Costing, Adobe Technique as a Sustainable Construction System in the City of Cuenca

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Abstract. Adobe is an old material used in construction but over time, this construction system has lost space and preference among population. Hence, the need to seek alternatives as professionals in the construction area to encourage the use of the Adobe technique has raised. Thus, the present study made a cost of the items involved in the construction of houses from the adobe based on the theoretical references. In addition, it established a unit price analysis that identifies the particularities of this system focusing on an analytical, descriptive-conclusive methodology whose data are analysed from the results of applying a survey (n = 96) to the inhabitants of the rural sector of Cuenca and construction experts (n = 11). The average price of the construction of houses with Adobe is $38,357.23 dollars for a house of 150 m2 taking into account that the real costs and the construction activity are sensitive to changes in the population and market prices.

1. Introduction

Construction is a sector with very significant relevance in a country's economy and represents an important contribution to a nation's Gross Domestic Product. It uses resources from industry such as iron and cement, etc. becoming the engine of economy. However, sustainable construction is an alternative which can meet housing needs in modern times avoiding compromising the resources of new generations. Solaimani, and Sedighi [1] affirm that the needs of a sustainable built environment are urgent since it encompasses environmental, economic and social values of sustainability. From the beginning, construction theory is associated with efficiency and a solid base in economic competition. Despite this, principles and practices currently focus on preserving social and environmental aspects as well.

Under this perspective, developing sustainable construction methods and environment is increasingly emphasized not only by academics but also by construction professionals in order to serve people and the planet profitably. Therefore, in the city of Cuenca there are no updated studies that allow understanding its benefits with these three axes: "consumers, benefit to the environment and utilities in the construction system." Well, according to Elkington’s criterion [2], the dimensions of sustainability are interdependent being able to argue that economy is intrinsic in society and society exists within environment.
In Ecuador, climatic biodiversity conditions, volcanic permeability and geological faults that are common in the southern zone are the motivation to master ancestral construction systems. Sustainability concepts applied to infrastructure housing with adobe go hand in hand with relevant costs which make it clear that the problem is not addressed and updated with construction market conditions since low costs that Adobe construction can represent, its insulation characteristics and temperature variation control must be added to an efficient analysis of unit prices.

Considering this, the present study aims to make a cost of the items that are incurred in the construction of houses from adobe. To do this, constructive aspects that this ancestral practice has are identified through theory as well as improvements made over time to identify the benefits of this construction system for communities through an analysis of unit prices that identifies particularities of a system based on current regulations, beneficiaries and contribution to nature as an alternative for housing solutions.

2. Methodology

The application and analysis of the results obtained from a survey administrated to inhabitants of the rural sector of Cuenca constituted by 313 “mediagua” (typical emergency housing in rural areas) according to the INEC registry [3] was carried out. In addition, an analysis of Unit Prices was applied which was raised based on the items of: labor, materials, transport, equipment-tools in order to establish updated data of the minimum / maximum prices to work on this type of construction systems showing the advantages of using the adobe besides the improvements that can be adopted to minimize environmental impact.

The study had a qualitative approach through the analysis of bibliographic documents referring to the study area, instruments and regulations applied to systems, instruments and regulations applied to this type of construction systems. It was quantitative based on the calculations related to the items that incur in the construction of houses from Adobe.

The study population was 313 homes in the rural sector of Cuenca in 2020 considering that sample refers to those elements of the universe selected to be subjected to observation. For the sample, the finite population statistical formula was applied, giving 96 dwellings where the instrument was applied. The study participants were inhabitants of the rural sector, since the research focuses on the cost-benefit analysis in these areas where the presence of Adobe construction system has a greater acceptance considering ancestral techniques that support it.

A focus group was conducted with construction experts in Cuenca through a semi-structured questionnaire that allowed to know the cost of the items required in the construction of a low-income housing (type) using Adobe as raw material.

