Environmental impact: comparison between earthen architecture and conventional construction

M. F. Elizondo[1], L. F. Guerrero[2] & L. A. Mendoza[1]
[1]*Facultad de Arquitectura y Diseño, Universidad de Colima, México*
[2]*División de Ciencias y Artes para el Diseño, Universidad Autónoma Metropolitana-Xochimilco, México*

Abstract

Today more than ever the path towards sustainable development should guarantee people's well-being without jeopardizing resources for future generations. However, excessive exploitation of the resources from certain places has repercussions on other locations. Therefore adequate management of resources is required. Modifying environments in order to create human habitats is no exception. Designers and constructors daily work is directly related to sustainable customs of human settlements. Thus, their activities should be based on a vision of sustainable development. This paper shows a comparative analysis of the environmental impact caused by both conventional and earthen architecture. Conventional architecture is made from industrial materials such as steel and concrete. Earthen architecture is made from earthen materials such as adobe, compressed stabilized mud, rammed earth, and wall daub. The analysis was performed using the Environmental Impact Assessment method to detect and weigh the environmental impact of settlements, and has been used worldwide for hundreds of years. At the end we discuss the results of the analysis and suggest respective mitigation; compensation or restoration.
Keywords: environmental impact assessment, sustainable construction, conventional construction, raw earthen architecture.

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1 Introduction

"*Environmental problems are not recent, are as old as man himself, what is new is its size and scale.*"
(Esteban, M.T., 1971)

Throughout history people have built dwellings from the available materials of their immediate surroundings, such as raw soil, which has been a construction material for millennia.

Traditional constructions have a lower impact on the environment and are prone to sustainability. Their thermo-physical properties are climate adequate for houses.

On the other hand, conventional constructions greatly consume natural resources and have a higher impact on the environment. To meet people's comfort requirements they rely on climate-control devices that consume a great amount of energy and generate pollutants.

We need to measure the real impact of both the traditional and the conventional construction systems to define a decision-making basis for designing truly sustainable buildings. We should not romanticize buildings made of traditional materials as if "the past was better". We should weigh actual operating conditions from both systems and use the best of each to suit present and future requirements.

Earthen architecture is habitable constructions made of soaked natural soil, molded into bricks and sun dried. This technological process lies in the solidity and stability of molded natural soil (Guerrero [1]).

In this paper we report on the progress of the results of research conducted with the architecture of land in western Mexico in the states of Colima, Jalisco and Michoacán, but the results and insights can be applied in other geographical contexts. The currently used process is of one simplified method developing qualitative weighting of the construction, under criteria of sustainability.

We compare the environmental impact caused by conventional architecture using cement, steel and cement-sand brick, and traditional architecture which includes the use of different natural soils: adobe, compressed clay brick (BTC), wall daub, or bajareque, techno-daub, and rammed earth.

2 Traditional construction systems

Traditional construction techniques can be grouped into five categories.

2.1 Adobe

Adobe bricks are popular for their similarity to masonry construction systems in terms of having the possibility to store prefabricated pieces for later use. The use of geometric patterns, leads to increased production of handmade bricks.

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Figure 1: Building process of adobe wall. Picture: M. F. Elizondo (2009).

Figure 2: Experimental building with rammed earth wall. Picture: M. F. Elizondo (2009).

2.2 Compressed clay bricks (BTC)

Compressed clay bricks are similar to those of traditional adobe, but hand pressed into a mold, or with specialized machinery. The bricks are often mixed with small amounts of lime.

2.3 Rammed earth

Earth-wall or tapia is also known as mud, cob, or rammed earth. It is a single process where the soil handling and the dwelling construction happen at the same time. Soil selection and work organization are key components in this process. Evidence of walls built using this technique thousands of years ago are in places as far apart as India, China, Egypt, Syria, Lebanon, Bolivia and Peru. In China the use of this technique to make forts and palaces are found during the Shang Dynasty, dating from the period between 1766 and 1045 B.C. The technique was also found in various sections of the Great Wall built between the fifth and third centuries B.C.

2.4 Wall daub, or bajareque

The system is a moist soil mix and plant material. The possible origin of this material dates back to the days of settled communities over seven thousand years ago, when primitive man had to hunt animals for food, temporary shelters were built with materials made in motion as mats, skins and parts of plants such as poles, straw and leaves. Gradually, when basketry evolved, the construction technology improved with cabins made with woven materials (Reyes [2]).

2.5 Techno-daub, or techno-bajareque

Is a mixture of moist soil with a three-dimensional structure of steel. We propose the use of this material as a viable alternative for contemporary use in the construction of affordable housing. This material has a high sustainable yield when considering environmental issues, economic, social and cultural rights.

Figure 3: Building the vegetable structure of bajareque wall. Picture: M. F. Elizondo (2009).

3 Methodological tools for decision making in terms of sustainable development

The Ecological Footprint is a measure of human pressures on ecosystems due to urban life. Once measured, the estimated real production areas (crops, pastures, forests, sea and urban) and the sum of all local carrying capacity is measured in hectares per capita.

