Key words: Sustainable Architecture, Bio-Climatic Buildings, Energy Saving Buildings, Social Housing.

Introduction

Over the past decade, sustainable development has emerged as the favoured way of responding to the continuing degradation of the global environment. One particular aspect has to be pointed out in this context: the steadily increasing energy consumption, and building designs or architecture, urban design and planning not adapted to local climatic circumstances [1].

Too often climatic factors are neglected in construction because they are not of immediate interest and concern to the building industry, builders, designers, developers and owners. With the input of sufficient energy almost everything seems possible but present construction trends in tropical and subtropical regions still show little awareness about energy conservation. The widely applied international concrete box and iron sheet style of ubiquitous buildings is not adapted to local climatic conditions and hence its worldwide influence is questionable [2].

A possible alternative, the climate responsive building, involves the application of soft measures and natural means to reduce energy consumption by design, construction and materials appropriate for a specific climate. This also has positive consequences in terms of economy as well as in terms of proper use of local resources. Improvements can be achieved when buildings are conceived in an integrated approach. This includes the settlement pattern, the urban forms and the selection of the site according to microclimatic criteria. The shape and type of buildings and their orientation, the integration of suitable vegetation and the arrangement of the external and internal space require careful consideration. The correct use of building materials, designs of openings and their shading, natural cooling, passive solar heating and the well-aimed utilisation of prevailing winds for ventilation are important supporting elements [3].

Architecture and urban design have an important impact on the energy efficiency and sustainability of societies. In Brazil, an emerging country, 42% of the electrical energy is consumed in buildings [4]. The direct effects on energy consumption can be observed all over the world. As an example, the average energy consumption of office buildings in Rio de Janeiro is around 340 kWh/m² [4]. The private consumption is also stepping up, with still an enormous potential to grow: in Brazil the share of air conditioning in the total energy consumption in private households is 7%, with a market saturation of only 6% [5].

It is well known that all countries in the tropics do have a long history of sustainable buildings: the vernacular architecture. The hot and dry regions with hot days and cold nights developed over centuries a perfect balance of shading and day lighting, natural ventilation and heat storage. In the hot and humid regions natural ventilation and shading systems were perfectly adapted to the local climate [6].

While the principal concepts are very similar for residential and commercial buildings, the approaches are different. In residential buildings the low-tech approach will prevail for the vast majority of the buildings, due to the cost structure and more active user behaviour. In commercial buildings a more technical approach seems to be more successful, taking into consideration a generally higher initial investment and more passive user behaviour.

Building Construction Concepts

Modular Coordination

In 1950 in Brazil, the first norm about Modular Construction entitled NB-25R: 'Modulação das Construções was published. Up to now, 26 Brazilian technical norms related to this specific subject, have been published by the CB-2 ("Comitê Brasileiro de Construção Civil") and CE-2:02.15 ("Comissão de Estudo de Coordenação Modular da Construção") [7]. According to NBR 5706: "Coordenação Modular da construção – procedimento", Modular Coordination is defined as: "the technique that allows adequation of project dimensions to modular dimensions by using a module of reference". In terms of sustainability, Modular Coordination reduces the consumption of raw materials and increases the exchange capacity of building components, facilitating its maintainability through a logical process of analysing spaces [8]. Modular Coordination promotes constructiveness, which means, in a simplified form, ease of execution [9].

The execution becomes a typified assembly, because it uses standardized, interchangeable components that do not require cutting, and therefore reduce waste. In addition, the priory established graphical, descriptive and technical language facilitates a good coordination between all the parts involved in the process, increasing professional project approach and providing a greater architectural creativity. Nevertheless, the advantage of cost and production control, by increasing productivity and reducing expense, contribute to the qualification of the construction industry [10].

