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The environmentally sustainable performance of siphonic rainwater drainage system in large roofs

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ABSTRACT

The objective of this article was to describe the performance of the two drainage systems, the Conventional Rainwater Drainage System (SCDAP) and the Siphonic Rainwater Drainage System (SSDAP), in order to differentiate these systems and associate them with environmental sustainability, therefore, evaluating their performance in the dematerialization and flood mitigation of a building. In the process of the bibliographic review for this article, knowledge was obtained that underlies the mitigation of floods and dematerialization, published in scientific journals, books, dissertations, theses and electronic network, from 1982 to 2023. The study was carried out using the international standards in force, ASPE 45:2018, BS 8490:2007 and VDI 3806:2000. Although the siphonic rainwater drainage system has completed approximately 50 years since its development, in Brazil it is still not very widespread, hence the relevance of the photographic data presented and analyzed by the authors. The dematerialization based on the calculation of the length and weight in the collector pipes and downpipes of the rainwater drainage system of a building allows carrying out a design exercise in which it can be concluded that there was a reduction in weight, energy consumption and emission of carbon dioxide from SSDAP in HDPE compared to SCDAP, both in PVC and HDPE.

KEYWORDS: Siphonic system. Roof drainage system. Dematerialization.

1 INTRODUCTION

The definition of sustainability in a broader sense is based on a tripod: environmental, social and economic sustainability (PETRIDES *et al.*, 2018). This author also defines dematerialization as the use of fewer materials in industrial products, linked to a more efficient use of energy. Other authors are concerned about problems arising from global warming such as flooding and its impacts on the most vulnerable communities living in floodplain areas (MEIRELLES *et al.*, 2019).

In recent decades, there has been a growing increase in the intensity, frequency and duration of rainfall, and due to urban densification, increasing waterproofing of surfaces, in addition to deficiencies in basic sanitation, flooding has occurred with material and human damage.

The Siphonic Rainwater Drainage System (SSDAP), developed since 1968, is a rainwater drainage system that can not only contribute to the mitigation of floods, but also provide dematerialization due to its characteristics, through reduction of energy consumption and reduction of carbon dioxide emissions (GAUTAM, BUDDHI, SIVASHANKAR, 2017).

The contribution of the SSDAP to sustainability will be evaluated through the simulation of a study in a fictitious work, evaluating the characteristics of the conventional and siphonic systems, in order to differentiate the dematerialization for this building and, in a global way, the potential for the mitigation of floods.

This article analyzes the SSDAP used in large roofs of commercial and industrial buildings, including hospitals, distribution centers, hotels, industries, stadiums and shopping malls, and its contribution to: i) flood mitigation through performance efficiency, and the characteristics of its operation, and ii) dematerialization based on the pipes used in the drainage systems, differentiating the conventional and siphonic systems.

The drainage of rainwater is part of the roofing of buildings, and its operation must be ensured by sizing in accordance with national (when existing) or international standards. Rainwater drainage systems are divided into SCDAP, which operates by gravity, according to standard NBR 10844:1989, and SSDAP, which operates by negative pressure (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 1989).

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The SSDAP is suitable for capturing water in large roofs. According to German standard VDI 3806:2000, large industrial and commercial roofs must have at least an area of 5,000 square meters (VEREIN DEUTSCHER INGENIEURE, 2000). The commercialization of SSDAP started slowly in Europe from 1976 onwards in Scandinavia, Germany, Switzerland and England (BRAMHALL, 2005).

Historically, SSDAP was developed in 1968, in the Nordic Countries, by researchers Olavi Ebeling and Risto Lunden (BRAMHALL, 2005). The system is formed by siphonic outlets, collector pipes and downpipes, which allow a full-bore flow in design flow rates, taking advantage of the total height difference between the siphonic outlet and the tailpipe of the system. According to Bramhall (2005), in full-bore flow, water and small amounts of air occupy the full bore of a pipe. The siphonic outlet is a component designed for the entry of water into a siphonic system, in order to allow the drainage of rainwater from a roof or gutter, in order to prevent air inflow into the pipe.

May (1997) contributed to the development of SSDAP describing the sizing of SCDAP and SSDAP, detailing the operation of both systems with equations. He concluded that there are several important points: the correct choice of rainfall intensity; the correct sizing of siphonic outlets in order to avoid air inflow; the importance and monitoring of the negative pressure in the pipes; the priming of the siphonic system; and the need for integration between the siphonic system and the drainage network outside the building.

According to Arthur and Swaffield (1999), the siphonic system operates by negative pressure, according to the Bernoulli principle, and has a greater drainage capacity than the conventional system. Negative pressure is the vacuum that forms in the siphonic system after priming. Also according to Arthur and Swaffield (1999), the conventional system operates according to the principles of free-flow conduits, that is, exclusively by gravity, and is sized to operate partially full, with pressure equal to or greater than atmospheric pressure. On the other hand, the siphonic system follows the principles of penstocks. This is possible thanks to the hydrostatic pressure difference between the water level in the gutter and the lower section of the downpipe.

