Data collection and constructive classification of superadobe buildings

Levantamento e classificação tipológica construtiva das construções em superadobe

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ABSTRACT

Earth constructions are recognized as low environmental impact solutions. They are durable constructions, strong, climatically efficient, formally flexible and the resources are renewable and reusable, promoting sustainable development. Also known as "bagged adobe", "continuous bag stabilized earth", "earthbag building" or "Earth-filled bags", the superadobe is a construction technique where the walls are basically built by bags filled with earth, stacked and reinforced, with barbed wire between them. The technique was developed as a possible solution for building on the moon, then applied to solve the social housing issue, and it is now possible to find buildings in robust superadobe with different uses and with other constructive technical associations. This article aims make an overview of literature dedicated to superadobe construction and offer an alternative of their topologic classification supported by already implemented constructions, in order to assist future research on recognizing and overcoming the limits and variations of the construction technique. The method is qualitative research with an exploratory nature through survey in magazines, books and webpages dedicates to architecture, engineering and sustainability fields.

Key-words: Superadobe. Sustainability. Architecture. Earth construction.

RESUMO

As construções em terra são soluções reconhecidas de baixo impacto ambiental. São construções duráveis, fortes, climaticamente eficientes, formalmente flexíveis e são compostas por recursos renováveis e reaproveitáveis favorecendo o desenvolvimento sustentável. Também conhecido como “adobe ensacado”, “saco contínuo de terra estabilizada”, “*earthbag building*” ou “*Earth-filled bags*”, o superadobe consiste na técnica construtiva onde as paredes são construídas basicamente por sacos preenchidos com terra e areia empilhados, e travados com arame farpado entre eles. A técnica foi desenvolvida como possível solução de construção na lua, depois foi aplicada pare resolver a problemática de habitação popular. Atualmente é possível encontrar construções em superadobe robustas, com diferentes usos e com associações de outras técnicas construtivas. Este artigo tem por objetivo fazer um apanhado geral sobre a literatura dedicada as construções em superadobe e oferecer uma alternativa para sua classificação tipológica com base nas construções já executadas, a fim de auxiliar pesquisas futuras no reconhecimento e superação dos limites e variações da técnica construtiva. O método é descritivo qualitativo, com investigação de cunho exploratório interdisciplinar, por meio de levantamento em revistas científicas, livros e páginas eletrônicas dedicadas aos temas de arquitetura, engenharia e sustentabilidade.

Palavras-Chave: Superadobe. Sustentabilidade. Arquitetura. Construção em terra.

1 INTRODUCTION

Groups of ecologists, bioconstructors and permacultors fighting against social and environmental degradation, are returning to use natural materials in constructions in order to avoid harm to nature, landscape, ecosystems, and human health. They aim at creating alternative solutions to the existing life system that is supported by high energy consumption, pollution and consumerist. As a main strategy, they try to work with nature, not against it.

By using natural materials, the disposal of construction are easily reusable; there is a reduction of chemical additions and synthetic materials. With correct strategies of design, it is possible to guarantee an efficient building with good conditions in terms of natural ventilation and lighting.

Based on this reasoning, the object of this article is to make an overview of the earth architecture project, with an emphasis on the superadobe technique highlighting its particular qualities and advantages. Compared with the others types of earth construction, the superadobe, or earthbag needs less maintenance, can have a plastic appeal, has a higher speed of construction, and has no necessity of formwork or additional structure (HUNTER and KIFFMEYER 2004).

Another important motivation is that there is not much scientific research about superadobe. To start this research, an inquiry was made on the periodics database from “Capes”, a virtual Brazilian library that contains 123 reference bases. The keywords searched were “superadobe” and “earthbag”. Only two indexed articles were found with double blind review process. In both of these articles, it was not possible identify the variants of superadobe construction. They were focused on testing the qualities of the material itself.

In order to help filling this gap in science, this article aims at classifying all the existing types of superadobe constructions. Furthermore, a systematic classification of the technique may provide objective studies regarding the development of best practice recommendations as well as tools to support “superadobe” design. The final aim of the research is the development of BIM and parametric design tools for “superadobe” construction. The classification presented in this paper defines a rigorous starting point for the development of such tools.

