

59. Quantification of Water Consumption during the Construction Process of Single Family Housing Type. Minimization Strategies

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Abstract

The water consumption during the construction process is not resolved yet in Bolivia, in this sense, a methodology for quantification of water consumption in the construction process in a housing type is presented, this being the most built type of construction during the period this study was conducted. Establish the consumption of water per square meter built is reached with the methodology, data of water consumption is a projection of the same, taking into account the housing demand and necessary square meters that must be built to meet this demand and will establish the amount of water to be used. Against the alarming result arises strategies to minimize the consumption of water in the building process, coming to establish a significant reduction, and also its should raise in an objective way and almost immediate for the next constructions. This proposed methodology can be applied to other types of buildings in order to establish the quantification of water consumption in various civil works.

Key words Quantification, Consumption, Water, Housing, Minimization

1 Introduction

Water plays a key role in the development of societies as an essential requirement for human health, economic growth, and environmental sustainability. However, nowadays, water management presents important challenges such as increasing water demand tied with insufficient land use planning and increased pollution, vulnerability to climate change, and lack of awareness of the influence that human actions have over natural systems. In this context, it is necessary to be aware of the different uses and potential risks that are faced in the management of water resources.

Water is used in different activities and it is necessary to know with medium accuracy the quantity demanded in each one of them, this knowledge can lead us to establish savings policies as well as the introduction of new technologies that try to obtain the same objective with lower consumption.

In this work the amount of water used in the construction process of a model building is determined and some strategies are explored to minimize the consumption of this valuable element. The quantification process takes into account all the activities that must be carried out during the construction of the model building (housing) and all possible uses of water in this process. It is emphasized that a well-planned construction process can achieve a significant saving in water consumption.

2 Problem Statement

At the "Dublin International Conference on Water and the Environment" held in January 1992, principles were proclaimed for the effective and sustainable management of water resources:

- *Fresh water is a finite and vulnerable resource, essential for sustaining life, development and for the environment. This principle calls for awareness of the importance of water.*
- *The use and management of water should be based on an approach based on the participation of users, planners and decision-makers at all levels. By which the current approach to water management should be replaced by a more comprehensive and systemic vision, where water is linked to urban and community planning and development within the framework of systemic sustainability policies.*
- *Water has an economic value in all its various competing uses to which it is intended and should be recognized as an economic good. Therefore, attention should be paid to both efficiency and equity in water use.*

In the following decades, several attempts were made to improve efficiency and sustainability in water management; however, the objectives set were not achieved due not only to insufficient investment but also to a lack of coordination and cooperation between the Actors involved. Nowadays, urban water management presents significant challenges (World Bank, 2012). Firstly, the fast urbanization of

the territory, where the increasing demand for water combined with scarce land use planning and increased diffuse pollution, threaten water supply, increase the risk of flooding and affect the quality of life of the population. Secondly, vulnerability to climate change, which causes water management to take into account the water stress produced by the temperature rise, as well as the change in rainfall patterns that may increase the risk of shortages and floods. Thirdly, inefficient water management, whose current approaches are predominantly local and sectoral, and lack the innovation and scope to meet these challenges.

In this way, urban water management must be replaced by a more comprehensive and systemic vision, where water is linked to urban planning, development and sustainability policies. The growing construction activity as a response to the need to meet the demand for housing and infrastructure in the city causes environmental impacts, among which one of the most relevant is the increase of water use and pollution during the construction process. In this context, and within the framework of the eco-efficient construction approach (Huete, 2005), the present research work seeks to determine the amount of water used during the construction process (an aspect that is not usually taken into account, and some strategies are explored to minimize the environmental consequences of the indiscriminate use of water in construction.

This task is based on the following objectives:

- Identification and quantification of total water consumption in the construction process.
- Identification of the items with the highest water consumption in the construction process.
- Approach strategies to minimize water consumption in construction

3 Eco-efficient Constructions

Eco-efficient Constructions are those that can respond to the current requirements of the real estate market with criteria of respect and environmental protection (Huete, 2005). An eco-efficient construction model seeks to select and reduce the resources and inputs used, minimize waste and emissions, and improve the health of users by limiting the use of toxic and polluting products, such as materials, processes and specifications are established considering environmental variables as another of the project decision factors.