Sommerhein (1999) analyzed and highlighted the most important parameters in the design of a siphonic system, in the case of a series of failures in installations which occurred in the United Kingdom in the 1990s. He concluded that the problems that occurred in the United Kingdom were linked to the type of construction of industrial and commercial buildings at that time, in addition to the design of siphonic systems with rainfall intensity of 75 mm/h. He highlighted the correct choice of the sizing roadmap, the importance of the height of the water depth in the gutters, the verification of the correct available load, the sizing of the downpipe, the priming time of the siphonic system and the use of different shafts for roofs in different levels.

Arthur and Swaffield (2001) provided a summary of the state of the art of the siphonic system, after almost 30 years of existence. The first operational topic highlighted is "operating pressure". Although the SSDAP is designed to operate at negative pressures of up to -800 mbar or -80 kPa, unexpected variations may arise due to: a) interaction with external drainage network; b) partial or total blockage and/or clogging of one or more siphonic outlets; c) post-design changes in the layout of the siphonic system, and d) inflow of unforeseen amounts of air

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into the siphonic system. They conclude by highlighting the importance of verifying the water height in the gutters in full operation, which must be carried out during sizing, in addition to the topics of priming of the siphonic system and maintenance, which is often neglected.

May (2004) established, at *Report SR 654*, the basic guidelines for a siphonic system design, encompassed in the BS 8490:2007 standard (British Standards Institute, 2007). Based on these 2004 guidelines, May has experimented over the years with water flow in gutters, roofs, air in pipes, cavitation in pipes, and a study of drainage in the conventional system. He highlighted the following topics: i) hydraulic sizing principles; ii) prerequisites for verifying imbalancing of the siphonic system; iii) minimum flow speeds in the siphonic system; iv) priming speed in the siphonic system and v) minimum pressures allowed.

2 OBJECTIVES

The objective of this article was to describe the performance of the two drainage systems, SCDAP and SSDAP, in order to differentiate these systems and associate them with environmental sustainability, therefore, evaluating their performance in the dematerialization and flood mitigation of a building.

3 METHODOLOGY

The methodology applied was literature review followed by a demonstration with differentiating studies. In the literature review, the systems, their components, their operation and sizing proposed by references to rainwater drainage systems were identified and described. As demonstration, a design exercise was carried out. In the analysis of international standards, emphasis was given to those that address and describe in detail the use of the SCDAP and SSDAP systems. National and international authors who study and research in universities and research institutions were identified.

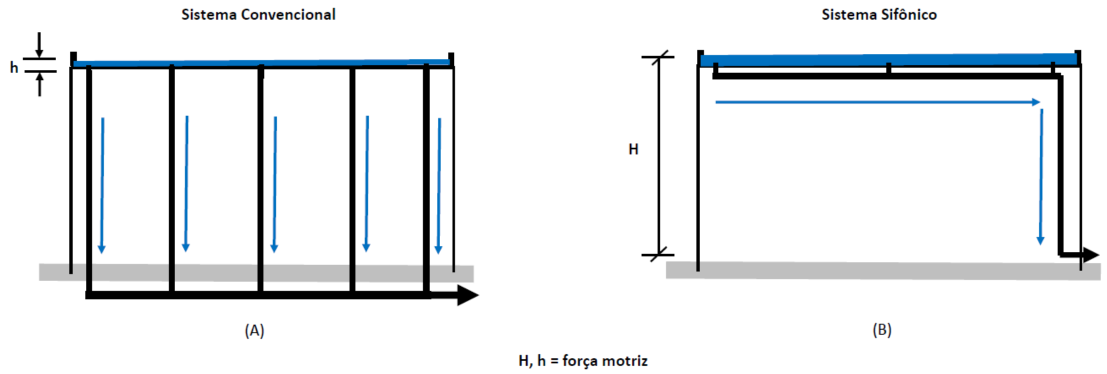
The following search terms were used: differences between roof drainage systems, siphonic systems, green roofs, flood mitigation and dematerialization. The main standards used were ASPE 45:2018 (AMERICAN SOCIETY OF PLUMBING ENGINEERS, 2018), BS 8490:2007 and VDI 3806:2000, in addition to the works by Rickmann (2019), Friedrich (2019) and Keidel (2020). The illustrations in this article come from the bibliographic references collected and from the design exercise.

4 RESULTS

4.1 Differentiation between SSDAP and SCDAP

Figure 1 shows schematically some of the differences between the conventional system and the siphonic system. In the conventional system (A) the rainwater is collected by nozzles being routed to several downpipes leaving the building through a collector pipe, below the floor. In the siphonic system (B) the rainwater colected by siphonic outlets is routed to a suspended collector pipe, leaving the building through a downpipe. Note that the siphonic system in (B) allows a gain in space inside the building, unlike the conventional system in (A). Heights "H" and "h" express the height available for the driving force required for the systems to operate.

