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Sustainable Construction and Architecture in Cape Verde

Study on Sustainable Design Strategies for buildings Construction

Extended Abstract of the Master Dissertation in
Civil Engineering

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1. Introduction

This dissertation consists of a research work which aims to study the architectural and constructive design strategies for Cape Verde, taking into account the use of the natural resources, the climatic, social, economic, historical and cultural conditions that characterize it.

1.1 Methodology and objectives of the dissertation

The conceptual and methodological basis of this work are rooted in the awareness that, in recent years, Cape Verde has been grown exponentially and unsustainably. Since there is still a lack of bibliography concerning the architectural and constructive design strategies able to support the sustainable development, this study seeks to be a contribution and incentive for converting the current Cape Verde's growing to a sustainable one.

The study of the design strategies was based on bioclimatic architectural concepts for tropical hot and dry climates, gathered from the existing literature. Analysis of the different existing architectural and constructive typologies were made, based on the economic environment, social and cultural framework of Cape Verde and the results of surveys conducted in Praia city.

1.2 Organization of the dissertation and the extended abstract

The organization of the dissertation and this extended abstract, is made as follows: both initially begin by making a brief presentation of Cape Verde as well as a diagnosis of its construction. Then, the main architectural and constructive typologies in Cape Verde are identified. The following chapter presents a study of the sustainable design strategies for the climatic context and thereafter, the environmental performance of the different architectural and constructions typologies are analysed while pointing its main constraints. Finally, the essential recommendations for Cape Verde are referred, highlighting the policy measures and the rules of good construction practices. Both the dissertation and the extended abstract end with the conclusions and bibliography, followed by some relevant Annexes (for the dissertation only).

2. Context: Presentation of the Archipelago of Cape Verde

Cape Verde is located 500 km apart from the African coast (west of Senegal) and consists on an archipelago of ten volcanic islands, which are distributed in two regions, according to their positions in relation to Northeast wind (trade winds) (Figure 1).

One of the main particular social situations of Cape Verde is the poverty (essentially structural), which is related and articulated with the fragility of the productive base and the country's economic characteristics (Barros, 2011). However, the economy has had a reasonable overall performance since the country gained its Independence (in 1975) and the Gross Domestic Product (GDP) has been showing a gradual growth over the past year. The fastest growing economic sector in recent years was the secondary, driven by investments in construction.



Figure 1 - Archipelago of Cape Verde.

In Barros (2011).

3. Diagnosis of construction

The construction in Cape Verde faces specific climatic conditions, (due to its geographic location), which increases the habitation and urban problems, already affected by the habitational and infrastructural lack.

According to the climatic context of Cape Verde, the high solar radiation, winds accompanied by dust in suspension, the scarcity of vegetation and the irregular and torrential rains, are the main concerns for the construction (Lopes, 2001).

The strong population growth has been hindering the implementation of sustainable solutions for the resolution of habitation and urban problems. The habitation problematic applies both to the family accommodation, as well as the minimum acceptable conditions for habitation. In general, the dwellings have low functional, construction and comfort quality, mainly due to the low family income and response capacity on physical and socio-economic planning of the country.

In this sense, it is important to understand the architectural and constructive practiced typologies in Cape Verde, in order to understand how these fit into the historical, economic, cultural and environmental development of Cape Verde.

4. Architectural and Constructive typologies

In the conducted study, three different main architectural and constructive typologies were identified in Cape Verde. This chapter identifies and characterizes these different typologies, including the Vernacular Architecture, the Colonial architecture and the modern trends of architecture in Cape Verde.

4.1 Vernacular Architecture

The Vernacular Architecture is present in most rural areas of Cape Verde, as well as in parts of the urban fringe area. It is characterized by traditional stone houses whose walls are built with masonry of volcanic stone and the use of straw as roofing (Figure 2 to the left).

4.2 Colonial Architecture

The architectural design of the Archipelago cities are essentially the heritage of the trends from the Portuguese cities layout, patent in the dwellings of stone masonry with mortar of clay and sand, with ceramic tile coverings, usually a high roof-rise , the front porch and protection flaps over the windows (Figure 2 to the right) (Lopes, 2001).



Figure 2 - Vernacular typology (left) and colonial typology (right).

4.3 Contemporary trends

Recently, the periphery of the main cities has been dominated by contemporary buildings for habitation, commerce or offices, which privilege the use of noble materials such as structural elements in concrete, cement block walls and sometimes tiled roofs.

In some main cities of urban areas (like Praia and Mindelo), one can distinguish two different types of houses, belonging to different social levels, according to the economic power of the population: illegal housing or housing located in poor neighbourhoods and housing in upscale neighbourhoods (Figure 3).