Therefore, it is argued that in a well-planned construction process, significant savings can be achieved in the quantity of inputs used, the associated energy costs and in the treatment of wastewater. All of this without compromising the performance and the acceptability by the users.

The present work focuses on the construction of houses, in that sense the requirements are:

- **Stability:** Responding to external actions

- **Habitability:** Achieve the necessary comfort
- **Economy:** Adapt to available resources
- **Eco-efficiency:** Environmental compatibility

In this "environmental compatibility", a balance must be pursued between the satisfaction of the current needs with which future generations may have, hence our conformity with the concept of Sustainable Development "that satisfies the needs of the present, without compromising the capacity of future generations to meet their own needs ", which was coined by the World Commission on the Environment (Brunlandt Commission) in 1987 and is the inspiring principle of many activities that require the modification of our way of understanding the social development and the necessary adaptation of the conventional models of production of goods

4 Selection of the construction model

The typological model of analysis is a single-family dwelling, with two floors, with reinforced concrete structure, brick factory walls, without dividing walls, conventional construction and medium finishes.

The choice of the construction model is based on both representativeness (within the constructions that are carried out in the study area) and its usefulness for works and projects in other regions and countries.

Representativeness. Based on data provided by the Urban Cadastre Office of the Honorable Municipal City Hall of Tarija and Cercado Province, it was determined that from a total of 20,570 properties registered by Cadastral, 17,634 (85.73%) correspond to houses.

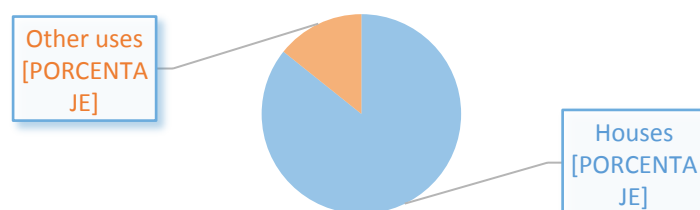


Fig. 1 Construction uses in the city of Tarija

- **Typology and area chosen.** The chosen typology of the building (single-family dwelling), corresponds to the economic type, two floors, with an area of 100 to 200 square meters

5 Quantification of Water Consumption in the model

5.1 Identification of water during the construction process

The quantification of the water consumption in the construction process was made taking into account the function it fulfills. The function of water in the construction process can be:

- **As an essential component of the process (QI).** It refers to those activities of the items that use water as an essential element, which, without it, such action would be impossible to perform. Example: concrete, pastes, mortars, plasters, water paints, compaction process and others.
- **As part of the process or material (QM).** It refers to those activities of the items that use water as material or in some part of the construction process when developing the different activities of a given item. Ex: irrigation of formwork, curing of concrete, mortars and plasters, as refrigerant and others
- **As auxiliary (QA).** It refers to those activities of the items that use the water as an auxiliary to be able to develop in a suitable way the different activities of the item. Ex: cleaning of formworks, tools and equipment and others
- **As part of the controls or tests (QP).** It refers to those items or activities part of the construction process that need controls or tests. Ex: to make test tubes and cure them in water to verify their resistance, also in the part of the hydraulic installations it is necessary to prove its correct installation, as well as in the windows and cover verifying its impermeability

5.1.1 Quality of the required water during the construction process

En la realización del trabajo también se tomó en cuenta los tipos de agua que puede usarse en los diferentes ítems del proceso constructivo, debido a que las exigencias de calidad del agua pueden variar de acuerdo al tipo de actividad.

5.2 Water cycle during the construction process

The water cycle in the construction process refers to the water required for the entire process against the water being poured, leaving a percentage in the building lot in an encrypted or trapped manner, and another percentage that is poured such as contaminated or uncontaminated water. This analysis of the quantities of water is called the water cycle in the construction process, reaching to establish percentages of the total used water, trapped in the work and spilled.