Construction Materials and Handwork

Through the history of mankind, human beings used to have only one or two different materials to build their buildings while nowadays there is a wide range of building materials which makes the choice of these materials a difficult task. Professionals select materials that satisfy their constructive and aesthetic purposes. The choice should consider costs, aesthetic value, transmission of solar radiation, ventilation rates, durability, impermeability, local availability and resistance. However, taking into account the environmental performance of the components, one should bear in mind that the understanding of ecological systems introduces a new set of criteria for the choice of materials, seeking support in natural processes and considers the impacts of production and use, making selection a more complex process. New construction trends in Brazil, seek to encourage the increase of responsibility among fabricants for the materials produced, including steps ranging from extraction of raw materials to final disposal, emphasizing the importance of reducing the amount of material and energy content of products, the reduction of emissions during use, ease of maintenance and recyclability. The new prospects try to encompass all the possibilities offered by the concept of sustainable construction. CIB (Council for Building Research) notes that one of the advantages of emerging economies is the tradition of using sustainable materials, local construction methods and hand-work. A series of strategies for achieving environmental performance of building, are presented by EBN (Environmental Building News) throughout general guidelines such as: preference for local materials that require minimal maintenance and replacement, and that are also durable; avoid promiscuous use of materials that contain cement or other fossil derivates, as well as plastics in general; avoid toxic materials for a better building conservation; orientate to materials with low industrialization rate (such as adobe, bricks and roof tiles, mud, reforestation wood without toxic treatment, bamboo, straws among others).

Eco-technology

Eco-technology integrates two complementary fields of study: the "ecology of techniques" and the "techniques of ecology," requiring a substantial understanding of the structures and processes of ecosystems and societies. Researchers relate to eco-technology as the use of technological means for ecosystem management, based upon deep ecological understanding, to minimizing the costs of measures and their harm to the environment. Engineering and eco-technology can be defined as the design of human society with its natural environment for the benefit of both [11].

Mastering development and application of eco-technology in industry and the services sector is therefore a key requirement. The quality of eco-technological knowledge depends on the efficiency of the multidisciplinary synthesis of knowledge and skills in natural sciences and technologies, economics, information, communication, legal and social sciences. Ecological engineering combines basic and applied science for the restoration, design and construction of ecosystems, and has been the most favourable method frequently used in developed countries like the United States and Europe and also offer great opportunities for developing countries with tropical or subtropical climates due to their cost-effectiveness.

Green Building Certificates – LEED

The Green Buildings Certificate is carried out by non-governmental entities such as USGBC (United States Green Building Council) that developed a rating system called LEED (Leadership in Energy and Environmental Design) globally accepted and recognized. Recently created Green Building Council Brazil is an entity responsible for the adaptation of the LEED criteria to Brazilian conditions and realities serving as a reference for the transformation of the country's construction industry towards sustainability. The GBC Brazil's LEED Committee is divided into five thematic subcommittees, which address five evaluating LEED rules: Materials and Resources (MR), Energy and Atmosphere (EA), Sustainable Area (SS), Internal Environmental Quality (EQ) and Rational Use of Water (WE) [12].

The mission of GBCB is to develop the national sustainable construction industry, using market forces to conduct the adoption of Green Building practices in an integrated process of conception, implementation, construction and operation of buildings and constructed spaces. The vision is to achieve sustainability in the Brazilian market and lead the effective and comprehensive implementation of its concepts: reduction of energy consumption by using hydroelectric non polluting power, reduction in consumption of natural resources such as the use of raw or local materials, recycling, rehabilitation of degraded sites, socio-environmental issues increasing quality of life for occupants. Last year, three Brazilian projects won LEED certification, and 44 new projects have been registered, with an increase of 100% over the previous year. Until January, there were a number of 89 enterprises in the certification process, which lead Brazil to the fifth position in ranking for the label.