Figure 3 - Spontaneous habitations (left) and habitation in upscale neighbourhood (right).

The ecotourism construction is another contemporary trend that finds in Cape Verde a viable market seeking to be explored consciously (Barros, 2011). Most of the ecotourism buildings are based on vernacular architecture, reproducing the basalt stone houses with straw roofs (with some extra care regarding its preservation). This kind of construction allows increasing valorisation of the local context important elements, the industries and economic activities prevailing in the area, as well as the people and the environment.

The next chapter deals with the sustainable design strategies in which the bioclimatic design strategies play a key role in achieving thermal comfort, as well as in reducing the energy cost of buildings.

5. Sustainable design strategies

The sustainable construction is based on ecological and effective resources principles, in which its philosophy also includes the principles of bioclimatic architecture, with regard to the use of passive techniques to maintain the comfort and quality of internal environments and energy efficiency of buildings (Guedes, *et al.*, 2011).

5.1 Bioclimatic Architecture

The concept of “Bioclimatic Architecture” can be defined as an architecture that in its design, addresses the climate as an essential variable on a project process, with special attention to the important interaction between the sun and its trajectory and the building under study.

Prior to the study of passive design strategies, it is important to clarify the concept of hydrothermal comfort in buildings, which is presented in the following subchapter.

5.1.1 Hydrothermal comfort in buildings

The environmental conditions that are considered comfortable vary with the impact and ratio of the thermal environmental factors (temperature, humidity and wind, among others), as well as with factors like clothing and level of activity (Rodrigues, Piedade e Braga, 2009).

Several studies were made (including Givoni (1994) and Baker (1987)), in order to establish the thermal comfort zone, that is, the definition of the set of environmental factors values that provide conditions of hydrothermal comfort for most of users.

Thermal comfort in non-air-conditioned environments varies mainly with the climatic zones. As an example, it is well known that people living in hot climates tolerate higher temperatures than people living in temperate climates, but they are also more sensitive to cool conditions (Koch-Nielson, 2002).

Next, the strategies for passive protection and heat dissipation in the hot and dry climates are analysed.

5.1.2 Passive techniques for heat protection and dissipation

The heat protection techniques offer thermal protection against unwanted heat gain into the building, minimizing the internal heats gains. Among these techniques we may find the shading, the reflective coating, the thermal insulation and the design of glazed areas, which are considered essential for the climatic context of Cape Verde (Guedes *et al.*, 2011).

The light-coloured reflective coating has a greater capacity of solar radiation reflection, contributing by decrease of the heat gain. The outer walls and roof are the components which usually are directly exposed to solar radiation, and should therefore receive a reflective coating and a proper thermal insulation (which can be achieved by using insulating materials, such as straw) (Koch-Nielson, 2002)..

The facades with large areas of glass must be avoided, because they contribute to overheating into the building. Ordinary window glass transmits a large proportion of all radiation. Varying the composition of the glass can (known as special glasses), however, produce selective transmittance of the glass, which affects heat light transmission.

Heat dissipation strategies provide loss of the heat accumulated inside the building and may dissipate it through natural ventilation, evaporation, or taking advantage of thermal inertia (Guedes *et al.*, 2011).

One way to promote natural ventilation is through the inclusion of courtyard buildings. During the day the courtyard space heats up quickly compared with the buildings around it. This will create a stack effect, i.e. the movement of air due to height and temperature differences. As the hot air rises, it will draw air into the internal spaces, thereby setting up a breeze. This makes courtyards good thermal regulators. If this moving air crosses over water or planting on its way into the building, the cooling effects will be even greater. During the night the courtyard space acts as a sink, collecting the cool air flowing down from the roof (Figure 4).

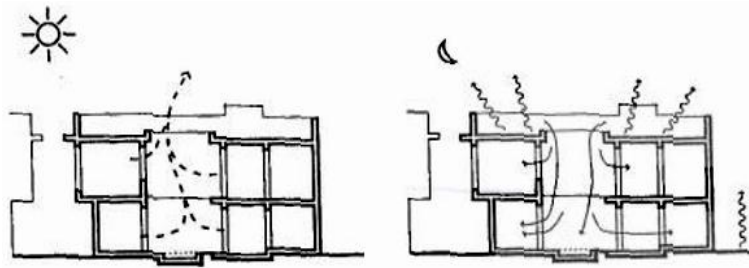


Figure 4 - The courtyard model's response during the day and night.
In Koch-Nielson (2002).

