WATER CONSUMPTION BALANCE AT DWELLING AND DISTRICT SCALE: AN INNOVATIVE PROSPECTIVE FOR *CARTEGENA DE INDIAS – EL POZÓN*

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Abstract

The consequences of climate change are affecting informal neighbourhoods, exacerbating even more the instability and insecurity of these settlements. For instance, the settlement of *El Pozón*, located in the Colombian city of *Cartagena de Indias*, in addition to its social and economic problems, is characterized by a contradictory environmental situation: on the one hand it suffers the problem of floods due to its proximity to the *La Virgen* swamp and to seasonal heavy rainfall. On the other hand, the supply of drinking and domestic water is problematic - specially in dry season- and reaches unsustainable costs for a population who lives in marginal conditions (Guarín Cobos, 2003).

The project of the *Pontificia Universidad Javeriana* of Bogotá and the *Politecnico di Torino*, presented at the Solar Decathlon Latin America & Caribbean 2019 was aimed at improving the quality of life of the *El Pozón* inhabitants, offering a new model of economic and sustainable house, self-sufficient from an energy point of view and achievable largely in self-construction with local materials and dry technologies. The prototype, that was built and tested for the duration of the contest, proposed an integrated water use strategy at the building scale, which combines different low-tech systems. This article presents a possible methodology to realize a low-tech water technology: a blue-green roof module to incorporate into the design of the Solar Decathlon prototype. The main purpose is to stimulate the inhabitants to address problems such as lack of sanitation, water quality and environmental improvement, through a scalable, sustainable and cost-effective solution, using mainly waste materials.

Keywords: domestic water, water cycle, *vivienda social*, rain garden.

Introduction

Currently, large population areas around the world are being affected by phenomena related to human activities: climate change and incorrect urbanization (UN Habitat, 2018). With the guidance of the public and private sectors, some of these areas are already arming themselves with urban plans for greening and depaving, proposing appropriate solutions aimed at achieving resilience against these phenomena – e.g., Sustainable Urban Drainage Systems (SUDS) (Zhou, 2014). Unfortunately, in marginal situations such as informal neighbourhoods that arise spontaneously, the population is abandoned to itself (UN Habitat, 2018). The main purpose of the study is to identify a possible methodology that can stimulate informal settlements inhabitants to address problems such as lack of sanitation and water scarcity through a scalable, sustainable and cost-effective solution.

This paper presents one case study in particular, the informal neighbourhood *El Pozón* in *Cartagena de Indias*, Colombia. It is located near the southern bank of the *La Virgen* swamp, where a multiplicity of houses, mostly self-constructed, rise spontaneously and without any building regulations. The uncontrolled - and in some cases inexperienced - housing construction has generated different problems regarding basic living conditions. Furthermore, due to its proximity to the mangrove's lagoon, the settlement - as well as others in the area - has been subject to flooding several times in the past, being the most serious episode in 2011[1].

The *Pontificia Universidad Javeriana* of Bogota, together with the *Politecnico di Torino* tried to provide an appropriate response for a more resilient and sustainable development of the neighbourhood, through the urban project *Máquina Verde - El Arca*. A prototype housing module of the project was proposed and built for the international competition Solar Decathlon Latin America & Caribbean 2019 which took place in Cali, Colombia, and in which the authors of this article participated as part of the *Máquina Verde - El Arca* design and construction team. The particular assignment of the authors was to determining the hydraulic design of the prototype housing module with a sustainability focus regarding the saving, recovery and reuse of water resources. This experience has brought the team to work with experts in the field and local companies. At the same time, information was acquired about the water needs of the occupants and forecast consumption and the savings of individual equipment were planned.

Following the realization of the prototype at the Solar Decathlon competition, the team carried out further visits to *El Pozón*. The tours to the area provided an idea to integrate into the house's plumbing system: the development of a modular prototype of a green roof system for the collection and cleaning of rainwater. Following a research of modules currently present on the market that serve this function, and the analysis of the elements and materials that compose them, it was decided to design a green module in self-construction with the aim of reusing waste materials and giving them new life. The technical part of the research demonstrates the performance of water management strategies used on the private spaces, trying to apply them also to the green public spaces of the *Máquina Verde - El Arca* project through a connected network system, from the microscale of the housing module to the Masterplan. The study determines a possible solution, leaving the door open to the possibility of a future development of the *Máquina Verde - El Arca* project that incorporates these technologies, providing a large-scale impact to reduce the environmental pollution that affects the *La Virgen* swamp and, at the same time, to counteract the floods result of climate change (Ayala García & Meisel Roca, 2017).

Case study: *EL Pozón, Cartagena de Indias*

The different social groups that over the centuries have interacted on the territory of Colombia have brought with them their own culture, customs and lifestyles, contributing to the ethnic diversity of the nation. Although this condition was recognized by the Colombian State in the Constitution of 1991, race-related conflicts are still present today, as well as imbalances – social and economic inequalities - between communities and territories (Sánchez-Torres, 2017). For all these reasons, the internal – especially rural - populations are displaced and are continually forced to move to the cities in search of better living conditions. According to official data of the

[1] Information obtained from interviews with the inhabitants of the sector and verified through journals and news reports of the time.