Figure 1 – Differentiation between conventional (A) and siphonic (B) systems, and with outer and inner gutters and piping layout

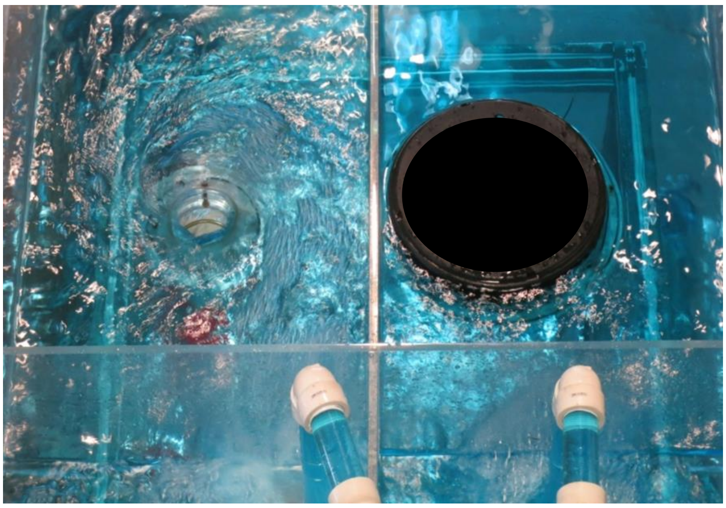


Source: (A) and (B) modified from Verstraten (2019, p.92).

Figure 2 shows the collection of rainwater in the conventional system with the formation of a vortex (A), in (B) a siphonic outlet is visualized capturing rainwater, fully covered, that is, working at the design flow rate.

Figure 2: Conventional system - Collection of rainwater with vortex formation(A) and siphonic system - Rainwater collection with siphonic outlet (B)

(A) (B)



Source: Richers (2023).

Table 1 presents a summary of the main characteristics and operating parameters that differentiate conventional and siphonic rainwater drainage systems, highlighting the following parameters: i) pipe diameters; ii) degree of filling of the pipes; iii) inclination of the pipes; iv) collection points; v) operating principle; vi) number of junction boxes; vii) need for an emergency system; viii) need for junction boxes, and ix) pipe speed. The information was obtained from the main international standards in force.

Table 1 – Summary of the main characteristics and design parameters of the conventional and siphonic systems

Parâmetros	Sistema Convencional	Sistema Sifônico
Tube diameter	DN 75 until DN 400	DN 75 - DN 300 (The tube has a smaller diameter than in the conventional system)
Filling the tubes	horizontal conductors filling 50 - 65% / vertical conductors filling 35%	horizontal and vertical conductors 95-97%
Tube inclination	yes, 1,0 - 1,5 %	it is not necessary
Collection points in gutters and roofs / plumbed	many colletion points / more plumbs (1 plumb occupies 0.5 m2 of floor)	few collection points / less plumb
Operation principle	gravity	gravity up to 40% filling of the tubes, above this value siphoning begins
Number of junction boxes	more plumb ones require a greater number of internal and external junction boxes	less plumb require fewer junction boxes
Internal gutter drainage requires an emergency system	yes	yes
Drainage of internal gutters without internal junction boxes	no	yes
Water speed in pipes / cleaning	max. 0.6 - 0.7 m/s / system is not self-cleaning	1.0 to 7.0 m/s / system is self-cleaning

Source: The authors, based on international standards ASPE 45:2018 of the American Society of Plumbing Engineers (2018); BS 8490:2007 British Standards Institute (2007); VDI 3806:2000 Verein Deutscher Ingenieure (2000).

4.2 The importance of efficient and sustainable roof drainage systems

The differentiation between the two roof rainwater drainage systems, the SCDAP and the SSDAP, in terms of their environmental sustainability, will be evaluated by analyzing their performance in dematerialization and in mitigating floods.

4.2.1 Dematerialization

According to Petrides (2018) dematerialization is linked to the technological development of products, to the rebound effect, the latter defined as the phenomenon in which savings in materials and energy are offset by the more frequent use of these prod ucts and other carbon-intensive generation actions linked to Life Cycle Analysis (LCA). The optimization of dematerialization occurs through the dematerialization index that is greater than the material consumption index and leads to environmental sustainability, observing each stage of the products life cycle.