Potential of Energy Saving Buildings in Brazil

The building sector in Brazil is heavily influenced by culture, climate and history. As the sector is booming, social housing, commercial and residential buildings are growing very fast. But it is not just about new construction; Brazil has a large building stock to be refurbished. There are about 60.000 local constructors in Brazil and they contribute about a fifth of commercial building and a quarter of residential. The formal market is modern, regulated, following basic building codes and normal Brazilian building practices and is becoming dominated by bigger companies which focus on commercial and bigger residential developments. This makes it hard to estimate the size of the building market. The experts note that formal building sector in the Metropolitan area of Sao Paulo produced about eight million square meters per year. Assuming that the Metropolitan area is about a third of greater Sao Paulo, we can get an estimation of total building production figures for Brazil of around 100 million m2 per year. This is about the same as the building capacity in India, while China; produces about 20 times as much.

Brazil got an energy "wake-up call" back in 2001 when a black-out paralyzed the southern part of the country. They quickly cut energy demand by about a quarter but the drive to save energy is fading. The Brazilian footprint is increasing rapidly. Brazil will need more energy but without an elaborated policy of "controlled energy growth", there is a risk that Brazil moves away from its sustainable hydro electricity production towards considering fossil (carbon) derived energy sources to support their rapid expansion [13].

Existing technologies combined with common sense design can increase energy efficiency by 35% and reduce heating costs by 80 % for the average building in industrialized markets. Life cycle analysis shows that 80% to 85% of the total energy consumption and CO2 emissions of a building comes from occupancy through heating, cooling, ventilation, and hot water use. If we want to make an impact on climate change, we therefore need to tackle this challenge. Combining the right materials when designing a building envelope can greatly reduce a building's energy requirements, increase its life span and ensure consistent performance over time. Buildings already represent approximately 40 percent of primary energy use globally and energy consumption in buildings is projected to rise substantially in the world's most populous and fast growing countries. Zero net energy buildings will reduce demand by design, be highly efficient and generate at least as much energy as they consume. Therefore, in order to enable an efficient use of energy following strategies can be applied such as responsible urban and space management, extern and intern flows of energy, areas that need to be visited every day located closer, while less frequently visited sites located farther; improvement of special design for elements that require sun, light, wind, rain, fire and water flows among others [14].

Sustainability in Social Housing Programs

In terms of social housing, the tag should not be synonymous to low quality. Simple solutions associated with new technologies can be used to build more decent housing. This is what professionals from areas such as architecture and civil engineering are seeking to demonstrate by enrolling in various programs that support the construction of prototype homes. The process incorporates concepts of economy, performance, quality and comfort in social housing. The goal is for these buildings to serve as models for the dissemination of non-conventional technologies, and a practical base for research studies such as the evaluation of innovative materials.

In Florianopolis, at the UFSC (Federal University of Santa Catarina) campus, two similar houses [Fig. 1] were built using different technologies: reforestation pine wood on one hand, and prefabricated blocks of concrete and mortars with addition of waste on the other hand. While the timber prototype aimed to reduce costs without losing quality, the other one led to the study and utilization of additional new materials such as thermoelectric ashes, rice shells and construction wastes. The 37 square feet, two storey model, was designed to meet the interests of the middle and upper-middle class. Therefore, an important feature of its production system is flexibility, allowing expansion through modular panels. The proposal takes into account the research performed by Ghab, *Grupo de Estudos da Habitação* at UFSC in social housing sets, and the diagnose regarding the perpetual changes of the original construction, the traditional *puxadinhos*. It refers to the constant adjustments that the resident ends up doing in order to meet his needs and that can compromise the functioning and security of housing. Consequently, the project must incorporate these needs, allowing the construction in stages.

Another solution for further development possibilities is stipulated in the design of the second house, by using prefabricated blocks of structural masonry [Fig. 2]. The idea of the prototype and working with alternative materials in a modular system for social housing can reduce costs and speed up the construction of dwellings. Prefabrication can help avoid excesses and seek greater quality control of housing. Additionally, besides generating an alternative product for construction, thermoelectric ashes resolve the problem of the final deposit of this waste. The prototype is just a basic demonstration of sustainable construction solutions such as: electrical installations optimized for low energy consumption, a power generation system based on photovoltaic panels, a sewage treatment system at the construction site and proper use of rain water.