For the consumption of products and services, Life Cycle Analysis is applied. It is an objective procedure for quantifying energy consumption and environmental consequences associated with a process or activity and sets by identifying the energy used, materials needed, and waste emissions into the environment (Gómez [3]).

Figure 4: Architecture students building with techno-bajareque wall. Picture: M. F. Elizondo (2009).

For works projects and specific projects, we used the Environmental Impact Assessment. This is the a priori analysis of the impacts that could result in a project or human activity. It requires the application of objective methods and interdisciplinary participation of specialists. It is an eminently preventive tool, used to predict the environmental impacts resulting from the application of human activity or projects. This can help to make the right decisions on the environmental viability of such projects (Arenas [4]).

For the analysis in this case study, we applied various aspects of the ecological footprint, as well as life cycle analysis, the mainly used methods for assessing environmental impact.

4 Environment impact, task pendent

In buildings and cities, people spend most of their existence often as victims of the wrong decisions or the successful design and construction of our habitat, whether at home, the workplace, neighborhood or city. People should be aware of this reflection, if not by conviction, then either by simple survival instinct.

The concept of environmental impact has been discussed and hence evolved. We can say the impact is the difference in the environment "with" and "without" human involvement. In this case, we analyze the impact of the occupation and use of space, the impact in the building of settlements, in summary, the environmental impact due to the design and construction of the human habitat with earthen building, or conventional construction with steel and cement.

Reference mentions that in the results of several studies the data shows that residential and trade buildings consume 20 to 40 percent of total energy contributing 9.9 and 5.4 percent, respectively, of global emission CO2, and specifically in Mexico, the total emissions of CO2 of the building industry contributes with 7.6 and 3.5 percent, respectively (Del Toro [5]).

In Mexico, environmental impacts caused by construction, have been considered normatively as a result of human activities "low risk "or "minimal impact". This is consistent considering that the activities who are considered high risk, are the activities that use hazardous materials in their processes, heavy industry or other human activities, settled in very fragile ecosystems such as coastal areas or jungles, among others (Elizondo [6]).

Table 1: Simplified matrix of impact for building process.

DETECTION AND WEIGHTING IMPACT				Building factors potential impact				
				Materials supply	Site preparation stage	Construction Stage	Operation Stage	Abandon-ment Stage
ENVIRONMENTAL IMPACT	Factors potentially impacted	Water resource	Quality Changing channels of runoff, Reloading	@-D-N &-D-N	@-D-N &-D-N	@-D-N &-D-N	@-D-N &-D-N	
		Soil resource	Soil Characteristics Geomorphology Permeability Composition and soil quality Erosion hydro or eolic	@-D-N &-D-N	@-D-N &-D-N	@-D-N &-D-N	@-D-N &-D-P	@-D-N &-D-P
		Air resource	Quality, Noise, Weather (micro & macro)	@-D-N &-D-N	@-D-N &-D-N	@-D-N &-D-N		
		Biotic resources	Trees, Shrubs, Herbs, Low-status species, Mammals Birds, Reptiles Low-status species	@-D-N &-D-N	@-D-N &-D-N	@-D-N &-D-N		
		Landscape resource	Panoramic view Open spaces Unique physical aspects, Parks and reserves, Historic or natural monuments, Places historic or archeological	@-D-N &-I-P	@-D-N &-I-P	@-D-N &-I-P	@-D-N &-I-P	@-D-N &-I-P
SOCIOECO-NOMIC IMPACT	Factors potentially impacted	Building cost				@-D-N &-D-P		
		Employment		@-D-P &-D-P	@-D-P &-D-P	@-D-P &-D-P		
		Population density						
		Equitable distribution of wealth		@-I-N &-D-P	@-I-N &-D-P	@-I-N &-D-P		
		Health and safety					@-I-N &-D-P	
CULTURE IMPACT	Factors potentially impacted	Life styles					@-I-N &-D-P	
		identity					@-I-N &-D-P	
		Cultural patterns					@-I-N &-D-P	
		Popular knowledge					@-I-N &-D-P	

Legend: Source: Own authors
"@": Impact of Conventional Building
"&": Impact of Earthen Architecture
"D": Direct Impact, "I": Indirect impact
"P": Positive impact, "N": Negative Impact

5 Interpretation of the impacts detected

In summary, the described, interpreted and the identified impacts most relevant in each of the four pillars of sustainability are: the environmental, the economic, the social and the cultural.

5.1 Environmental axis impact

When considering the impacts in terms of energy conservation and reduced use of non-renewables materials, reuse and recycling and resource management, then definitely earthen architecture generates the least amount of negative impacts of the environment, is more sustainable than conventional building systems, with use of industrial materials (Elizondo [7]).

Table 2: Building factors potentially impactor.

