Int. Journal for Housing Science, Vol.35, No.1 pp. 1-9, 2011 Published in the United States

# SUSTAINABLE AND APPROPRIATE TECHNOLOGIES IN SOCIAL HOUSING: THE POTENTIAL OF RAMMED EARTH TECHNIQUES

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# ABSTRACT

Better environmental practices in terms of processes and products are becoming a major issue. Construction technologies focused on the production of social housing can contribute to reduce the housing demand. This paper focuses on identifying construction processes based on concepts of sustainability and their influence on technological, economic, social, and environmental aspects of social housing construction. Used mostly in suburbs and rural areas for single family dwellings, elements of the building envelope such as walls and roofs made of rammed earth are analyzed. The objective of this paper is to contribute to new technological and sustainable approaches based on the use of soil, also considering appropriate technologies in social sustainability.

Key words: Rammed Earth Construction, Sustainable Technologies, Appropriate Technologies, Social Housing.

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## Introduction

Architectonic design solutions and constructive typologies for social housing should incorporate sustainability principles for the environment surrounding constructions, considering technological, environmental, economic, and social aspects.

Interest in sustainability mainly for economically vulnerable social groups has grown out of the need to improve quality of life and take advantage of opportunities that economic development can offer, considering the shortage of raw materials and environmental preservation for present and future generations. This perception is not the same in different countries, especially developing countries. These countries are normally lacking in social areas, which causes profound environmental impacts with different natures and significance than those in developed countries. Moreover the perception of sustainable development does not arise in the same manner in population groups or society's representative institutions in a given country.

However, the concept of sustainable development must be distinguished from the concepts of economic development. Integration of man with his natural and social environment requires a regenerative capacity and at the same time preservation of scarce resources is fundamental for survival and development. Substitution of natural capital by other activities undertaken by man must be considered in order to guarantee independence of future generations regarding non-renewable resources.

In the construction industry, principles of sustainability presuppose a healthy environment, efficient energy, ecologically correct materials, environmental shape and adequate design. Application of some of these principles can be set up as a reference of design and construction with sustainable characteristics being utilized to provide social housing in Brazil, either supported by public policy or developed by social, businesses or academic segments [1].

## Sustainable and Appropriate Technology in the Built Environment

Faced with the predictable impacts of technological choices on living conditions, management of cities and rural areas, the participation of the population has a strong influence on choices and technological usage, construction processes, construction materials and energy sources, being they as client and beneficiary of social housing or as part of the work force. Unlike in the past, when technology was expensive and natural resources cheap and plentiful, nowadays technology is abundant and natural resources such as water are expensive and scarce. The great challenge for technology has come to be less in creating and replicating it, and more in making it accessible to sustainable use [2].

Among the references for sustainable construction projects, those related to materials, labor, production process, energy, equipment, transportation, organization and investment common to any modality of residential building stand out. Regarding the use of sustainable and appropriate technology, construction is based mainly on use of methods and technologies that incorporate some of the following requirements, from the architectural design to construction and maintenance:

- adequate design, preferably with indigenous techniques and construction;
- natural local conditions and integration with the environment;
- ecologically correct raw materials and supplies;
- use of clean and efficient energy sources with reduced water and energy consumption;
- labor intensive technologies;
- socially, culturally acceptable and transformative technologies developed and/or applied in interaction with and appropriate to the populace;
- comfort and well being of the residents.

Buildings made of earth, present in almost all continents, demonstrate the cultural diversity of people and its versatility in terms of application of spontaneous or vernacular techniques. Use of earth in construction encompasses the entire American Continent from the south of the United States to Patagonia. It was even used in the Andes that were strongly influenced by seismic effects. Along with Europe and India, these regions make up the most important in development of earth architecture in the modern world.