Figure 1 : The prototypes

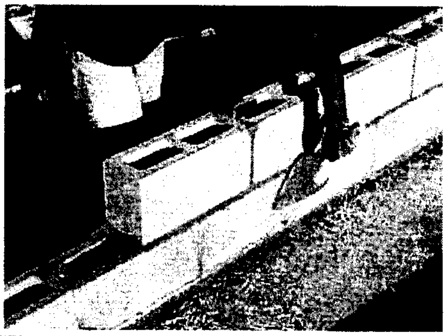

Figure 2 : Prefabricated blocks

Besides these two lodgings, the pursuit for sustainable technologies in social housing is also achieved through the construction of a prototypal home in Rio Grande do Sul, at the UFRGS (Federal University of Rio Grande do Sul) campus in cooperation with *Programa Habitare* [15]. The 46 square feet house was designed based on concepts of sustainability and higher quality standards than normally achieved by public housing. Allowing the study, design and implementation of construction techniques in which ecological and bioclimatic principles are a priority, the building, however takes into account, important issues of costs. In terms of bioclimatic architecture, the small home considers various studies of solar radiation and wind direction in order to benefit from thermal comfort. The outside of the house is designed with pergolas, wooden structures used to support the deciduous species that lose their leaves in winter, providing greater input of solar radiation, and are leafy in summer, creating a shaded environment [Fig. 3]. The roof has double ceiling to ensure warmth during winter, and an air circulation overlay to assist cooling during summer. The proposal also includes simple solutions such as the use of wood stoves for cooking and heating during cold days. In addition to seeking a reduction in power consumption, these principles work with improving the quality of social housing.

Figure 3 : The proper use of pergolas

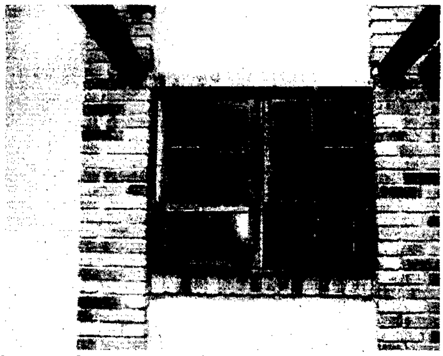

Figure 4 : Detail of a wooden window frame

Furthermore, the project design uses concepts of perm culture by seeking a harmonious and sustainable relationship between the environment, people and their needs for housing, food and energy, among others. According to these principles, the material chosen for the construction was ceramic brick, produced in Rio Grande do Sul. All doors and windows are made of eucalyptus treated with a non-toxic product based on essential oils extracted from Amazonian plants [Fig. 4]. Subscribing the general idea of material reuse, recycled aluminium plates, act as a barrier for heat within the ceiling. The house is equipped with rainwater collectors for toilets and garden irrigation. A sewage treatment system is also being implemented on site to separates black water (toilet) from grey water (all the other wastewaters generated in the building). Each is treated separately and after mingling, conducted to a decanter on which plants are grown. The roots of these plants seek the necessary nutrients in the decanter`s effluents and thereby further purify the water originally black. Finally, this effluent is led to a small pool, where aquatic plants add the final "polish" to the wastewater. The project´s goal is for the components of the house to create a new paradigm for public housing, providing, at this cost, much more than a house. It builds a more dignified lodging, for a family of four or five people, significantly reducing the impacts on the environment. The adoption of at least some of the principles applied for the prototype, already helps in improving housing, not only the housing itself, but the awareness about the need to preserve the environment, to stimulate local food production, the construction of cooperative projects supported by systems of self-management or self-construction and job generation in local production of buildings.