The most important building envelope component is the roof as it is exposed to the greatest amount of solar radiation and it is the most difficult to protect. Its performance will depend on its form, construction and materials. A variety of roof forms and construction are appropriate for hot and dry climates, as long as some cares are taken into account, for example: to cool the external surface of the roof, its slope should be orientated towards prevailing breezes and ventilation openings in roof spaces should be designed to remove hot air that would otherwise be trapped and transferred internally (Figure 5).

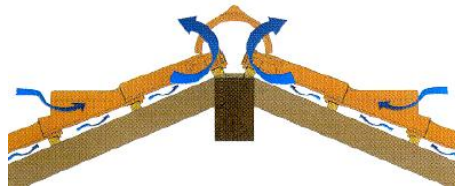


Figure 5 - Application of ventilation tiles.
In Brito and Paulo (2010).

The thermal inertia of a building is the ability and ease of heat storage, regulating and smoothing fluctuations in temperature. Its performance depends on the capacity of the building's constructive characteristics to transfer heat to the space (Hyde, 2000). The traditional and popular construction in Cape Verde involves the use of solid materials, which provide thermal inertia to buildings.

The principles of sustainable design also privilege the use of local constructive materials. In the next subchapter, an approach is made on the local materials, taking into account the thermal properties suitable for the climatic context of Cape Verde.

5.2 Local construction materials

In Cape Verde, the most abundant material is basalt, existing also plenty of natural inerts of rocky source (basalt), such as sand, pebbles and small fragments of volcanic basalt called *jorras*. The stone is a material with high thermal inertia, which is a good property for the climate context under study.

The pozolanas is also an abundant material in Cape Verde, especially in Santo Antão. Studies such as Velosa (2006), Botelho (2003) and Roberts (2004) have indicated that the properties of pozolanas of Cape Verde are distinct. With this material, one can construct cooler walls than those built with cement blocks, contributing to the improvement of thermal comfort in buildings.

The earth is a local material that can also be explored. This was used in mortar for joining stone masonry blocks and recently has been used in the production of soil-cement blocks. The buildings made of soil-cement results in environments with great thermal comfort due to high thermal inertia of the earth.

5.3 Active renewable energy systems

Cape Verde enjoys good natural conditions for taking advantage of renewable energy. The wind and solar energy are presented as potential alternatives of macroeconomic growth strategy, to allow the increase of an energy capacity that is essential for all sectors of the economy (Guedes et al., 2011).

After the identification and characterization of the main constructive typologies in Cape Verde (Chapter 4) and the study of sustainable design strategies (Chapter 5), Chapter 6 presents the analysis of the constructive aspects for the different typologies, from the point of view of environmental comfort.

6. Analysis of Constructive and Architectural typologies

This chapter presents an analysis of the constructive aspects for the different architectural typologies, based on questionnaires conducted by the dwelling residents. For this purpose, account was taken into the building materials, environmental performance and the main constraints derived from these typologies.

6.1 Questionnaire analysis

In total, 100 questionnaires were performed in which 19% of respondents were construction, architecture or urban planning technicians, 28% were 4th year students of construction or architecture, and the remaining respondents were local habitants without training in the area. The addressed issues are related to construction materials, satisfaction and comfort inside buildings, and to sustainable construction.

Concerning the construction materials, it was noticed that (Figure 6) most of the typologies are built of concrete blocks walls and roofs of reinforced concrete, being classified as Contemporary type 1 Arch. (45%) and a minority with unmortared stone masonry walls with straw roofs, corresponding to Vernacular Arch. (9%). The remaining identified typologies were: cement blocks walls / concrete and tiled roofs (wall / roof, respectively), classified as type Contemporary type 2 Arch (12%), stone and bricks with mortared joints (lime and sand) /ceramic tiles ,

corresponding to Colonial Arch. (12%) and stone masonry with mortared joints (clay) / ceramic tile, classified as Vernacular chanced Arch. (11%).

It was verified that the level of satisfaction with the temperature is worse (32%) on Contemporary type 1 Arch. housing and is better (70%) in the housing Contemporary type 2 Arch. (housing in upscale neighbourhood). This result may be related to the user's economic power in the second type of architecture, since they resort to better insulation and finishes, or even the use of mechanical cooling. The opposite happens with users of the housing of Contemporary trends of type 1, since they represent the layer of spontaneous housing or housing in a poor neighbourhood housing.

As regards to humidity, the users of Contemporary type 2 Arch. also have a higher comfort level (76%) and, in this case, the traditional vernacular housing has a higher level of dissatisfaction (59%). The dissatisfaction of the users of traditional vernacular housing is justified by the fact that the straw have a bad performance against humidity, unlike for the ceramic roof tile, which can better withstand humidity and also take advantage of the good insulation, according to economic power of users.