The civil construction sector is being pressured worldwide to adopt more sustainable designs, with an emphasis on the extraction and use of raw materials. The projection for the next 50 years indicates that there may be an increase of 2.3 billion square meters in buildings (mainly residential due to the increase in the world population) in civil construction, linked to a 50% increase in global energy consumption according to Skillington and Crawford (2020). The potential of dematerialization of plastic resins applied in pipes and connections, among others, can be seen in Figure 3 (A). Authors Pickard and Sharp (2020), based on the world consumption of plastic resins in civil construction, of 65 million tons in 2015, made a projection until 2050 and

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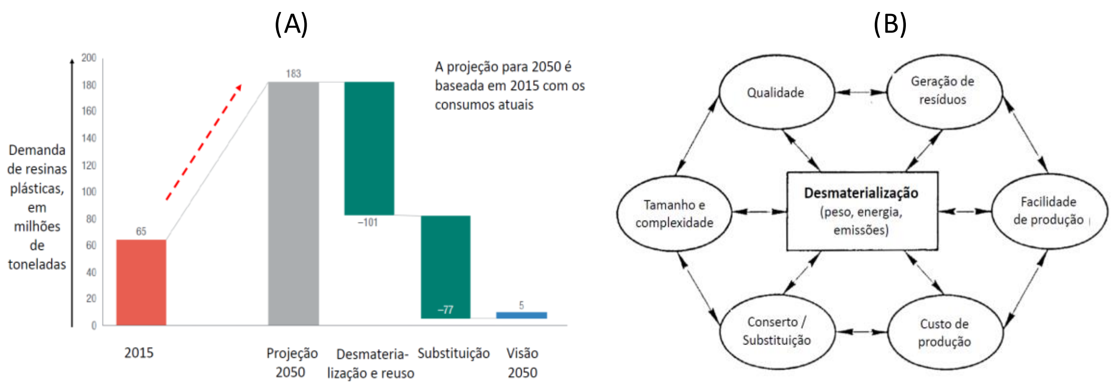
suggest quantities that could be dematerialized and used, replaced and remaining in 2050. The amount attributed to dematerialization and use is significant (55% of the total of 183 million tons in 2050).

The dematerialization of a given product according to Herman, Arkedani and Ausubel (1990) is affected and influenced by a series of factors besides the quality of the product. These factors include the production process, production costs, product size and complexity, whether the product can be repaired or replaced, and the amounts of waste that are generated that must be processed. The influence of these factors on each other is schematically shown in Figure 3 (B). Additional relevant factors are economic and population growth.

Figure 3 – Potential for reducing the consumption of plastic resins, including dematerialization, projection for 2050, starting in 2015 in (A) and factors of dematerialization in (B)



Source: Modified from Pickard and Sharp (2020) in (A) and translated from Herman, Arkedani and Ausubel (1990) in (B).

Gautam, Buddhi and Sivashankar (2017) define sustainable development in civil construction, in which the occupants of a habitat have the greatest comfort with the least possible environmental impact as green construction. They also report that, in commercial and industrial buildings with large roofs, there are few components with such a high potential for dematerialization as SCDAP, and SSDAP is an efficient technology for roof drainage with the use of less material than the conventional system, as it requires less pipes with smaller diameters.

Despite all efforts to implement cleaner energy and more sustainable environmental policies, the amount of greenhouse gases emissions is increasing (GAUTAM, BUDDHI, SIVASHANKAR, 2017). Additionally, climate changes are occurring with an increase in the intensity, frequency and duration of rain. It is imperative to size rainwater drainage systems to increase the safety and life cycle of buildings.

4.2.2 Evaluation of dematerialization in a design study

The building to be used as an example is a shed with approximately 32,300 square meters of roof, with outer and inner gutters. Dematerialization in this building will be demonstrated by calculating the length and weight of the collector pipe and downpipe. Dematerialization can be characterized by the weight of the plastic resin pipes used, the energy consumption and the emission of carbon dioxide. Two different and more common cases will be evaluated: i)

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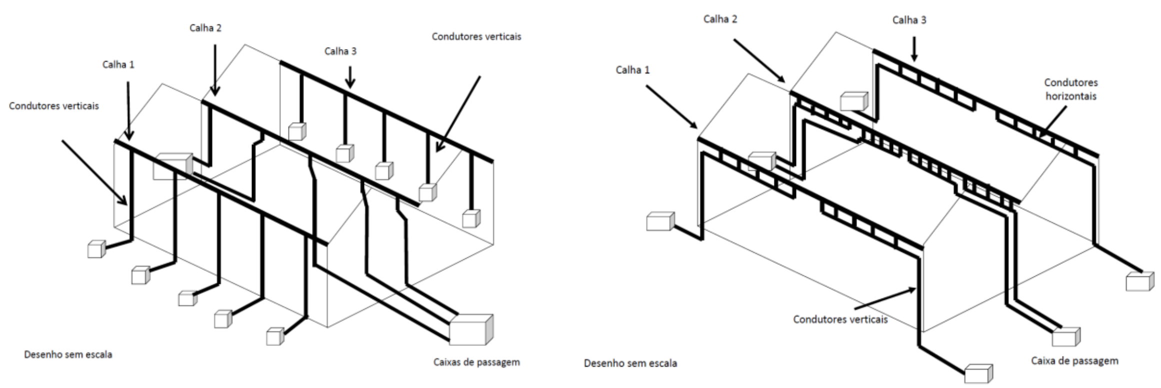
conventional system in Polyvinyl Chloride (PVC) and siphonic system in HDPE, and ii) conventional and siphonic system in HDPE. It is important to point out that the conventional system normally presents quantities of pipes with larger diameters and lengths, unlike the siphonic system, as previously mentioned in this work. Below are some parameters of the building used as an example (RICHERS, 2018).