The paper is divided as follows: Brief state of art, disadvantages and advantages, methodology, different superadobe applications, conclusion, final considerations, acknowledgements and references.

2 BRIEF STATE OF ART

The superadobe technique was created by the architect Nader Khalili in 1985. It was a contribution for NASA research aiming at finding out a way to build houses on the moon, associating high tech with the use of local materials (KHALILI 1989). After this work he thought to apply this new technique to answer the crisis of social habitation (MINKE 2013; HUNTER and KIFFMEYER 2004).

This technique consists in a constructive system that uses polypropylene, raffia or other bags, barbed wire and earth. These bags are acquired in rows, which can variate from thirty to sixty centimeters of length. They are filled with inorganic earth to create walls, domes and arches. The bags can be cut by the desired size and filled with a funnel using 20% humidity earth.

As soon as these bags are filled, they are stacked in layers with barbed wire between them, to improve security and stability, until the entire wall is complete. The length of the walls vary according to the length of the bags, and is only limited by load restrictions.

Sometimes chicken wires are applied over the walls and underside the building openings windows to provide extra texture and develop a grippy surface, helping for the application of a plaster finish later on.

Many variations of soil can be used in this technique because of bags retention capacities (CALKINS 2009), however it is suggested the mixture of approximately thirty percent of loamy soil and seventy percent of sandy soil. This mixture was adopted by most of the old buildings of rammed earth in the world that can still be seen nowadays (HUNTER and KIFFMEYER 2004).

3 DISADVANTAGES AND ADVANTAGES

Because of the natural material advantages, this technique was proposed to build small constructions to answer social housing problems. Just after was tried to apply in buildings of different sizes and uses, such as ecovilles, hotels, exhibition pavilions, and others.

The known disadvantages to use this material are just a few, and most of these are related to the unfamiliarity of the technique by the population. TABLE 1 summarizes these advantages and disadvantages, as the next paragraphs will talk more about what the literature has written about this theme.

Table 1 – Resume of advantages and disadvantages to the use of superadobe

Advantages	Disadvantages
Flexible Form Speed of construction Thermal comfort Energy efficiency Low cost Structural strength Self-supporting for up to 2 floors Low maintenance Recyclable and reusable resources	Unknowledge (architects, engineers, constructors, etc.) Legal issues Social acceptance Technical limitations Fragility of site construction Specific Tools of Computer aided design

Source: Authors

3.1 DISADVANTAGES

Unknowledge: In general, neither architects nor engineers have received adequate formation to create superadobe designs during their academic backgrounds. To solve this problem, it is recommended to make a short workshop qualification before starting to build a superadobe dome on large scale (HUNTER and KIFFMEYER 2004).

Legal issues: There are few countries that include earth in their building codes. Even those ones that have included earth, do not have the superadobe technique (HUNTER and KIFFMEYER 2004). Moreover, the natural loam (mixture of clay, sand and aggregates) is not a standardized material; these characteristics may differ depending on the place from which it was extracted. (MINKE 2013) This lack of accuracy in composition may prevent its industrialization process and hence hinder the quality control.

Social acceptance: Earth architecture has faced many allegations, dominated by psychological factors that are based on unrealistic concerns, such as they can not be durable, they have always a primitive design or they are buildings for poor people. (SAMEH 2014)

Technical limitations: The self-supporting dome is best employed on constructions up to 6 meters of internal diameter. To create projects with bigger internal areas, other project strategies are needed. For example, connecting small domes, or using other structural support in association with the bags, or trying other designs with perpendicular walls (HUNTER and KIFFMEYER 2004). Another question is that the material is not water resistant, then it is important to protect and make walls and foundations waterproof. (MINKE 2013).

Low resistance of site construction: As the material is not resistant to water, the site construction must be protected from rain because there is the risk of collapsing rows before applying the cover application or closing the dome.

Specific Tools of Computer aided design missing: The material “superadobe” is not available in libraries of computer aided design software, nor of BIM (Building information Modeling) systems.