The Federal University of Santa Maria (UFSM) is another institution that participates in the program of building prototypes initialized by Habitare. In self-help system, held with the participation of future residents, five different social housing prototypes were raised. The aim of these constructions was to provide decent housing by associating technical and economical aspects. Built in Santa Maria and Santa Cruz do Sul, both at Rio Grande do Sul state, the houses were designed taking into account the climatic conditions of the area, and therefore, a streamlined building system using hollowed ceramic blocks was adopted. These vertical hallows allow the passage of electrical and hydraulic installations, avoiding cracks within the walls. The ease of construction and waste reduction indicates that the technology could be further implemented on a large scale.

In terms of sustainable technologies, alternative methods for housing programs and low cost infrastructure, both of social interest, are under way in Brazil. Being one of them, the soil stabilization processes seek to combine cost reduction with a less aggressive product for the environment. Given the peculiarities of Brazilian soils and the systems advantages the technique was implemented in the manufacturing of "interlocked bricks" [Fig. 5], leading to design and construction rationalization, ease of implementation, quality and refinement among others. Unlike the conventional bricks, which when broken are no longer usable, the ones made of stabilized soil can be repaired and reused. If the soil from the construction site can be use for bricks production, transportation costs can also be eliminated providing a reduction of the final work expense of approximately 30% to 40%. According to the researchers, the technology has the additional benefit of providing thermal and acoustic comfort, quality that is lacked by conventional constructions [Fig. 6].

Figure 5 : Interlocked bricks

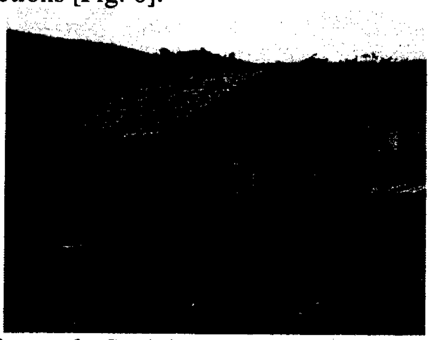

Figure 6 : Social House in Rio de Janeiro

In the city of Volta Redonda, the factory that produces 'ecologic bricks' was set up to manufacture blocks with addition of industrial waste. The blocks are used in social housing programs. The process used in the factory is another advantage of the technology of soil stabilization because it does not require combustion. It is estimated that producing one thousand traditional clay bricks requires a cubic meter of wood for the furnaces, which is equivalent to burning approximately six medium trees [15]. Although the characteristics the soil stabilization technology should contribute to reducing housing deficit, the opposite sometimes happens. The upper class is the one that makes use of it due to lack of planning, politics, people`s prejudice, who associate soil with poverty, ignorance and technical errors of the past. Within the socio-economical environment, the soil is revealed as a material with great potential for harmonizing architectural design with local materials and building systems. Despite all, a dissenting fact came across: the obstruction of cold potteries. The main reason of failure is the total lack of professional guidance for manufacturers in accordance to the technical specifications required. Unlike concrete, the issue of quality in the stabilized soil`s case does not exist. The intermediate state in the technology of soil stabilization is problematic; the slightest mistake can cause serious further problems. All in all, while there are many positive trends, there are also negative aspects: cheap and inefficient air conditioning in poor homes, a virtually non-existent insulation industry, skills and capacity shortages, social housing lagging behind.

Conclusion

Green buildings and sustainability are beginning to gain popularity in Brazil. In fact, the label is sometimes over-used and everything is named *sustentável*. The country is now starting to implement building energy standards and wants to transform the way projects are realized. In terms of sustainable technologies, alternative methods for housing programs and low cost infrastructure, both of social interest, are under way. Aiming to reduce costs without losing quality, researchers and builders try to implement innovative technologies by using new, alternative materials; introducing ecological and bioclimatic principles in the design and implementation of construction techniques; developing a flexible production system, that allows expansion through modular panels and speeds up the construction of dwellings; improving and disseminating the soil stabilization technology among others. Considering these programs and technologies, and promoting citizenship, sustainable trends in social housing production seek to contribute to increasing efficiency and quality with reduced costs.

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