Incorporated. - It refers to the water that remains in some part of the construction process in a trapped or encrypted way, this amount of water is the one that is not recovered and is part of the constructive elements.

Poured. - It refers to water that does not remain in the construction process, and is discarded or dumped after giving some use during the process.

Contaminated - Refers to water discharged or discarded after it has been used in the construction process and has contaminants that make this water a dangerous element for the recipient body that receives it, this polluted water must have some

type of treatment Prior to being reused in the same constructive process or discharged to the receiving body.

Not contaminated. - Refers to water discharged or discarded after giving or not some use in the construction process, this water does not require any treatment and can be used again or poured without problems to the receiving body.

5.3 Methodology to be used to quantify water in the construction

The used methodology in the development of this research is:

Step 1.- Given the typology of the selected and justified housing, as well as the built area properly supported, a standard plan is elaborated, from the plane, the metric computations or volumes of work are obtained for each item of the dwelling.

Step 2.- Once identified the items of the housing, proceed to its corresponding ordering, to have the same classification by general headings, it is noted that all the activities of the construction process are taken into account with their respective items that intervene in the home, regardless of whether they consume or not water.

Step 3.- Then proceed to perform the codification of water use in the construction process, according to the function it fulfills, following the following nomenclature:

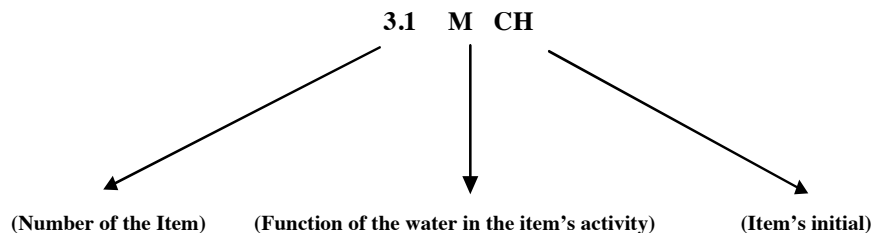
- As an indispensable component. Code **I**
- As a part of the process or material Code **M**
- As auxiliar. Code **A**
- As part of the controls or tests Code **P**

CODIFICATION SYSTEM

The following codification system will be used:

(Number of the Item) (Code) (Item's initial)

For example: for item 3.1 Reinforced concrete column



Step 4.- Tabulation of all the item's activities, which indicates the function that water fulfills in each activity, the code that is used and the water quality required.

Step 5.- Once the activities of the items using water in the construction process have been identified, with their respective codification and the water quality required for each activity, the water is quantified in detail for each item activity, justifying in each instance its consumption with technical and rational parameters.

Step 6.- Once the water is quantified in all the activities of the different items of the construction process, the water cycle is analyzed in the construction process, determining the amount of water used according to its function in the whole construction process, the amount of water that is burned in the process and the amount of water that is poured, it can be contaminated or not.

6 Analysis of Results

From the previous chart, the following is appreciated:

- The total water consumption in the Construction Process is 105.33 cubic meters for the selected typology.
- The water consumption for the selected typology is 684.16 liters per built square meter.
- The item that consumes the most water is the Stone Underlayment, with 16.37 cubic meters.
- It is evident that there is no uncontaminated water.
- The contaminated water discharged represents 52.81% of the total used.
- Water that evaporates or remains encrypted in the construction process represents 47.19% of the total used.
- The percentage distribution of water consumption due to the type of consumption is as follows:

Chart 1 Percental distribution of water consumption

QM: As a part of the process or material	61,81%
QI: As an indispensable component	22,71%
QA: As auxiliary	14,13%
QP: As part of the controls or tests	1,35%
	100,00%