3.2 ADVANTAGES

Flexible form: The material plasticity allows creating freeform walls in horizontal projection. In vertical projection, orthogonal walls, arches or domes can be easily executed(CALKINS 2009; HUNTER and KIFFMEYER 2004).

Speed of construction: It was made an experiment with the “Honey house” that was built in 19 days by a team of five persons that spend 5 hours per day at work. (HUNTER and KIFFMEYER 2004). This fastness happens because the bags are located wet above others, differently from alternative earth constructions where there is the need to wait for the earth to dry before continuing to build (CALKINS 2009).

Thermal comfort: Earth walls are natural thermal isolators; they create more comfortable internal microclimate. They are also natural regulators of internal moisture, allowing the absorption of its excess letting it escape to the external environment. However, for dry climates, these walls are able to do the reverse process and release moist in the air, regulating the internal space. (HUNTER and KIFFMEYER 2004)

Energy efficiency: the earthbag thickness combined with an exterior insulation creates a kind of air buffer of resistance to extreme external temperature change. Other suggestion to get benefit of passive solar design creating a wraparound porch, which provides shadow to the walls during summer, and receive the solar rays during winter. (HUNTER and KIFFMEYER 2004)

Low cost: In 2011, a superadobe Project earned the third place in the competition named “The $300 Houses Challenge”. The objective was creating a low cost sustainable project, that could be built in community (eliminating the cost of labor), by applying low technology. The calculation memory of this project, according to the architect Rogério Almeida and the engineer Gustavo Thron, started that 14 superadobe terraced houses, would cost $283,33 each (JOVOTO, 2011).

Picture 1 - earthbag specimen with loading plates on top and bottom

Souce: DAIGLE, 2011

Structural resistance: Nader Kalili has tested superadobe foundations to simulate earthquake movement, according to ICBO standarts for an earthquake zone 4, no deflection was observed during the tests. (HUNTER and KIFFMEYER 2004) (WOJCIECHOWSKA 2001). In 2013, the researchers Ross, Willis, Datin and Scott did a laboratory experiment with a superadobe wall to test the effects of wind pressure. They subjected a superadobe wall to out-of-plane pressure up to 3.16Kpa. It did not collapse during loading (ROSS 2013). In 2009, the researchers Daigle, Hall, and MacDougall did another structural experiment with superadobe, this time exploring vertical compressive loading. The method was based on submit earthbag specimen with loading plates on top and bottom (Picture 1). They concluded the adequacy of earthbag technology for use in housing applications from a compressive strength perspective. (DAIGLE 2011)

Self-supporting for up to duplex: It was not found in the consulted literature a limitation to the height of these kind of buildings. However, some cases were found of self-supporting dome working as a duplex. In this case, the second floor is made of timber, which just sit on the walls between the earthbags, with no need of columns.

Two of these examples are: the earth house domes of Solscape in New Zeeland (Picture 2) and the “Majestic dome” in Panamá designed by the engineer Knott (Picture 3).

Picture 2 - House dome of Solscape, New Zeeland.

Source: http://www.theshelterblog.com/the-beautiful-tiny-earth-domes-of-solscape/

Picture 3 - Construction of 2nd floor of Majestic Dome, Panamá.

Source: http://www.landtrees.net/earthbag-building.html

Low maintenance: As the walls must be finished and waterproofed, their surface have the maintenance reduced. Waterproofing finishes can be natural or synthetic such as plasters and stucco, that provide a wearing layer that is affected first in case of erosion. Other finishes are able to waterproof the building such as tile, stone, asphalt and others (CALKINS 2009).

Recyclable and reusable resources: The biggest amount of employed materials in this constructive technique, as it was shown, is the earth, which is completely natural. The others materials (bags and wire), although not natural, are easily recyclable or reusable, supporting the sustainable development.

4 METHODOLOGY

The adopted methodology is based on a qualitative analysis of documents. The documental research aims at a retrospective study starting with information on documents events that already happened.