As a counterpoint to these traditional or vernacular earth technologies, the majority of the construction processes currently adopted in Brazil and in the majority of the Latino and Central American countries are based on manufactured technology with elevated energy usage in production and generation of a lot of waste at construction sites. This model, in addition to being ecologically unsustainable due to limited natural resources and energy consumption in their extraction, processing and utilization which elevate costs, has moved out of reach for a large part of the population. The need to change this developmental paradigm is emphasized, moving through discussion and concretization of concepts of sustainable construction, study of possibilities, limitation of low-impact, and low-cost construction methods [2].

In this context, questions about using raw earth as a building technique are discussed with building techniques that are appropriate and sustainable in order to satisfy structural, economic, environmental, comfort and safety requirements.

## Raw Earth Buildings

One of the main and oldest structural construction materials is dirt. The use of raw earth as a building material has predominantly been to build dwelling walls in all of the habitable places on the planet, from the beginnings of human civilization in spontaneous or vernacular architectural forms. For populations that live in desert areas or were there's little rainfall, raw earth is also used for the roof of buildings in vaults and domes.

Due to earth's characteristics of physical resistance and thermal comfort, low cost and sustainable characteristics such as environmental, economic and social, important advancements have been occurring in these areas regarding study, documentation and promotion of earth architecture, especially in conservation of heritage, in social housing, in is appropriateness for use in seismic risk zones, in technological spread and normalization. Earth architecture is technologically simple. It is based on efficient structural forms that are in harmony with the surroundings resulting from different factors and environmental, economic and social conditions that influence conception and materialization of the architectural unit, mainly in the methods of self production of construction elements and self construction.

## Technical Specifications and Conditions for Use of Raw Earth in Construction

Raw earth buildings have a lot of potential, such as:

- high thermal comfort associated with the thermal inertia that earth offers;
- good acoustic behavior associated with its mass;
- inherent energy savings in terms of production and utilization;
- long-lasting buildings if maintenance is performed;
- lack of manufactured rubble because of the excess material is the main raw material, earth.

The earth used in the construction process must be the first layers of soil, free of organic material, basically made up of sand, gravel, clay and silt in different proportions depending on the type of rock or origin. Moist soil can be used in a raw or natural form, or with organic, chemical additives or stabilizers. Some of the most common chemical stabilizers are cement, plaster, lime, meta-kaolin, borax, sodium chloride, calcium chloride, calcium hydroxide and calcium carbide sludge among others. Organic stabilizers can be straw, bitumen, dung, animal blood, plant sap, tannin from leather tanning, waste paper, among others [1, 3].

In Latin American countries, there are more than fifty registered techniques for using soil in construction presently being used or in development [4]. Techniques based on soil can be divided into three groups [3, 4]:

- A. Monolithic, generally load-bearing structures
- B. Manufactured, load-bearing structures (building walls and roofs) or insulation walls, either molded or extruded
- C. Filled in, generally insulation panels

Depending on its structural form and components, the classification of the main earth construction techniques is shown in Table 1.

STRUCTURAL FORMAT	CLASSIFICATION	CHARACTERISTICS	CLASSIFICATION	EARTH CONSTRUCTION TECHNIQUE	
	molded in shapes (tail-board)	wet soil compressed in formwork (or tail-board)	A 2 A 5	rammed, light rammed, rammed earth, apisoned	
MONOLITHIC	molded in plastic bags	S\soil compressed in continuous or separate plastic bags (around 60 kg) laid in lairs.	A 3	superadobe, continuous taipa, earthbag	
	molded in blocks	wet soil molded in blocks, compressed with a little water and sun dried	B 6 B 12 B 13	adobe	
MANUFACTURED		mechanically molded soil in manual or hydraulic presses with added stabilizers.	B 7	CEB - compressed earth blocks (also known as soil cement blocks or bricks or ecological bricks)	
FILLED IN	wattle and daub	wet earth filling frameworks made of wood, bamboo or fibers	C 14 C 15	wattle and daub, hedge, framed mud, hand (or slap) rammed, partitions, bahareque, fajin	

**Table 1 :** Characteristics of Earth Construction Techniques

# Structural Enveloping Elements

Considering the objectives of this research, based on design specification for materials and labor used in social housing, the analysis of structural elements of buildings was focused on – walls and roofs of the basic type for single family social housing. This choice was justified by compatibility of the building type with forms of dwelling produced by the user, generally coordinated and/or assisted by a technical overseer, or in individual building types made by the use without planning or professional orientation.