For the results presentation, the description that supports meeting the objectives of the study and proposing a Unit Price Analysis was used. In this regard, the following was considered as an independent variable: economic reliability of the use of Adobe as a constructive system and dependent variables: labor, materials, transport, equipment and tools. Both Excel and SPSS were used for data recording and analysis to show all the analyzed information in an understandable way.

A typical house is made up of two floors to take advantage of the conditions provided by Adobe in environmental and housing conditions with an anchoring system and foundations taking advantage of natural land, double-pane wood doors and windows, mortar, block walls of adobe and roof structure with joists and wooden bracing.
3. Results and discussions

Soils are clayey components, construction materials widely used in traditional construction and with a low level of use. Additionally, they continue to be used in several countries of the world and Ecuador is not the exception even the area of Austro such as Cuenca. Despite what has been indicated, the knowledge of the Adobe construction system is not known, both for professionals and for the population. Moreover, a questionnaire of structured questions was applied to know the perception of the construction from Adobe.

74% of those surveyed live in a brick / block house; the exterior part is made up of 91% of the participants with brick and the interior components of similar construction with 98%. In the same way, 53% have finished with the same material. Data that show the lack of application of the construction system in Adobe as an alternative for housing construction. A research carried out by Padilla and Lipa [4] indicates that Adobe is the second material used to build houses in Trujillo (Peru) particularly in rural areas which is contrary to the results of this research since in the rural area of Cuenca mixed constructions of brick, block and cement predominate.

75% of those surveyed affirm that they know little about the construction system at Adobe demonstrating the need and requirement to make the adobe technique known to the population as an integral strategy for the sustainability of construction. Mortada [5] argues that it implies using resources with maximum efficiency at a rate that does not compromise the needs and lives of future generations. 13.5% and 11.5%, respectively, affirm that they know quite a lot about Adobe construction technique; 42.7% of them learned it from family experiences, 37.5% affirmed that they knew it through other means, only 19.8% linked it to work experience. Information that guides that the technique is still transmitted between generations. That can be used for a new diffusion hand in hand with cutting-edge technology as well as a cost that allows associating the benefits of building with Adobe in addition to the alternative prices and materials used in the process.

Most of those surveyed affirm that Adobe construction techniques have been used for more than 100 years (79.2%). But 8.3% are unaware of their construction tradition which allows us to reflect on the importance of proposing strategies from academy, builders' unions and professionals to make people, especially new generations aware of the advantages and costs of masonry from Adobe. Based on the above, according to Galindo and Mena [6], Adobe is an ancient construction material which has been recognized worldwide since the Neolithic period (8000 to 6000 BC). In addition, it is inexpensive and easy to use to structure walls, houses, churches and other buildings.

Thus, 68.8% of those surveyed have seen how walls are built from Adobe, 26% report having experience living / lived in Adobe homes and 5.2% having built using this system. Regarding the last data, it is reflected that one of the drawbacks that building with Adobe can have is to obtain a qualified hand which guarantees adequate engineering when building houses. Thus, Guerrero and Hastings [7] point out that replicability related to the transfer of knowledge about construction with Adobe is necessary using materials and skilled labor.

71.9% of those surveyed indicated that grass is used in masonry with Adobe. 20.8% think that other materials such as horsehair (2.1%), straw (17.8%), manure (3.1%) and straw (2.1%) are used. 7.3% affirm that coarse sand is used. In fact, for the structure of Adobe soil-mud, sand / straw is used which according to Pons [8], Adobe is hydrophilic which means it absorbs moisture from atmosphere which causes the loss of resistance to efforts; those that at low compression range between 3 to 5 Kg / cm2.

Out of the total number of people who participated in the study, the majority 59.4% believe that the lack of properly constructed foundations is the cause of homes deterioration with Adobe; and 33.3% indicate that it is due to poor construction. Therefore, relevant properties to examine in the construction
material with Adobe are resistance to pressure, atmospheric effects and dissolution with water. Such characteristics make it possible to survive for a long time without damage [9].

