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Rainwater storage tank sizing: Case study of a commercial building

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Abstract

To revert the non-sustainable tendency of increasing surface and groundwater extraction to satisfy the rising demand of water, a more sustainable use of this essential resource must be done. Rainwater harvesting (RWH) systems are progressively becoming a part of the sustainable water management measures. However, they require a careful study to assess their feasibility, especially in large buildings, since they employ considerable investment costs and, in some cases, long payback periods.

This paper aims to define the best configuration for an RWH system of a commercial building, considering different scenarios of supplied non-potable uses, each of them with a subsequent rainwater storage volume. The results from three different scenarios are presented.

Keywords: Rainwater; Storage tank; Rippl method

1. Introduction

Water stress, that occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use (EEA, 2009), is a reality in many countries and climate change will only accentuate the frequency and intensity of those events in the future, namely in southern European countries (EEA, 2009), such as Portugal that has a high potential of water resources, although not available to use due to inappropriate temporal and spatial distributions. Besides, Portugal is already in the rank of countries with medium water stress (10–20%) worsened by high values of water use inefficiency, mainly in agriculture and urban areas (Melo-Batista, 2002).

To reverse the non-sustainable tendency of increasing surface and groundwater extraction to satisfy the rising demand of water, some changes must be done. In urban areas, those changes must focus on transforming people's behaviour, application of efficient measurements to reduce leakage and illegal water consumption in public supply systems, and raising the efficiency of water use. This efficiency shall be achieved by decreasing potable water consumption as well as wastewater production without compromising the comfort requirements on use. Urban water use is one

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of the most expensive potable water uses, whereby an increase of its efficiency will also provide significant economical savings.

Water scarcity is relevant not only to water threatened regions but also to those with an appropriate water supply infrastructure, due to the need to provide a constant water supply, essential for urban activities and development. In order to reduce potable water demand and minimize water scarcity consequences, the use of rainwater to supply non potable purposes has been investigated by many researchers in different countries (Herrmann and Schmida, 1999; Coombes et al., 1999; Fewkes, 1999; Cheng, 2003; Deng, 2003; Cheng and Hong, 2004; Ghisi, 2006; Wung et al., 2006; Ghisi and Oliveira, 2007; Ghisi and Ferreira, 2007; Ghisi et al., 2007; Panigrahi et al., 2007; Rahman et al., 2012; Imteaz et al., 2012). In fact, rainwater harvesting (RWH) renders one of the most reasonable solutions in dealing with current conditions, and several countries are reevaluating its importance (Hatt et al., 2006; Han et al., 2009; Zhang et al., 2009; Rygaard et al., 2011).

RWH systems are also becoming progressively a part of the sustainable storm water management measures (Butler et al., 2010). In countries with abundant water resources, it can also be used to reduce the load on urban drainage systems during intense precipitation (EEA, 2012).

An RWH system generally consists of a catchment area, a filter, a storage tank, a supply facility, pipes and an overflow unit. As a consequence, the main operational parameters that affect the system's efficiency are the amount of rainfall, the catchment area, the tank volume, the water demand, the efficiency of runoff collection and the filter (Mun and Han, 2012). Stored rainwater can be used in non-potable purposes, such as toilet flushing, pavement washing, irrigation, and washing machines.

These systems require, however, a careful study to assess their feasibility, especially in large buildings, since they involve considerable investment costs and, in some cases, long payback periods. The storage tank size is by far the largest factor of the total installation cost (Chilton et al., 2000); hence its optimization is essential in what concerns to feasibility criteria. Methods for design and operation of water supply reservoirs are usually worked on the basis of time intervals of one month (Treiber and Schultz, 1976). This coarse interval of time yields results of acceptable accuracy. The Rippl method found required reservoir capacity by use of the mass curve of an observed runoff time series of, usually, monthly values. According to Treiber and Schultz (1976) the Rippl method has two major deficiencies: the observed data are subject to sampling errors influencing the design results and the coarse time discretization produces too small required reservoir capacities. The influence of the coarse time discretization can be reduced by choosing daily time intervals instead of monthly values. However, it is known qualitatively that a reservoir designed with the aid of daily discharge values will become larger than a reservoir designed using monthly values. A proper analysis and design before implementing these systems is important to improve their performance and amplify the benefits and effectiveness (Imteaz et al., 2011; Mun and Han, 2012). Hence, determining the optimal tank capacity of an RWH system requires evaluation of system performance by the operational parameters that represent the system's efficiency (Mun and Han, 2012). The ratio tank volume *vs* catchment area recommended by the Korean Ministry of Environment (2008) is 0.05 m^3/m^2. The amount of rainwater collected and the level of demand for non-potable water uses must also be taken into account (ARSIT, 1998; German Institute for Standards, 2001).

Ward et al. (2010) have evaluated the design of two different RWH systems using three system design methods and presented necessity of refined continuous simulation tools. Normative and technical documents existing in Germany, UK and Portugal (ANQIP, 2009; BSI, 2009; fbr, 2002) recommend the use of a "detailed approach" based on daily simulations of the system's operation by using a model of yield and demand that considers continuous daily rainfall data corresponding to a time series from 3 to 10 years. However, the criteria to calculate the tank size using this approach are not referred, leading to the necessity to simulate several scenarios in order to obtain the storage volume that leads to an efficient and feasible system (Santos and Taveira-Pinto, 2013).

Chilton et al. (2000) studied a rainwater recovery system in a commercial building with a large roof area and obtained a payback period of 12 years. Although the payback was longer than would normally be considered economically viable, the rainwater system was implemented, since there are financial benefits of having reduced water and sewerage charges as well as securing an enhancement of the image as a company that is environmentally friendly.

This paper aims to define the best configuration for an RWH system of a commercial building, considering different scenarios of supplied non-potable uses, each of them with a subsequent rainwater storage volume. To achieve the proposed goals, a case study of a new commercial building in Braga, Portugal, was used. The results from the three different scenarios are presented.

2. Case study

Dolce Vita Braga is a new commercial building located in the north of Portugal, in Braga. This shopping centre (Fig. 1) includes several distinct but complementary areas, namely a shopping area (with commercial and retail area spaces), restaurants, leisure areas and a supermarket. The intervention area available for the project is 159,971 m^2, and the footprint of the whole commercial area is 46,611 m^2, for a gross floor area of 90,000 m^2. Structurally, the commercial building is distributed on three floors. The retail units are on a single floor, supported by a public parking spread over four floors. Overall, the whole business will be associated with a gross leasable area of 75,000 m^2, corresponding to 165 units, which will be allocated to different activities. There will be a total parking area of 62,000 m^2,