Basic parameters of the example construction (design study): i) coverage area 32,300 square meters; ii) length 190 m; iii) width 170 m; iv) amount of water and area 4 x 8,075 square meters; v) internal junction boxes: none; vi) number of outer gutters 2; vii) number of inner gutters 1; viii) inclination of the gutters 0.5%; ix) outer gutter section 0.8 x 0.45 m; x) inner gutter section 1.0 x 0.65 m and xi) rainfall intensity 191 mm/h.

Figure 4 shows schematically the building and the layout of the collector pipe and downpipe for a conventional system (A) and for a siphonic system (B), referring to the design study.

Figure 4 – Building with conventional system (A) and siphonic system (B) of the design study



(A) (B)

Source: Modified from Richers (2018).

The application of the basic construction parameters mentioned above makes it possible to calculate the total lengths of the collector pipe and downpipe and their respective diameters: i) conventional PVC system with 230 m DN 100 pipes, 1,316 m DN 300 pipes, totaling 1,546 m and ii) HDPE siphonic system with 76 m DN 125 pipes, 114 m DN 160 pipes, 114 m DN 200 pipes, 266 m DN 250 pipes and 112 m DN 315 pipes, totaling 682 m.

Table 2 represents the diameters, lengths, weights per meter, partial weight and weight of the pipes of the conventional and siphonic systems with PVC and HDPE pipes, as well as the calculation of energy consumption and carbon dioxide emissions. Thus: i) item (A) represents the calculation of the weight of the PVC pipes (14,775.0 kg) of the conventional system, based on the previously calculated length (1,546.0 m); ii) item (B) represents the calculation of the weight of the HDPE pipes (12,890.3 kg) of the conventional system, based on the previously calculated length (1,546.0 m); iii) item (C) represents the calculation of the weight of the HDPE pipes (3,586.1 kg) of the siphonic system, based on the previously calculated length (682.0 m); iv) item (D) represents the calculation of energy consumption and carbon dioxide emission,

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comparing the conventional PVC system and the siphonic HDPE system. The reduction is expressed as a percentage (%) and v) item (E) represents the calculation of energy consumption and carbon dioxide emission, comparing the conventional system and the siphonic system, both in HDPE. The reduction is expressed as a percentage (%).

Table 2 – Conventional and siphonic system – diameters, lengths, weights per meter, total weight, energy consumption and carbon dioxide emissions

(A) PVC pipes - Conventional system						
Type	Diameter in millimeters (mm)	Length in meters (m)	Wall thickness (mm)	Weight per meter (Kg/m)	Total weight (kg)	
1	DN 100	230,0	2,5	1,30	299,00	
2	DN 300	1.316,0	7,7	11,00	14.476,00	
	TOTAL	**1.546,0**			**14.775,00**	
(B) HDPE pipes - Conventional system						
Type	Diameter in millimeters (mm)	Length in meters (m)	Wall thickness (mm)	Weight per meter (Kg/m)	Total weight (kg)	
1	DN 125	230,0	4,8	1,86	427,80	
2	DN 315	1.316,0	9,7	9,47	12.462,52	
	TOTAL	**1.546,0**			**12.890,32**	
(C) HDPE pipes - Siphonic system						
Type	Diameter in millimeters (mm)	Length in meters (m)	Wall thickness (mm)	Weight per meter (Kg/m)	Total weight (kg)	
1	DN 125	76,0	4,8	1,86	141,36	
2	DN 160	114,0	6,2	3,08	351,12	
3	DN 200	114,0	6,2	3,88	442,32	
4	DN 250	266,0	7,7	5,98	1.590,68	
5	DN 315	112,0	9,7	9,47	1.060,64	
	TOTAL	**682,0**			**3.586,12**	
(D) Calculation of energy consumption and carbon dioxide emission - Conventional system in PVC and siphonic system in HDPE						
Physical data		PVC (pipes)	HDPE (tubes)	Conventional System (SCDAP) PVC (A)	Siphonic System in (SSDAP) HDPE (B)	Reduction in % (A - B / A)
Weight (kg)				14.775,0	3.586,12	75,7
Energy consumption (MJ/Kg)		67,5	84,4	997.312,5	302.666,84	69,6
CO2 emission (KgCO2/Kg)		2,5	2,0	36.937,5	7.172,20	80,6
(E) Calculation of energy consumption and carbon dioxide emission - Conventional system and siphonic system in HDPE						
Physical data		HDPE	Conventional System (SCDAP) HDPE (A)	Siphonic System in (SSDAP) HDPE (B)	Reduction in % (A - B / A)	
Weight (kg)			12.890,3	3.586,12	72,2	
Energy consumption (MJ/Kg)		84,4	1.087.941,3	302.666,84	72,2	
CO2 emission (KgCO2/Kg)		2,0	25.780,6	7.172,24	72,2	

Source: Authors and NBR 7362-2:1999 Brazilian Association of Technical Standards (1999, p.2), DIN 8074:2011, Deutsches Institut für Normung (2011, p.13) and energy consumption and carbon dioxide emissions Hammond, Jones - ICE (2008, p.13).