In the opinion of 49% of those surveyed, they do not know that construction and repair processes is one of the causes of abandonment of homes. 41.7% contrasts it with the benefit of houses with cement. 9.4% believe that due to insecurity and deterioration, Adobe homes are left after some time. Furthermore, during the second half of the 20th century, in some countries of the region, Adobe ceased to be the main building material for houses which was replaced by industrialized materials such as brick and concrete blocks. When it stops being used, there is no production so knowledge is lost with people who stop considering it as a constructive option. This is more common with houses destroyed due to lack of maintenance, abandonment, or because they are considered a waste not suitable for construction [10].

When inquiring about the possibility of acquiring homes based on the Adobe construction system, 65.6% answered yes; 30.2% approached a possibility and only 4.2% indicated no. Data shows the population interest on the indicated constructive alternative which directs challenges to builders, state policies and those involved in sustainability of the environment to consider strategies that motivate as well as adjustments to the use of cutting-edge technologies for low-income homes of Adobe. According to Virgen [11], sustainability is defined in various ways at a global level, but it is always link to things present on earth. Then, there are three pillars that explain the importance of sustainability, economy, social and environmental issues. That is to say, if one of them is weak, the system as a whole is unsustainable.

With what has been stated in the previous paragraphs, this study focuses its interest on the economic part in searching for alternatives of updated cost associated with the current reality of construction market, a latent need to have traditional alternatives made known nowadays with innovative resources that guarantee construction systems such as Adobe. In this regard, the opinion of experts in the construction of ancestral construction systems reflects the items incurred with the estimated costs demanded by the construction of Adobe-type homes, or of social interest taken as a reference for the analysis.

Price criterion according to the items described was validated by 11 construction experts. The minimum and maximum values, the mean and standard deviation (SD) were calculated. With these data, the unit prices for manufacturing Adobe homes are analyzed based on three items: a) Adobe masonry firing which is a part of the repair and crack applicable to walls. It also includes unstitching and consolidation of wall heads; b) Adobe masonry which corresponds to the structure of walls of approximately 40 cm; and c) common Adobe masonry applied from the building material with dry mud, earth and plus straw. For respective calculations, the value of the average will be taken as a basis, the indicated data will be taken out of the analysis of the total cost that involves the tools-equipment, labor and transport-materials.

Regarding costs, they are estimated according to their nature. That is to say, if they are direct (CD) or indirect (CI). However, both are part of the costing classification taking into account that CDs represent all expenses immediate agents involved in the work as material, labor, equipment and tools. Meanwhile, CIs are expenses caused by logistics including administrative, surveillance, transportation and technical direction. Taking into account that to establish the value of a cost, there is no defined process; however, the calculation method starts from the reference prices given by experts and theoretical review of other experiences with the construction of Adobe. Additional, the congruence of criteria among the researcher (s) it is taken into account since the cost estimate is approximate. Despite this, the purpose of the study is to make flexibility of work visible in the construction system based on the minimum and maximum prices registered in the area.
Two groups are considered in the works budget: the first related to operation and the other with the work itself. The operating costs are: administrative technical expenses, machinery rental, depreciation as well as other consumable materials. On the other hand, CDs on site such as transfer of personnel and communications, etc. Within the budget, the calculation of the work is important which is systematically planned based on the items according to the sector chosen for the analysis, since the unit references differ in urban and rural areas. Thus, this document considers Short-term budgets for the construction of a 150m² typical house applying an Adobe construction technique.

The cost analysis started by identifying the minimum / maximum prices referenced by experts calculating the mean and SD. With this, an estimated% variation was obtained.

The average variation percentage calculated is 10.67%; value with which the minimum / maximum costs that Adobe type homes can be built were calculated without altering the utility and benefits of those who acquire them. For the case study, a typical house (150m²) of construction and of social interest in the rural sector of Cuenca was taken into account.

**Figure 1. Average Adobe Housing Unit Cost.**

Based on the analyzed data, the unit price for the previous works in the construction of standard homes (150m²) with the Adobe construction system was $ 2.17 for the stakeout and $ 10.88 for excavations; different value than the estimated by Cabrera [12] which was $ 90 after a study carried out in Peru based on the construction of an earthquake resistant house with Adobe. Such price variation is attributed to the fact that the Peruvian study was in 2018, currently prices, labor and its performance have other peculiarities.