> *The characteristic of documental research is that the source of data collection it is restricted to documents, written or not, constituting what is named as primary sources. These can be made at the time the event or phenomenon occurs, or after. (LAKATOS; MARCONI, 2006, p. 176)*[1]

From the beginning, a research was made in specialized books, then in scientific journals and at the end in specialized websites. The articles of scientific journals were inefficient in this paper, because it did not contain information on the variations of superadobe technique. These were just the studies about material resistance presented in this paper.

5 DIFFERENT SUPERADOBE APPLICATIONS

In order to tabulate and classify superadobe variants, variations of roofing, foundations, structural variants and formal compositions were systematically approached.

5.1 ROOFING

Earthbags can make roofs just in case of domes and small vaults. In both cases, the earthbag roof will receive a layer of a waterproof material, then a natural or artificial covering such as grass, papercrete, bamboo wrapped around grass overlapping, loam, stones, tiles, and others. (WOJCIECHOWSKA 2001).

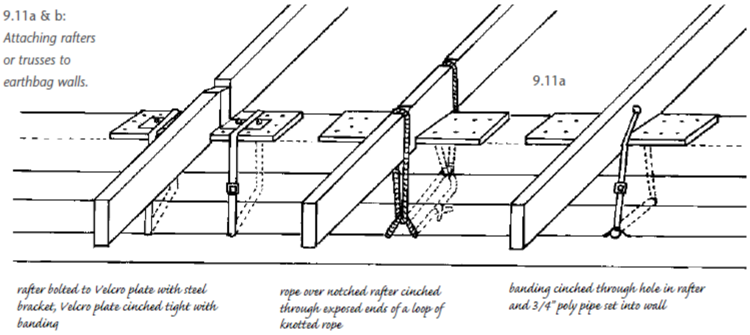
[1] Original passage: “A característica da pesquisa documental é que a fonte de coleta de dados está restrita a documentos, escritos ou não, constituindo o que se denomina de fontes primárias. Estas podem ser feitas no momento em que o fato ou fenômeno ocorre, ou depois. ” (LAKATOS; MARCONI, 2006, p. 176)

For the others superadobe structures, most of all existing styles of roof that already exists in other constructive types can be adapted to use in superadobe. (HART 2015)

There are different ways to attach the beams and trusses to the walls. The most simple is apply them directly between superadobe layers, creating a tension ring with halos of barbed wire in between rafters. (HUNTER and KIFFMEYER 2004)

To improve the resistance of tension between superadobe walls and beams and trusses, some details were created with Velcro plates (Picture 4).

Picture 4 - Details to improve attachment of roof into the walls



Source: (HUNTER and KIFFMEYER 2004, 55)

Other option is create a wood or concrete roof frame over the superadobe wall to attach the ceiling structure.

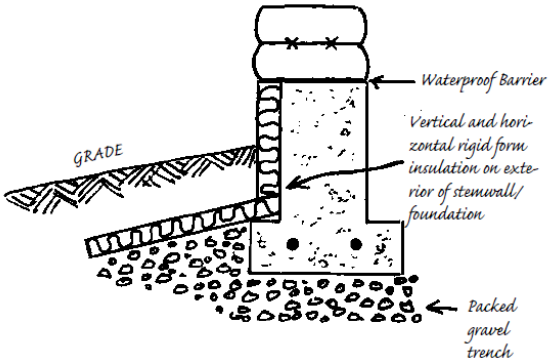
5.2 FOUNDATIONS

Many foundation systems can by applied to the superadobe building, Most of them starts digging a hole until find an undisturber ground. The depth aims find a level that is below the frost heave level to bedrock or compressed subsoil.

To fill the hole, there are some different kind of foundation such as concrete, “shallow, frost-protected”, “earthbag robble trench” and the earthbag foundation by itself.