International Fund for Agricultural Development (IFAD) in 2018, in rural Colombia, 7.2 per cent of the population -3.5 million of citizens- lived in extreme poverty[2]. For this segment of the population, the opportunities for access to adequate education and employment are minimal (Sánchez-Torres, 2017).

In addition to these problems there are also environmental difficulties, mainly caused by the rising temperatures and the sudden changes in rainfall, which affects the vulnerability of coastal areas, increasingly subject to frequent flooding (UN Habitat, 2018). One of the areas where the population is mainly affected by this issue is the Bolivar department, whose capital city - *Cartagena de Indias* - fully reflects the social and economic inequality of the nation (Hernandez Correa, 2018).

The historic centre of *Cartagena de Indias* is the most important tourist nucleus in the country. However, investigating the city's most recent history, it can be noticed a very serious imbalance between the more central areas and the outskirt, arising social problems - that affect most of the contemporary Colombian cities - such as insecurity, poverty, deficit in services and infrastructure and environmental issues (Ayala García & Meisel Roca, 2017). One of the most famous neighbourhoods on the outskirts is *El Pozón*, located in the far north-east area of the city. Its history is representative of the invasion phenomenon which remains today one of the most practised means of space occupation in popular sectors. Generally, these are areas of suburban or rural expansion established out of the bounds of the administrative borders.

Figure 1. Informal houses of *El Pozón* with different levels of consolidation. Photos taken during the visits to the neighbourhood

Figure 2. The bodies of water are in a high state of disrepair. Photos taken during the visits to the neighbourhood

El Pozón began in the early 1990s as an illegal neighbourhood, an invasion of the *La Virgen* swamp by people arriving mainly from villages and rural areas of the region. Many of them obliged to migrate because of forced displacement and violence. The form of occupation was based on the principle of the "4 sticks' law": this stated that whoever took possession of a plot on the water of the swamp, with a maximum size of 6x12 metres and took responsibility for filling it, could consider him/herself the owner of the land and could build his/her house. Some

[2] Information retrieved from https://www.ifad.org/

of the houses in *El Pozón* continue to be illegal, but others have become legal through agreements with the government. However, the expansion and filling of the swamp continues to inflict serious damages on the natural system of the area, causing the swamp to become an open sewer.

Reference study: The *Máquina Verde – El Arca* Project

After several research activities, surveys and visits to *El Pozón*, the dynamics, relationships and basic needs of the neighbourhood population were determined and served as basis for the Urban Master Plan proposal focusing on two essential themes: social housing and family habitability. *Máquina Verde - El Arca* proposed a reconnection of the human – nature relationship through a physical transition between urban expansion and the fragile ecosystem. The main idea was to develop an archipelago of social housing along with the construction of an Urban Boundary for Protection and Control of the swamp. The team decided to reach the density of 120 households per hectare in the archipelago, implementing a system of piled habitational units that could generate a cosy and healthy urban environment to the social development of the community. Taking into account the risk and vulnerability conditions that may generate flood cycles, the blocks of bi-familiar modules are disposed as stilt units connected through platforms, allowing water circulation to go below, contemplating different levels of flooding along the urban proposal.

The architectural project was elaborated following some concepts taken from several visits to *El Pozó*n. For instance, the prototype house was developed in a modular way with a c-shaped plan and a central patio that encourages circulation, ventilation and exposure to the sun, allowing the inside and the outside to blend. The concept of frame is predominant in the project, being useful to respond to different housing needs. The house was conceived as a subjective container, an ark, a structure with reconfigurable and progressivity features that can be filled according to what a specific family requires.

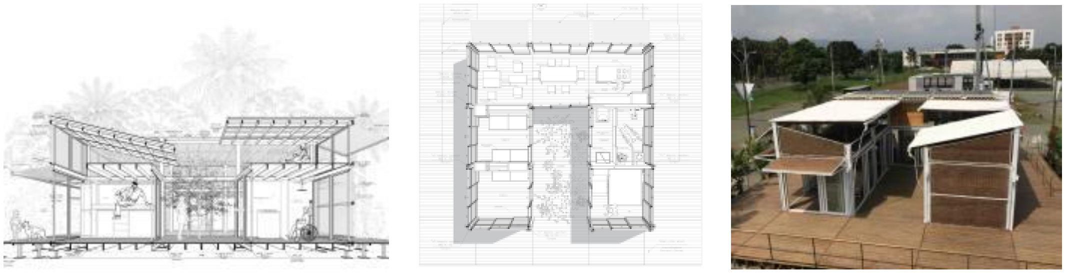

Figure 3. Perspective section, plan and photo of the *Máquina Verde – El Arca* prototype

The *Máquina Verde - El Arca* prototype uses passive technologies for ventilation of the rooms through the correct configuration of the openings that favour the exploitation of the prevailing winds and the protection to solar radiation. The energy needed is satisfied by 10 photovoltaic panels - 9 m2 - placed above the fixed roof of the social area. The need for hot water is guaranteed by 5 prototype panels - made by the team - that act as solar collectors and do not require electricity for operation.