On the other hand, required concrete structure is estimated that: “replantillo” has a unit price of $ 193.77; plinth structure $ 206.13, chains $ 190.68; $ 2.74 reinforcements and $ 34.76 for the sizing as referential unit prices. For Adobe and wood elements required for houses, an estimated $ 1.51 for blocks, glued for $ 34.76; mortar for $ 23.20; wooden beams for $ 29.48, wooden columns for $ 26.45, use of reinforcement reed for $ 4.29 and internal stair for $ 1,757.61. Carpentry required for home sites shows unit prices of $ 280.94 for wood door and $ 331.38 for windows.

Roof items has a value of $ 19.77 for tile roof and $ 56.49 for the structure. Sanitary facilities are registered with a unit price of $ 26.85 for sewage system. Sanitary parts such as sinks are estimated to be worth $ 75 and toilets at $ 90. Finishes with the use of ceramic are estimated to be priced at $ 30.70.
The cost analysis carried out shows that the construction of a typical 150 m² house in the rural sector of the city of Cuenca goes up to $ 41,495.98 considering the average prices taken from the opinion of expert builders as well as other respondents. In theory, particularly those established in the salary tables of Ecuador in relation to labor, an item that constitutes a value that cannot be lowered to those established in the norm. However, in the market supply and demand, there are prices that tend to rise but not to fall.

The minimum price estimated in the study is $ 38,357.13 dollars for the construction of a 150 m² house in the rural sector of Cuenca. The maximum price is $ 45,923.38 and the average value is $ 41,495.78 dollars. Data that allow consumers to consider alternatives in the construction of their homes as well as builders, architects, civil engineers and professionals in order to technically approach direct and indirect costs that this type of construction requires. Economic advantages are sustainable with an adequate management of engineering, durable over time and resistant to natural events thereby contributing to solve a latent social and economic problem that is the lack of housing to serve the least favored sectors.

4. Conclusions
Through this article, it is observed that the current prices of housing units developed to serve rural areas with low economic resources face some barriers associated regarding final housing price. Although it is true, the perception of the inhabitants of concrete houses shows their preference for design and safety. A good percentage of people were not familiar in depth with the construction system using Adobe and its economic advantage. Understanding that to access affordable housing, many individuals also have to request loans which led to a unit price analysis regarding construction with Adobe. The calculated cost is variable but the average value is $ 38,357.23 dollars for a house of 150 m². In fact, the unit cost could be lower taking into account that the owners could do self-construction contributing labor as it is an item that is standardized and regulated by the Ministry of Labor which tends to rise. However, with the help of its future owners besides reducing its cost, the time to complete the construction work would be reduced as well.

It is not common for engineers and architects to participate in the construction process considering that it is generally an informal construction. Despite this, in projects of social interest and / or others financed by the State, private entities professionals would be in charge of the construction processes and the structural design giving constructive design guarantees to Adobe techniques as an alternative in the construction of social housing. Moreover, this type of construction is detailed in the Ecuadorian construction codes and norms but a specific application process for the rural sector is not identified.

For Ecuadorian population, an Adobe technique is possibly considered as new taking into account new generations but it shows some characteristics such as low cost that does not require qualified labor with materials that are easy to find in the territory. That is to say, in theory, it is a less complex constructive application than current ones. As indicated, disseminating a technology as adequate as it may be, it is complex as shown in the perception of those surveyed in this study which is why it is necessary to promote the use of this constructive system including factors for dissemination and success from the perspective of caring for the environment.

With this, the document mainly contributes with a series of selected data to identify unit prices that are incurred in the construction of Adobe houses, real costs, plus the construction activity that are sensitive to changes in population and at market prices without neglecting that the construction system must guarantee quality of houses where it is made clear that “shocks” in house prices do not have long-term effects compared to concrete construction.

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