In concrete foundation system, apply a concrete “footer” wider than width of the superadobe compacted wall. In this case, it is recommended to build the firsts layers with gravel-filled bags, or place a whaterproof barrier on top of the foundation wall, to avoid concrete sending humidity to the wall. (HUNTER e KIFFMEYER 2004) (HART 2015)

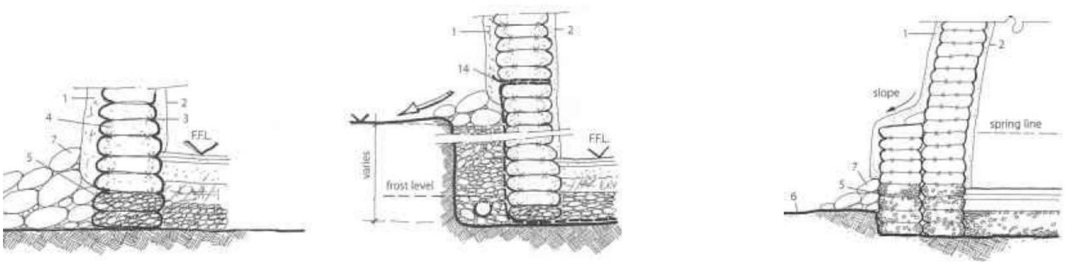
Picture 5 – Scheme of shallow, frost-protected foundation



Source: (HUNTER and KIFFMEYER 2004, 55)

In shallow, frost-protected foundation system (Picture 5) it is applied a vetical and horizontal rigid form insulation on exterior of stemwall to protect the structure to frost penetration. These protections also helps reduce heating cost. (HUNTER and KIFFMEYER 2004)

Picture 6 - Details of earthbag foundation variants



Source: (WOJCIECHOWSKA 2001, 36)

Otherwise, earthbags themselves make good foundation and their application can variate according to type of soil and climate characteristics (Picture 6). The “Earthbag rubble trench foundation” systems are based on the low cost technique developed by Frank Lloyd Wright for foundations in freeze areas. After dig the hole, apply packed gravel and ruble stone. This provides spaces between the stones to drain the humidity. The top of the hole may be recessed below, with the first layer of gravel-filled bags (HART 2015; WOJCIECHOWSKA 2001).

5.3 SELF-SUPPORTING

5.3.1 Superadobe Dome

There is the possibility of building an entire construction almost exclusively with superadobe, applying the dome design. The superadobe domes are simple and more resistant than a dome made with bricks. (HUNTER and KIFFMEYER 2004)

The cover of superadobe domes can be impermeabilized in different ways, such as: applying layers of quality clay plaster, multiple layers of lime plaster, or pally cement, and others.

Picture 7 - constructions of self-supporting superadobe domes

Source: http://images.arq.com.mx/eyecatcher/590590/20809-1.jpg

Some authors suggest that six meters of diameter is the maximum for self-supporting domes. They say that it is better building small domes connecting each other instead of building a large one (Picture 7) (HUNTER and KIFFMEYER 2004).

5.3.2 Superadobe Arch

The arch shape provide structural integrity to any building by stacking units such as bricks, stones and superadobe as well.

There were found two types of arches building with superadobe: The gothic and the roman. In most of seen examples, were founs application of both kind of arches. Routinely to support doors, windows or small corridors (Picture 8).

Picture 8 - Superadobe gothic arch as a small entrance corridor

Source: https://maggimck.files.wordpress.com/2014/03/blog-16_12.jpg

To build these structures it is necessary to use a temporary arch form, normally made with wood. The bags are stacked along the arch form using barbed wire between the layers. After complete, the form will be removed and the structure will support by itself.

5.3.3 Superadobe with linear design

There is also the possibility to build orthogonal self-supporting walls with superadobe (Picture 9). Empirical research suggest in this case, no more than three meter of height for the walls. More than that, will need extra structural resources. (HUNTER and KIFFMEYER 2004).

Picture 9 - Construction of self-supporting orthogonal earthbag building

Source: http://sitioamarelo.blogspot.pt/2010_04_01_archive.html

5.4 MIXED STRUCTURE

5.4.1 Wood

There were found two ways of building superadobe walls with wood. The first one is made with solid timber, driven into the ground and after filled the spaces between them with the earthbags (Picture 10).

Picture 10 – Superadobe construction with timber structure in Ceará, Brazil.

Source: Courtesy of the owner of the house.