The *vivienda azul-verde*

After the construction of the *Máquina Verde – El Arca* module, it was decided to study the implementation of a modular green roof. In addition to the main objective, i.e., to increase the water capturing surface of the roof, the placement of an extra – green - layer ensured better indoor environmental conditions, as it contributes to the insulation capacity. Once the ideal solution was identified and the existing typologies were studied, the next step was to contextualize it within *El Pozón* in order to design a module that could fit into the *Máquina Verde - El Arca* prototype. For this reason, in addition to implementing the territorial analyses already made for the competition, further inspections to the site project were carried out, which gave rise to some fundamental considerations for the composition of the module, particularly the materials to be used. During the visits a scouting process was led in order to identify a range of materials similar in composition and/or function to those required for the construction of the module. The ones more easily available, in particular those considered waste materials, were selected in order to design a module that the inhabitants could self-build with recycle -local - resources simply following the assembly instructions. It is interesting that during the interviews, the inhabitants themselves suggested possible solutions, showing interest in the topic and in the implementation of the module. The final design of this low-tech and low-cost solution was not only the result of the research and scouting phase, but also of the collaboration with the inhabitants of the neighbourhood.

The module is divided into two parts, a fixed one and a movable one. The first one consists of a lower tank, in which the overflow water is collected, that is composed as follow: a box made of plywood panels (1 cm) that allows the entire module to be anchored to the roof, covered with a truck tarpaulin (0,3 cm) that acts as the waterproofing. On the lower tank rests the fruit box, which holds all the elements of the green roof stratigraphy: the egg container, the coconut fibre and the growing medium. The egg container works as a drainage tray, allowing the water to collect in the egg pockets, whilst the coconut fibre (0,3 cm) holds the growing medium in position. A soilless modified mix, made of 50% sand, 30% clay and 20% compost is the most suitable choice for the module. Particular attention was paid to the anchoring methods, since the module is designed to be easily assembled and disassembled, given the need for maintenance. For this reason, the technology of the anchoring follows the two parts division. The lower tank has to be inserted in a structure that guarantees its fixing: in this case the structure is a wooden frame, to which the module is attached with screws. Instead, the upper part must be easier to remove as it requires more constant maintenance. Thereby, the fruit box is placed on two horizontal supports inside the short sides of the lower tank and anchored to it with adjustable clamps.

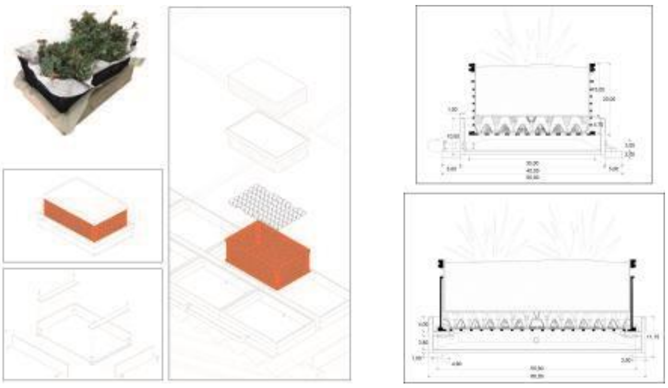

Figure 4. Image of the constructed prototype, exploded axonometric and sections of the blue green module

The operation of the module replicates exactly that of a green roof stratigraphy. When it rains, the water filters into the ground and fills the ovoid cavities that have the function of collecting water, which then goes up by capillarity in the soil above, with consequent nourishment of the vegetation. When all the ovoid slots are filled, the overflow process begins, so that water flows out of the tray. Since the cavities are connected and the holes are 3 cm higher than the edge, for the process to begin all cavities must be filled evenly and the water must reach a certain level throughout the tray. In the examples encountered, water escapes from the module and flows over the roof surface whilst, in the module presented here, the wood tank collects the excess water and, slowing down the precipitation pressure further, sends it to the main rainwater tank. It has to be noted that, according to the typology of the roof, the upper part of the module can work and therefore can be used independently. The configuration of the module causes the overflow process to start at a capacity of 6,8 l/m2, while the amount of water that is stored in the tanks is of 50 l/m2.

Conclusion

The *Máquina Verde – El Arca* adaptable living module was proposed to form an entire extension of *El Pozón*. In the same way, the green roof technology module makes multiscalarity its own connotation. Although the focus of the study was the scale of the building, it is important to underline how the effectiveness of the proposed model increases proportionally with its application on a large scale. The attempt was therefore to present a pilot project, based on the reference study and using nature-based and recycling technologies in order to benefit not only the micro-system of the building, but also the macro-system of the neighbourhood. It is hoped that a future implementation of this low-tech solution at the building level in *El Pozón*, will play a key role in raising people's awareness of the resilient project.

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