This study concluded that the main constraints of vernacular housing regards the problems caused during the rainy season (humidity pathologies), the buildings small compartments and housing dimensions. Although they integrate some passive design techniques (eg. the protection of glazing and natural ventilation), most of the dwellings of colonial architecture are not properly maintained, causing the environmental discomfort due to poor condition of building elements (roofs, floors and walls .)

Regarding to contemporary buildings, it was found that in upscale neighbourhoods housing, the energy expenditure arising from the use of mechanical equipment (when comfort is not achievable trough the passive design strategies) becomes one of the main constraints associated with this typology. Among all of them, the spontaneous housing typologies is the one which causes more constraints. Among other reasons, because the poor construction quality, due to weak economic power users, causes disorders in both seasons (dry and rainy).

As expected, it was noted that the concept of sustainable construction was unknown for most of not technician's respondents (52%). However, they eventually try to build according to some assumptions of sustainable construction, such as the demand for economic and locally available materials. What these respondents don't know and what remains to be incorporated in the projects, are the passive design strategies, such as natural ventilation and simple measures of protection against solar radiation.

Considering the characterization and analysis of architectural and constructive typologies that were made, as well as the study of design strategies for the construction of buildings in regions with hot and dry weather, the next chapter presents the main recommendations for Cape Verde.

7. General recommendation for Cape Verde

This chapter presents the main recommendations to Cape Verde with regard to the policy measures and the priorities and rules of good practice in buildings construction.

7.1 Policy Measures

The main policy measures to be taken to promote sustainable construction in Cape Verde are:

- Investment in education and training, providing information on sustainable construction and energy efficiency in schools;
- Incentive tax credits for the acquisition of active systems such as photovoltaic energy, thermal and wind micro generators for domestic consumption;

7.2 Priorities and rules of good practice for the construction of buildings

Basing on the fourth and fifth chapter, the following priorities and rules of good practice are suggested for future construction of buildings in Cape Verde:

- Construction with adequate solar orientation and secure location, considering the wind direction and the possible occurrence of torrential rains;
- Use of indigenous and durable materials, as well as the advantage off the sun and wind as renewable and clean energy;
- Buildings must be compact, with surfaces of a relatively small sun exposure, ie a low ratio surface / volume;
- The south direction should be avoided, given the high incidence of solar radiation, using the preferred orientation along the axis E-W, with predominance of the main facade to the north;
- It should be avoided to build houses on water lines, dry creeks and other areas vulnerable to flooding;
- Should be provided the shading of the windows facing south (for example by horizontal tabs) and the windows oriented towards the east and west (for example by vertical flaps);
- Should be used light colours on facade and roof, in order to reflect sunlight and prevent overheating of the building;
- Should be considered the inclusion of a farmyard in housing, to enable more openings in the facade, the ventilation of indoor enclosures, bringing additional benefits to the climate of the house;

- Should be selected roofing solutions that promote natural ventilation.
- The area of glazing must be less than 30% of the area in North and South facades and less than 20% of East and West facades.

8. Conclusion

It was concluded that the heat dissipation strategies, through natural ventilation and thermal inertia associated with adequate ventilation, as well as heat protection strategies (using shading devices), shown to be essential for achieving thermal comfort of buildings in Cape Verde. It is also important that the implementation of buildings takes into account the system of wind and sun exposure, and the location of the beds full.

Another essential step in the integration of sustainable design strategies, is the choice of indigenous construction materials. Cape Verde has indigenous materials of great economic value and largely unexplored, such as pozolanas and earth. These resources have potential, but require investigation and funding, making it necessary to integrate them in the objectives and priorities set by the authorities responsible for planning and managing the construction and urbanism in the country. Complementing the choice of local materials, it is necessary to implement the use of renewable sources of energy such as geolic and solar.

Regarding architectural and constructive typologies practiced in Cape Verde, it is important to pay a special attention on the vernacular housing typologies, in which the materials have been used for centuries to respond effectively to the needs of thermal comfort and environmental performance of the building.

It is hoped that further research arise, focused on quantifying the advantages and disadvantages of those different typologies, allowing for a better fundamented and conscious decision making when choosing the construction solutions to adopt in Cape Verde. Considering the current growth in the construction sector, it is timely intervention to contribute to the sustainable development of the country. In this context, perspective is that this work can serve as encouragement and support base for future research on Sustainable Architecture and Construction in Cape Verde.

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