Source: Own elaboration

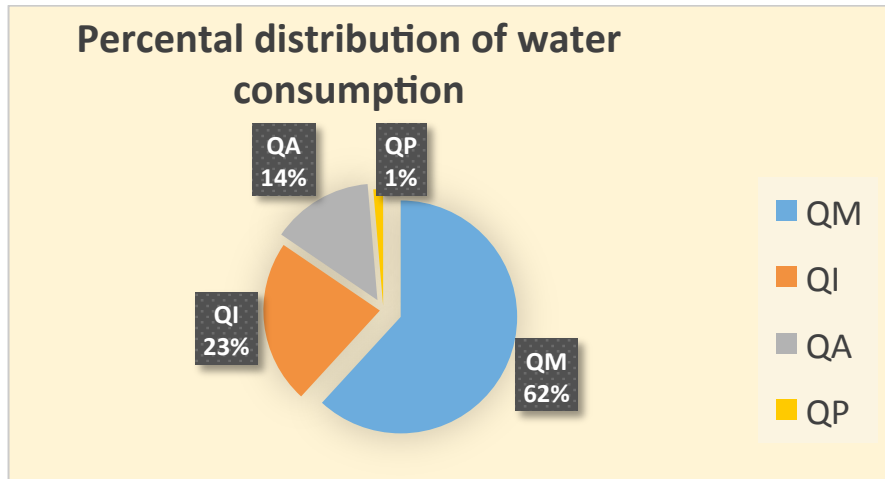


Chart 1: Percental distribution of water consumption

According to the consumption of water per square meter of built housing, it is estimated that future consumption of more than 50 thousand cubic meters of water by 2020 and almost 100 thousand cubic meters by 2040, according to the following table:

Chart 2 Water consumption per square meter Years: 2020 and 2040

Year	Habitants	Housing	Surface (m ²)	Consumption (m ³)
2003	148,080	35,595	3,559.500	2:435,267
2020	309,404	74,376 *	7,437.600 *	5:088,509 *
2040	736,260	176,986 *	17,698.600 *	12:108,675 *

* Estimated data

Source: Own elaboration

7 Proposal and strategies to minimize water consumption

7.1.1 Foreign measurements for technicians

In the normative and institutional environment, several measures can be established to promote a more responsible and efficient use of water in the construction, among which we have:

- **Regulate and invoice consumption of water**, this measure will help to promote rational use in the construction process and reduce waste.
- **To promote maintenance**, through the promotion of a culture of periodic maintenance of dwellings in order to avoid large deteriorations that motivate

the execution of significant volumes of work. The maintenance of a house implies budgeting resources to be used in repairs.

- **Establish "penalizing" measures** for those consumers who demonstrate their abusive and indiscriminate use of water.
- **Training and information**, it is fundamental for the population to know about the water problem at a global, regional and local level, so that it develops an awareness about the use of water. Water is a resource that costs to acquire it, due to its permanent shortage and the investment that has to be made to have it in a tap.

7.1.2 Measures that are incumbent to technicians

The decisions and actions of the people who are in charge of the design and execution of a construction project have a decisive influence on the efficiency and effectiveness of water use. In general, the actions and measures that the technician can assume during the "Project" may be framed in two large groups, the first corresponding to the design part, and the second to the technological decisions that are adopted in the "Project".

- **Project measures or decisions.** Correspond to the decisions made by the designer at the time of defining the constructive solution in the plane, they can be:
- **Reduce the impact of common elements**, prefer buildings in height than open developments. For example, in a vertical construction, the covered area is 100 m² which serves 4 floors, that is 4 dwellings, in an open urbanization would have needed 400 m² of roof, for the same area of housing, with the consequent increase in volume of work, which has an impact on the increase in the consumption of measured water, also contributes to the saving of communitarian spacing, which today are so necessary and scarce.
- **Quality of the project** in technical specifications and construction details, in order to avoid mistakes and injuries, the absence of which will result in a healthy construction and will not have the need for repairs. Likewise, demolitions will be avoided for misinterpretation of the plans.
- **Technological measures or decisions.** They correspond to the decisions that technicians can make in the selection of materials, the typology of the elements and in any situation, that has to choose a solution without affecting the architectural project, among these measures can be:
- **Evaluate solutions for each construction subsystem**, respect to the processes or products used. Measure refers, for example, to the foundations subsystem that covers a series of items that can be chosen in a global way, a subsystem of foundation that saves water consumption and not in isolation. Also important are imaginative construction solutions that make possible to save water during the Construction Process.
- **To be up-to-date in the use of new materials and products** used in construction, with the aim of being able to use them to save water consumption. It is of great importance, since the construction industry is very dynamic and innova-

tive and any new material or product can mean saving water in the construction process.