In the second way, the structure is made with a piece containing wood and metal named “EcoBeam”. It was created for the engineer Mike Temeer, membership of a South African company in Cape Town. They also created geo-textiles to make special bags that are able to contain any kind of earth, including just sand. The sandbags are staked between the EcoBeams and revolved with wire. (Picture 11) (STEMMETT s.d.)

Picture 11 – Before and after of a sandbags constructions with Ecobeam construction

Source: http://www.ecobeam.co.za/

In sequence, there are two examples of constructions that has adopted this constructive technology.

- 10x10 low cost housing project (Picture 12)

Designed by Luyanda Mpahlwa of “MMA Arquitects” office, it was made in September of 2008. Ten houses were made with the same shape at Cape Town in South Africa. This project won the international prize “Curry Stone Design Prize”.

Picture 12 – Habitational building with one block under construction and other already done

Source: http://www.designindaba.com/projects/10x10-low-cost-housing-project

-Sand bag pavilion Pavilion –AZA 2010 (Picture 13)

Project built in Joannesburg, at Mary Fitzgerald Square. Designed by the architects Sara Callburn and Dustin Tusnevios. It won the third place in the international prize “URBANIFORM”.

Picture 13 - Sandbag pavilion

Source: http://dustintusnovics.blogspot.pt/2011/01/aza-pavillon-was-realised-on-mary.html

5.4.2 Concrete

Structure of precast concrete

Consists in columns and beams made with blocks of precast concrete. The superadobe is used in the spaces between columns. For example, there is a construction made in Utah (Picture 14), where the local built code did not allow superadobe for structural buildings. The adopted solution was to use superadobe mixed with precast concrete structure.

Picture 14 – Superadobe construction made with precast concrete in Moab, Utah.

Source: (HUNTER and KIFFMEYER 2004, 74)

Confined earthbag constructions in reinforced concrete (Picture 15)

This kind of construction is made with columns and beams of reinforced concrete and the earthbags confined between them. In this case the columns are launched in the place after the lifting of the walls (RODRIGUEZ 2010).

Picture 15 – Detail of a confined earthbag construction with reinforced concrete

Source: http://www.naturalbuildingblog.com/confined-earthbag-construction/

6 CONCLUSION

This paper was focused on an extensive survey of existing examples of buildings built out of superadobe creating a systematic classification at all surveyed structural variants.

As a contribution, it was created the Table 2 which synthetizes the qualitative variants exposed during the paper.

Table 2 – Variants of superadobe applications.

<table>
<tr><th>Structural variant</th><th colspan="2">Formal composition</th><th>Foundations</th><th>Roofing</th></tr>
<tr><td rowspan="3">Self-supporting</td><td colspan="2">Dome</td><td rowspan="5">-Concrete
-Shallow, frost-protected
-Earthbag robble trench”</td><td rowspan="2">Natural and artificial covering</td></tr>
<tr><td colspan="2">Arches</td></tr>
<tr><td colspan="2">Linear design</td><td rowspan="5">Conventional roofs</td></tr>
<tr><td rowspan="4">Mixed structure</td><td rowspan="2">Wood</td><td>Solid</td></tr>
<tr><td>Ecobeam</td></tr>
<tr><td rowspan="2">Concrete</td><td>reinforced</td><td rowspan="2">-Concrete
-Shallow, frost-protected</td></tr>
<tr><td>Precast</td></tr>
</table>

Source: Authors

7 FINAL CONSIDERATIONS

Few academic researchers have attempted to study superadobe buildings. In this article we have classified several existing applications of superadobe technique.

Although there is not much scientific literature about this subject yet, we could find a set of technical qualitative consistencies and organize them according to their structural differences as found in table 2.

Once these classifications are compiled, we intend for future works, develop other classification table, this time with quantitative information about the application limits of each variation presented in this papper. After that, we intend to develop informatics tools using all those technical classifications as a reference for the codes, in order to help architects to design superadobe buildings faster, easier and more precise.

When those objectives for future researches come to the end, we expect as a contribution, help the promotion of this way to build with sustainable and natural resources.

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