## Raw or Additive-Stabilized Earth Walls

Raw earth walls are classified as biomaterials since they are ecological, sustainable, recyclable, biodegradable, efficient and durable. They employ locally available raw materials of natural origin or the result of recycling other inert non-organic materials. In addition, they use appropriate technological processes at a production scale considered clean from the point of view of the reduced volumes of raw material extraction and consumption, minimization of transportation, emissions and impacts, reduced manufacturing steps and intensive labor use.

Raw earth wall construction techniques can even guarantee an inherent energy savings, long-lasting buildings and no industrial rubble, allowing extra material to be reused. Its specifications are based on answers adequate to the environment, climate and local socio-cultural contexts, in harmony with the terrain and surroundings. There is an emphasis on applying varied techniques with natural materials and adaptation of structures along with other materials. Raw earth walls have high levels of thermal comfort, maintaining the internal temperature stable in both the summer and winter as well as having good acoustic behavior. Among the main construction techniques of raw earth walls, adobe, super adobe, rammed-earth, wattle and daub and soil cement brick can be cited, technically identified as CEB - compressed earth block [1].

## Adobe, Soil Cement Bricks and Blocks, and Ceramic Brick Roofs

The techniques for construction of roofs with different kinds of bricks with or without gantries, gutters and flashing are economical and flexible, both in ancient and modern construction. Forms are generated in harmonic arches with a variety of textures and high quality of internal space. Such techniques use low cost materials like common clay brick, compressed earth block or simply adobe, depending on exposure to humidity.

Vaults and domes without steel frames can be made using nubian techniques rediscovered by Hassan Fathy in Egypt. At present, techniques with these characteristics have been the object of a lot of research and development based on the use of adobe and ceramic or compressed earth overloaded brick. Another variation of roofs made of ceramic brick was developed by Eladio Dieste beginning in the 1950s, widely used in Uruguay and other South American countries. With either single-curve or double-curve vault shapes, an innovative construction system was developed using reinforced masonry ceramic shells. The constructed shells reach spans of around 50 meters with thicknesses of around 12 cm, with 10 cm of brick height and 2 cm of the upper layer made of mortar. The very aesthetically beautiful structural types in Dieste's works have excellent thermal and acoustic performance and were utilized in buildings for diverse uses, from centers of commerce, warehouses, service stations, and churches [5].

#### Comparative Analysis between Earth Design and Construction Technologies

Nowadays, the theme of sustainability has influenced approaches to construction designs and processes, appearing in the most varied environmental and urban conditions. In the same way, resources for building construction and operation such as labor, materials, energy and water have special attention in the conception of projects with the least possible environmental impact, which are part of some of the variables that have been explored by the construction industry. From the beginning, project methods and procedures should incorporate global effects of environmental, economic, and social character on the building's life cycle [1, 5].

The approach to this topic considers the process of construction by the user in social housing based on use of traditional and appropriate techniques. These techniques can make access to soil, materials, components and technology, technical assistance, financing and public resources viable, as well as participation of the users in specific steps of conception and production, in addition to work or employment opportunities. From the vernacular and traditional earth construction techniques studied, a survey was carried out for architectural design and construction solutions, focusing on questions of sustainability in social and technological bases adequate to social housing. A comparative analysis was developed between earth design and construction technologies considering knowledge about the best conditions for use and adequacy. The appropriate technology and sustainable construction techniques items were elucidated, comparing them with traditional or appropriate technology and materials, production, labor, energy, equipment, investment, organization, and transportation items. The analysis is presented on Table 2.