- In general, the overall consumption of water during the manufacturing and commissioning process of a product decreases as soon as the finished product comes out of the factory and, consequently, fewer operations will be necessary on site for installation and finishing. Industrial systems usually require lower water consumption than traditional on-site systems

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Annexes:

Expressions used to calculate the water consumption during the construction process

$$Q_T = \sum n_i = (Q_{Ti} + Q_{Mi} + Q_{Ai} + Q_{Pi})$$
$$Q_{VC} = \sum n_i = (Q_{VCMi} + Q_{VCAi} + Q_{VCPi})$$

$$Q_{VNC} = \sum n_i = (Q_{VNCM_i} + Q_{VNCA_i} + Q_{VNCP_i}) \quad (3)$$

$$Q_{RN} = \sum n_i = (Q_{RNI_i} + Q_{RNM_i} + Q_{RNA_i} + Q_{RNP_i}) \quad (4)$$

$$Q_{RSN} = \sum n_i = (Q_{RSN_i} + Q_{RSNM_i} + Q_{RSNA_i} + Q_{RSNP_i}) \quad (5)$$

Where:

n = Number of activities that consume water

i = Number of each activity that consumes water

Q_T = Total water consumed by each item

Q_I = Consumed water as an indispensable component during the activity

Q_M = Consumed water as part of the process or material in the activity

Q_A = Consumed water as auxiliary in the activity

Q_P = Consumed water as part of tests in the activity

Q_{VC} = Poured water contaminated by each item

Q_{VCM} = Poured water contaminated due to M consumption in the activity

Q_{VCA} = Poured water contaminated due to A consumption in the activity

Q_{VCP} = Poured water contaminated due to P consumption in the activity

Q_{VNC} = Poured water not contaminated by each item

Q_{VNCM} = Poured water not contaminated due to M consumption in the activity

Q_{VNCA} = Poured water not contaminated due to A consumption in the activity

Q_{VNCP} = Poured water not contaminated due to P consumption in the activity

Q_{RN} = Required water with quality standards by each item

Q_{RNI} = Water with quality standards requirement due to I consumption of the activity

Q_{RNM} = Water with quality standards requirement due to M consumption of the activity

Q_{RNA} = Water with quality standards requirement due to A consumption of the activity

Q_{RNP} = Water with quality standards requirement due to P consumption of the activity

Q_{RSN} = Agua requerida sin normas de calidad por cada ítem

Q_{RSNI} = Water without quality standard requirement due to I consumption in the activity

Q_{RSNM} = Water without quality standard requirement due to M consumption in the activity

Q_{RSNA} = Water without quality standard requirement due to A consumption in the activity

Q_{RSNP} = Water without quality standard requirement due to P consumption in the activity

$$Q_{TRN} + Q_{TRSN} = Q_{TT}$$

$$\% QTVC = \% QTVC * 100 / Q_{TT}$$

Where:

Q_{TT} = Total consumed water in

the construction = $\sum_{ni=1}^n(Q_{Ti})$

Q_{TRN} = Total required water with some standards in the construction. =

$$\sum_{ni=1}^n(Q_{RNi})$$

Q_{TRSN} = Total required water without quality standards in the construction =

$$\sum_{i=1}^n(Q_{RSNi})$$

Q_{TVC} = Total poured contaminated water in the construction =

$$\sum_{ni=1}^n(Q_{VCi})$$

Q_{TVNC} = Total poured not contaminated water in the construction =

$$\sum_{i=1}^n(Q_{VNCi})$$