Materials supply	Site preparation stage	Construction Stage	Operation Stage	Abandonment Stage
Stripping of the soil organic layer	Stripping of the soil organic layer	Cleaning of weeds and stones	Street maintenance	Reducing, reuse, recycling of parts
Extraction geological materials in the sky open	Cleaning of weeds and stones	Compaction	Public lighting	Waste generation
Processing of building materials	Earth moving	Sidewalks, streets, tree foundations	Hidden flaws housing	Vermin
Transporting material to the construction site	Equalization	Water network, drainage network, sewage system, electrification, public lighting	Homeownership, housing occupancy	Vandalism
	Machinery and vehicles	Digging, foundations, walls, Roof, facilities, finished	Waste generation	Crime

Source: Own authors.

5.2 Economic axis impact

Efficiency and economic performance are critical in terms of sustainability, have a positive impact on employment generation, in the extraction and material processing, and implementation of construction and preparation site. There are also other positive effects of conventional construction, especially in industrialized country, the modular building systems that enable faster construction process, and this results in reduce costs. In contrast, it causes a reduction in the workforce, creating a negative impact in terms of equitable distribution of wealth. This situation does not exist in earthen architecture, because when the material removal takes place near the land where construction takes place, costs are considerably lower.

5.3 Social axis impact

Each person can build their own home with raw land, since most people live in the architecture without architects. Earthen architecture does not require the transfer of technology on a large scale. This also makes possible social equity, which is another requirement for sustainability. Conventional construction is also affected by the phenomena of self-construction, but the formal and informal builders are captives of the use of certain building systems as a result of the need to acquire the materials provided with the same supplier and are also dependent on technology transfer.

5.4 Cultural axis impact

Cultural sustainability is directly related to the demystification of scientific knowledge as the only knowledge and to try to recover some of the traditional wisdom. That is, with the traditional wisdom of each part of the world related to the resources available for the creation of human habitats, this is a trait of cultural identity. In these terms, earthen architecture is much more sustainable than conventional construction. In Mexico, there has been a cultural phenomenon: the substantial reduction of the building with raw earth, due to the emergence of construction materials like steel and cement. In the first half of the twentieth century, and to date, due to the belief that traditional architecture is not reliable, in contrast, industrial architecture is a sign of greater economic and social status.

6 Conclusions

It is not intended to propose that conventional construction does not work in terms of sustainability, or that the earthen architecture is a panacea, a magic solution to provide affordable housing for people. It is to be objective and aware of the achievements and limitations of each building system, considering sustainability criteria.

Nor is it looking back with nostalgic and romantic vision. Rather it is about having a holistic view, where work is often multidisciplinary, and scientific and technological advances contribute to the improvement of raw land construction. We must also be aware that the earthen architecture can only solve part of the problem of creating a habitat for people. Currently, its use may be advisable in some cases in buildings of one or two floors, but it is unthinkable to build skyscrapers of raw land.

The earthen architecture has an undeniable value in our material culture, according to their remote origin, the level of subsistence and environmental adaptation. The problem is that it has been displaced and has gradually been abandoned or replaced by new construction systems, as a result of myths, seen as a technology of low-grade undeveloped (Houben and Doat [8]).

The people gradually have become aware of the advantages of earthen structures through study of the buildings that have survived after centuries, unlike other materials with a better reputation, which in fact has no record of their behavior over a hundred years, as is the case of reinforced concrete.

Earth or soil used as construction material is totally sustainable, as is well known, this is one of the most abundant materials in the world, needs no power source for processing and generates no polluting emissions or waste. It is easy to use to build and repair, also generates an efficient thermal control in the regulation of temperature and humidity inside. Finally, at the end of his life it can be recycled to build new structures of earth, or just go back to nature.

It is clear that in several regions of the planet, building using native soil as a construction material could actually deliver results much more efficient in terms of economy and ecology, the constructive system limitations are well known, and if addressed properly, it is possible to construct the ground without a hitch.

The starting point of this work deals with a comprehensive view of earthen architecture, the building systems, their structural relationship, their behavior on an urban scale and harmony with the natural and cultural environment that surrounds it. This way of thinking helps to explain some concepts related to holistic perception of the building systems, preservation of architectural heritage, through appropriate and ongoing maintenance of the buildings on raw earth and its study as a source for contemporary design of houses.

Therefore the earthen architecture preservation does not just focus on ways to maintain the buildings in that type. This also includes research, assessment, rescue and dissemination of the techniques that made these buildings, taking into account that most of them still exist.

Lot of buildings of raw land in countries like Mexico, are not monumental, most are houses in rural or suburban areas, which remain unprotected by the laws of conservation of existing architectural heritage. Today interventions should take into account the earthen architecture and its relation to new buildings that surround it, built with other materials and other building systems, looking for proper integration. We must promote a balance between past and future, respecting the natural environment, economic development and social and cultural development to which they belong. The starting point is the analysis and understanding of cultural backgrounds representing the traditional architecture, aware of the positive and negative impacts that entails. By the preservation of these buildings it is possible to improve the quality of peoples' life and is a step on the road to sustainable development of human habitat. Furthermore, the method used can be the basis for a simplified qualitative model (Groat and Wang [9]), which detects and ponders sustainability impacts for edification.

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