In Table 2, item (D), in the comparison of the conventional system in PVC and the siphonic system in HDPE, in the construction of the design study (Figure 4), there is a weight reduction of 75.7%, a reduction in energy consumption of 69.6% and a carbon dioxide emission reduction of 80.6%. Still in Table 2, item (E), in the comparison of the conventional system and the siphonic system, both in HDPE, applied to the construction of the design study (Figure 4), there is a reduction in weight, energy consumption and carbon dioxide emission of 72.2%. The unit values of energy consumption and carbon dioxide emission used in table 2 refer to the publication by Hammond, Jones (ICE), 2008, p.13.

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4.2.3 Flood mitigation

According to Andrade (2006), the terms overflow, flood and inundation are often mentioned as synonyms, but they must be used differently as they describe different phenomena. The author defines the term overflow as the situation in which, after rain, the channel of the watercourse is completely full. The term inundation refers to the extravasation of rainwater during heavy rains to the marginal areas of a watercourse and the term flood when the channel of the watercourse is not full but there is accumulation of water in the marginal areas.

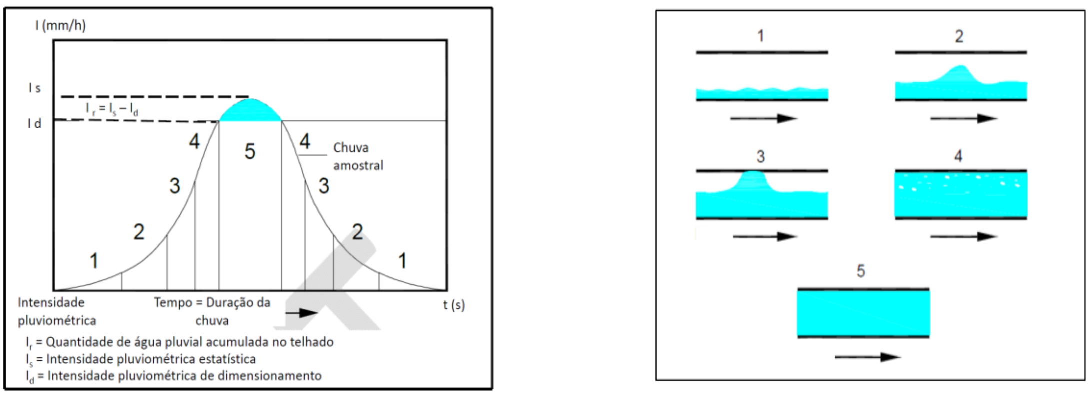
Rainwater drainage systems can be part of the measures to mitigate floods, in addition to other devices such as green roofs. In recent decades, there has been an increasing urbanization of cities due to the increase in population. Thus, in 1950, on a global scale, the share of the population concentrated in urban areas was 30%, increasing to 55% in 2018 and expected to reach 68% in 2050. According to the Institute for Applied Economic Research (2020), the United Nations, in its 2018 Perspectives for Urban Population publication, found that for Brazil, in 2015, there was already a concentration of population in urban areas corresponding to 85%, reaching 87% in 2018.

The siphonic system is a rainwater drainage system that operates intermittently. This characteristic is important to understand the ability of the system to: i) accumulate rainwater in the pipes of its layout, and ii) accumulate rainwater in the gutters as a function of the height of the water depth in the gutter, a fact that can be even more accentuated when the siphonic system has an emergency system that is also siphonic. SSDAP only starts operating when the entire pipeline is approximately 60% full. The design flow rate is achieved when the siphonic outlet is practically covered with water. In this situation, the water depth can reach more than 100 mm in height, depending on the type of siphonic outlet used.

In Figure 5 (A) according to the ASPE45:2018 standard, "Id" represents the sizing rainfall intensity, in this case, lower than the statistical rainfall intensity "Is", of a sample rain, with return time "T" and duration "t", in seconds. The area in blue is designated by "Ir", where Ir = Is – Id, representing the amount of rainwater accumulated on the roof and gutters, until the emergency exit level is reached or until the rain stops.

Figure 5 - Filling process of the siphonic system on the left and types of water flow in the pipe on the right

(A) (B)



Source: ASPE 45:2018 of the American Society of Plumbing Engineers (2018, p.14).