STRUCTURAL SHAPE	CLASSIFICATION	TRADITIONAL OR APPROPRIATE TECHNOLOGY							
		MATERIALS	PRODUCTION	LABOR	ENERGY	EQUIP- MENT	INVEST- MENT	ORGANI- ZATION	TRANS- PORT
MONOLITHIC	RAMMED	simple / sophisticated (smooth shapes); local raw materials either acquired or produced locally; few components	very small scale; understood, controlled and maintained by the user; collective or individual initiative	intensive, unskilled; user, family or small builders	little; non- commercial and local	simple tools	little or none	simple	manual or animal
	SUPERADOBE / EARTHBAG	simple / sophisticated (plastic bags); local raw materials, manufactured plastic bags; local production; few components	small scale; understood, controlled and maintained by the user; collective initiative	intensive unskilled; user, family or small builders	little; non- commercial and local	simple tools	little	simple	manual or animal

 Table 2 : Analysis of Earth Design and Construction Techniques Regarding

 Technology Employed

MANUFACTURED	ADOBE	simple; local raw materials; local production; few components	small scale; understood, controlled and maintained by the user; individual or collective initiative	intensive unskilled, user, family or small builders	little; non- commercial and local	simple tools	little or none	simple	manual or animal
	COMPRESSED EARTHBLOCK/SOIL CEMENT BRICK	simple; local raw materials; additives (natural / chemicals); streamlined production on the site; light manufacturing	small, medium or large scale; understood and maintained by the user; individual or collective initiative	intensive unskilled user, family or small builders.	little or average; commercial and local	or specialized equipment	little	complex, mostly carried out on the site	manual, animal or light machines
	COMMON CERAMIC BRICK	simple; local raw materials; additives; streamlined production on the plot or light manufacturing in a factory	small and large scale; understood, controlled and maintained by the user; individual or collective initiative	intensive; small and large builders	little; local non- commercial	simple or specialized equipment	little to average	complex, only partially carried out on site.	manual, animal or light machine
	CERAMIC BRICK WITH HOLES	simple; local raw material; streamlined production in a factory; light manufacturing	medium and large scale; understood, controlled and maintained by the user; collective initiative.	intensive skilled; small and large builders.	little; local non- commercial	specialized equipment	average to high	complex, only partially carried out on site	manual, light or heavy machine
FILLED IN	WATTLE AND DAUB	simple; local raw material; local production; few components	small scale; understood, controlled and maintained by the user; individual and collective initiative	intensive; user or small builder	very little; local non- commercial	simple tools	little or none	simple	manual or animal

#### **Conclusion**

Comparative analysis of earth design and construction techniques presented establishes references for material or construction technique capacity, considering technological, social, economic and environmental aspects. The following items stand out:

- technological: utilization of natural and available raw materials; utilization of recycled, recyclable and reused materials; use of chemical or organic stabilizers; drying and curing process; minimum time necessary for use; compression resistance; humidity absorption; structural function, as structural wall, non-load-bearing wall or roof; ease of execution; possibility to do away with external weatherproofing.
- social: preferentially obtaining materials by the user producing them; permission of production types by the user producing and constructing them, as well as community construction; intense use of unskilled or semi-skilled labor; generation

of employment opportunities and jobs; ability to pass on knowledge and voluntary technical assistance;

- economic: use of simple tools and equipment; low production and maintenance cost; reduced production and construction times; guaranteed production throughout the year independent of weather conditions;
- environmental: preferential use of human energy, with optional use of biomass or electromechanical energy; acoustic and thermal isolation capacity; guarantee of internal environmental quality.

The choice of earth construction techniques is also configured around understanding reduced cost of the extraction, material transportation and product manufacturing processes. Predominantly in the architectural types of single family housing units, the potentials involve: structural flexibility in the form of roofs, structural walls and non-load-bearing insulation walls; better thermal and acoustic behavior; inherent energy savings, in terms of production, utilization and preservation of natural energy sources; contribution to reducing the greenhouse effect; lack of manufactured waste; different aesthetics; and environmental suitability for social housing.

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