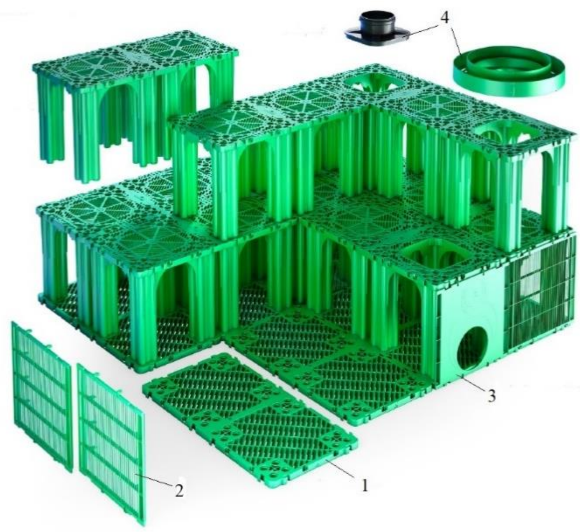

Figure 1 Modular tank component elements
1 – lower plate; 2 – side wall; 3 – pipe connection plate; 4- manhole adapters [9]

Figure 2 Modular tank component elements [10]

The design of such solutions necessitates a foundational understanding of three-dimensional design, a skill cultivated within building services engineering through the acquisition of knowledge from the earliest stages of engineering studies. It has been observed through studies, that the proficiency to mentally manipulate 2D and 3D figures is acquired following the study of descriptive geometry. [11]

2.1 Case study - residential complex

This case study is carried out for the storage of meteoric waters collected from 5050 m^2 of a residential complex having the height regime D+P+7E+R. The retention and infiltration tank are located both under the green space around the buildings and in the traffic area where a maximum speed of 60 km is allowed. The constructive form adopted is parallelepiped with dimensions 1200 * 600 * 600 mm occupying a volume of 432 L with a storage capacity of 412 L of water. The first stage in the realization of such a modular tank involves preparing the land where the modular elements will be installed. Subsequently, a geomembrane or geotextile is laid down, upon which the lower plates are assembled to outline the base of the reservoir in the designed shape (see fig.2). After defining the shape of the tank, the modules will be assembled vertically, and for access to the tank and ensuring ventilation inside, inspection chambers will be provided. For this case study, the inspection chambers are double-walled polypropylene mounted in the 4 corners of the parallelepiped.

Once all the component elements of the tank are assembled, it is enveloped with a geomembrane, which is then protected by a layer of compacted gravel, followed by the placement of soil. In the end, the planned organization from the exterior design project is put into place.

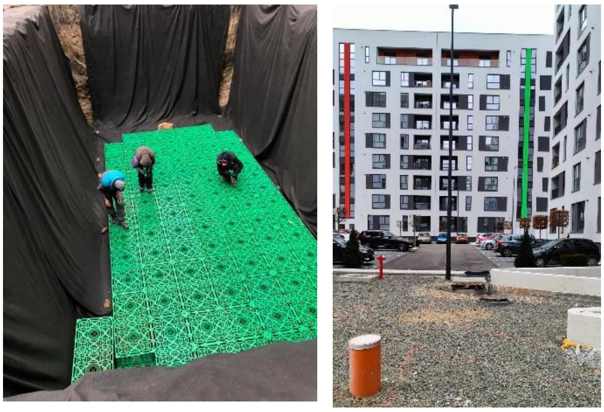

Figure 3 Stages in the realization of the project with modular tanks

In the solution presented, the modular tank serves to retain and infiltrate rainwater from the surfaces of the buildings' terraces.

2.2 Commercial complex case study

Considering the large areas of the commercial centres, managing stormwater, both from construction sites and parking lots, presents a persistent challenge.

The sewerage systems within these premises often operate at or beyond maximum capacity. To address this issue, infiltration tanks are utilized to gradually reintroduce accumulated water into the soil. This approach helps prevent overload of the locality's sewage system and wastewater treatment plants during periods of heavy rainfall.

This case study is carried out for a commercial centre in the capital area, where two retention and infiltration tanks were constructed. The first tank, designed to capture water from roofs and terraces, has a capacity of 173 Liters and spans a length of 18 meters, a width of 8.4 meters, and a depth of 1.2 meters. It stores water for external household needs such as watering green spaces and washing roads. The second tank has a capacity of 335 Liters, measuring 34.8 meters in length, 8.4 meters in width, and 1.2 meters in depth. From here, the water will seep into the ground gradually or it can be pumped controlled into the sewage system of the locality. As can be seen in figure 4, the 173l tank is equipped with geomembrane and geotextile being used for retention, and the 335l tank is covered only in geotextile, being used for infiltration. The placement of the reservoirs was carried out at a depth of 4.8 m compared to the level of the systematized land, so above them it will be possible to set up both green spaces and asphalted parking lots. [13,14]

An advantage of modular slab tanks is their short lead time. It took three weeks of working days for these two tanks. The construction stages are placing the first layer of geotextile and/or geomembrane, positioning the plates at the base of the tank, fixing the internal elements on the plates and then the side plates and the connecting ones.

Figure 4 Stages in the realization of modular tanks [12]

Subsequently, the entire structure is covered with a geomembrane or geotextile, with the number of layers chosen based on the intended use of the stored rainwater. Finally, ventilation holes, maintenance holes, and entrances and exits from the tank are provided, if such features are required.

Figure 5 Ventilation and maintenance holes of modular tanks [13]

For the solutions in which meteoric water is stored for later use, before the tank is covered with earth, tightness tests will be performed with compressed air. (see fig. 5) [12]

Figure 6 Carrying out the tightness test with compressed air [12]

The implementation of such solutions is more and more common considering the increase in meteorological events. There is an increasing demand on the sewage systems of the localities during periods of short duration but high intensity rains. In these moments with torrential rains, the sewerage networks of localities, urban ones in particular, are put under pressure. This situation also spreads in the sewage treatment plants, where large flows arrive that can disrupt the sewage treatment process. At the same time, climate changes, by registering higher and higher temperatures, subject the soil to water stress. The lack of water in the soil can lead to stability problems but also in agriculture.

In this scenario, the development of stormwater retention and local infiltration solutions is not just a necessity but a valuable resource. By implementing principles of the circular economy, such as water recovery, reuse, and restoration, we can effectively manage water resources and mitigate the impacts of extreme weather events.

3. CONCLUSIONS

Modular tanks are an efficient and sustainable solution for the reuse of stormwater. Their shape can be adapted in the design phase depending on the available space, but in situations when the situation on site requires it, these tanks can be given a different shape so that the capacity for which they were dimensioned is not changed. Adapting the designed solutions to what is actually on site can be done with 2D and 3D graphics.

Considering the European context in which amendments were made to Directive 91, which supports the development of local solutions for stormwater management, the solutions presented above correspond to these new amendments. This will reduce the amount of water discharged into the town's sewerage network, and the flow rates from the wastewater treatment plants.

Through the studies presented, it can be concluded that this idea can be applied both in the residential area and in the industrial-commercial area.

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