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Figure 5 (B), also according to the ASPE45:2018 standard, describes the five types of flow found in the siphonic system piping when it is fully primed and subsequent emptying. The direction of water flow is given by the arrows in Figure 5 (B). Type 1 flow occurs in light rains, well below the flow rate required for the priming of the pipes. The wave flow shown is found in type 1. Type 2 flow is a pulsating flow, normally occurring at the meeting of the tailpipe and the collector pipe. This type of flow usually occurs due to a sudden decrease in water speed, when the water leaves the smaller pipes and enters the larger ones. At this point, the fluid transitions from a supercritical to a subcritical regime, that is, a hydraulic jump. Type 3 flow occurs with increasing rainfall intensity and when the hydraulic jump peaks reach the upper inner part of the pipes, propagating towards the downpipe, that is, towards the tailpipe. In type 4 flow, with the further increase in rainfall, the pipes begin to fill and the amount of air in the water decreases. When the amount of air decreases to approximately 40%, the system begins to siphon, at the same time there is a decrease in static pressure, becoming less than atmospheric pressure, that is, becoming negative. The air that still exists in the pipes mixes with the water and is carried out of the system through the downpipe. Finally, the type 5 flow no longer contains air and is called typical flow of the priming, equivalent to reaching the design flow rate of the siphonic system. The small amounts of air still present are usually less than 5%. When the amount of rainfall decreases, the reversal of type 5 flow to type 1 occurs until the rain completely stops. With the variation of rainfall intensity, the flow can quickly change from type 1 to 5 and vice versa.

In Figure 6 below, the flow rate curve by flow time of the conventional system is presented, in blue color, in which the collector pipe and downpipe are filled with 30% to 50% of water. The remaining is air. The flow rate curve by flow time of the siphonic system, in green, in which the collector pipe and downpipe are filled with 100% of water and present a diameter that corresponds to half the diameter of the pipes in the conventional system. According to Keidel (2020), the design flow rate of an SSDAP is reached when the collector pipe and downpipe are completely filled and the siphonic outlets are practically covered. This priming time may take a few minutes, depending on the building. Roofs, slabs and gutters, depending on the building, can accumulate rainwater, contributing to mitigation. The rainwater stored in the collector pipe and downpipe and in the gutter until it covers the siphonic outlets represents a volume of retained water that can help mitigate potential flooding. Gutters, in particular inner gutters, must be provided with a secondary or emergency drainage system, as required by EN 12056-3:2000 (DEUTSCHES INSTITUT FÜR NORMUNG, 2000). There is a difference in the tracing of the flow curves and that between the conventional system and the siphonic system there is a lag that corresponds to the priming time of the siphonic system and the volume of water stored in the gutter. When the siphonic system reaches the design flow rate, the flow is constant for a period of time, decreasing after this time. As already mentioned, the siphonic system operates intermittently. In the conventional system, there is a very pronounced increase in the flow rate in a short period of time. The differentiation of the curves indicates that the siphonic system can act in the mitigation of floods depending on the flow curve traced by time, regulating the flow rate, with an effect on the external and/or internal junction boxes of the building (KEIDEl, 2020).

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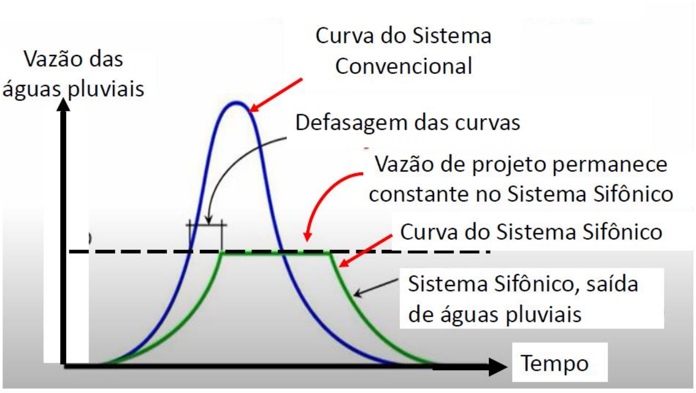
Figure 6 – Differentiation between the curves of the siphonic and conventional system regarding the variation in the flow of rainwater over time



Source: Keidel (2020), translated by the authors.

The gutters are not part of SCDAP and SSDAP. As rainwater can accumulate, the authors Rickmann (2019) and Friedrich (2019) report that a rainwater collector gutter may have a rainwater flow with three different heights: i) height of the water depth in the gutter with design flow rate; ii) height of the water depth in the gutter corresponding to the emergency exit, and iii) height of the freeboard gutter.

The DIN 1986-100:2008 standard establishes minimum values for the freeboard height depending on the height of the water depth in the gutter at the design flow rate (DEUTSCHES INSTITUT FÜR NORMUNG, 2008). Thus: i) for heights of the water depth in the gutter (always at the design flow rate) less than 85 mm, the freeboard must be greater than 25 mm; ii) for values between 85-250 mm the freeboard must be three times the height of the water depth, and iii) for heights of the water depth above 250mm the freeboard must be greater than 75 mm.

In Figure 7, in (A), sections of gutters with siphonic outlets are visualized in commercial and industrial buildings, partially submerged and totally submerged. It must be remembered that siphonic outlets only reach their design flow rate when they are covered by water.

Figure 7 – Section of gutter with rain and semi-submerged and fully submerged outlets (A) in emergency system (B)

(A) (B)

Source: Richers (2023).

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In commercial and industrial buildings, the inner gutters and occasionally also the outer ones have a rainwater drainage system called secondary or emergency, especially when the gutters are extensive, for example over 100 m. In Figure 7 (B), a section of gutter with two siphonic outlets is shown. The foreground siphonic outlet (bottom of the figure) is the primary siphonic outlet, and the background siphonic outlet (top of the figure) is a secondary or emergency siphonic outlet, installed over a stainless steel ring, or that is, the siphonic outlet operates at a higher level and only starts operating when the water level reaches the upper part of the ring. This arrangement of the siphonic outlets will avoid a possible overflow of the gutter.

4.2.4 Use of Rainwater

Lucke, Beecham and Zillante (2007) note the importance of water management as an integral part of the practice of sustainable construction. In some countries such as Australia, the focus in new buildings is on energy and water reduction, with rainwater being collected and used. The authors mention that in SSDAP, rainwater, due to its driving force from its potential energy and high speed, using few downpipes, can be directed to collection tanks even distant, without any need for pumping. In the case of SCDAP, due to the many downpipes and the use of junction boxes, rainwater needs to be pumped to a collection tank.

4.2.5 Green roofs

SSDAP can contribute to flood mitigation when installed on green roofs. The high speeds of rainwater in its conduits ensure self-cleaning, even if the SSDAP is operating at only 10-15% of its design flow rate (CAPCON, 2022). The green roofs of buildings can retain rainwater that will be slowly drained by the drainage system designed for this purpose. Figure 8 (A) shows a building with a green roof. Figure 8 (B) shows the section of a green roof. The green roof is composed of five layers: i) a layer of grass or similar vegetation; ii) layer of earth with sand; iii) felt or synthetic filter; iv) layer of filter material, and v) layer of impermeable or synthetic material. The positioning of the special siphonic outlets (with flange-type device and protection against clogging) is indicated by a red arrow.

Figure 8 – Building with green roof (A) and section of green roof with its composing layers (B)

(A)

(B)

Source: Mobility Summit (2020) in (A) and adapted by the authors of HydroMax™ Siphonic Drainage / B. Ross (2012) in (B).

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5 CONCLUSION

The differentiation regarding the characteristics and parameters of rainwater drainage, with SCDAP and SSDAP, was only possible from the collection of the three international standards in force, ASPE 45:2018, BS 8490:2007 and VDI 3806:2000. These standards highlight the following parameters: i) Smaller pipe diameters in the siphonic system, ii) Priming of the collector pipe and downpipe in the siphonic system and iii) Smaller number of junction boxes in the siphonic system due to the smaller amount of shafts.

The dematerialization based on the calculation of the length and weight in the collector pipe and downpipe of a building allows carrying out a design exercise in which it can be concluded that: i) SSDAP in HDPE has a weight reduction of 75.7%(kg), a reduction in energy consumption of 69.6%(MJ/kg) and a reduction in carbon dioxide emission of 80.6%(kgCO2/kg) compared to SCDAP in PVC and ii) the SSDAP in HDPE presents a 72.2% reduction in weight (kg), energy consumption (MJ/kg) and carbon dioxide gas emission (kgCO2/kg) in relation to SCDAP, also in HDPE.

The mitigation of flood is studied from three variables: i) The water flow rate, ii) The presence of gutters and iii) The installation of green roofs. In the first item, the difference in the tracing of the flow curves of the two systems points to a lag that corresponds to their priming time, in which the conventional system has a pronounced increase in the flow rate in a short period of time, which does not occur in the siphonic system. In the second item, the gutters in which a siphonic system is installed can store a considerable volume of rainwater, retaining the volume of water from flooding. Finally, in the third item, the installation of green roofs contributes in a similar way to item two, as it acts to retain the volume of rainwater, also mitigating the effect of flooding.

Although the SSDAP has already completed approximately 50 years since its development, in Brazil it is still not widespread. In Europe, Asia, Australia and the United States of America, the use of SSDAP is widespread and the sizing is based on standards, in addition to its well-known advantages. It is therefore concluded that the fact that SSDAP is still not widespread in Brazil is due, among other factors, to the lack of greater dissemination, the large-scale use of SCDAP and the lack of a Brazilian standard for SSDAP.

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