Good practices in sustainable construction: a design method for environmental control in educational buildings

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ABSTRACT: This study reports how built environment effects the natural environment, and vice-versa, dealing with school buildings in southern Brazil. With regard to the best practices in sustainable construction, besides the relationship with the climatic context, one must consider the interaction between the building and the urban context. This means taking into account not only the environmental impact of the isolated building, but also its implications on the urban surroundings, like built environment and green areas, infra-structures and services. The evaluation includes the selection of materials (Life Cycle Analysis) and constructive methods to achieve an efficient building in functional, technical, and, of course, environmental terms, which involves the design concepts and construction decisions, and the management of building operation and maintenance over its lifetime. In order to demonstrate these issues, a case study is discussed, dealing with a design methodology of environmental control, shown by a Ø-energy building or, in other words, a self-sufficient construction.

Conference Topic: 7 0-energy built environments
Keywords: sustainable construction, best practices on architecture, passive solar schools.

INTRODUCTION

This work is a part of the research in development at the doctorate program at Escuela Tècnica Superior de Arquitectura de Barcelona - Universitat Politècnica de Catalunya - ETSAB/UPC, which intends to approach questions related to the environmental effects and their interaction with built space, using the educational buildings as analysis element due to their specific program (functional, pedagogical, social and comfort requirements), and especially their insertion in the urban context.

Its goal is the definition of parameters and coefficients to assess the building performance in order to improve programs of integrated and participative planning and management of new equipment or qualifying the existing ones. The present work presents some preliminary results.

1. GOOD PRACTICES IN EDUCATIONAL BUILDINGS

The application of the best practices on sustainability in school buildings begins by carrying out research on local data (South Brazilian region) and evaluation consisting, preliminarily, of analyses according to three groups of concepts: a. technical and constructive; b. functional and c. environmental performance; objectively, this work focuses only on the environmental issues. It is directly linked with another research entitled "Post-Occupancy Evaluation (POE) in school environment: space, education and citizenship" in development at the Faculdade de Engenharia e Arquitetura of the Universidade de Passo Fundo.

Firstly, in order to define an appropriate benchmark, it fits to point out, amongst others, the contribution of the Environmental Plan of the Universitat Politècnica de Catalunya - UPC [1]. The plan presents a methodology based on the reduction of environmental impacts of the UPC’s buildings at its campus, through a dynamic process of planning and management that considers the environment in an integrated way.

The plan departs from the definition of aspects that must be considered during all the planning process, as well as during the construction and finally in the building occupancy. Three phases are distinguished in the following general aspects: a. environment impact; b. water conservation; c. wastes; d. energy; e. indoor quality; f. maintenance. Thus, it deals with the aspects that interfere with the reduction of impacts, increase the users’ comfort, reduction of the production of residues, minimize energy costs, operation and maintenance and in the increase of the durability of the buildings, objectified for the plan.

Serra [2] also contributes in this stage of research with the proposal of a computational design program and urban evaluation, in which the main objectives are to define the best practices and to present an environmental assessment, energy and ecological...
aspects and its respective relationship with the interior spaces, exterior and the urban tissue.

Table 1: Categories of analysis criteria.

A. Functional
A.1 Community commitment in planning process
A.2 Site context
A.3 Architectural features
A.4 Teaching and learning facilities
A.5 Psychological well-fare
A.6 Work conditions - teachers and staff
A.7 Universal accessibity
A.8 Flexibility and adaptability
A.9 Safety
A.10 Imaginative and stimulating environment
A.11 Social cohesion and community asset
A.12 Environmental education

B. Indoor comfort
B.1 Solar orientation
B.2 Daylighting
B.3 Artificial lighting
B.4 Sun protection - shading
B.5 Natural ventilation system
B.6 Passive heating system
B.7 Passive cooling system
B.8 HVAC system
B.9 Exterior noise conditions
B.10 Indoor noise levels
B.11 Control and operation arrangements

C. Energy
C.1 Energy consumption: HVAC
C.2 Energy consumption: lighting
C.3 Other energy consumption
C.4 Energy self-production
C.5 Water consumption
C.6 Rain-water use
C.7 Grey water reuse
C.8 Energy consumption during construction
C.9 Construction costs
C.10 Maintenance costs

D. Environment
D.1 Material excavated
D.2 Life Cycle Analysis (LCA)
D.3 Construction systems: efficiency
D.4 Construction systems: durability
D.5 Renewable energy
D.6 Sanitary waste water disposal
D.7 Solid and organic waste disposal
D.8 Soil permeability and ground areas
D.9 Microclimatic changes: temperature
D.10 Microclimatic changes: winds
D.11 Acoustical effects at neighbourhood
D.12 Home to school transport policy
D.13 Reduction O3 layer
D.14 CO2 levels
D.15 Recycling - deconstruction

However, bearing in mind that other aspects must be incorporated in the evaluation, e.g. the functional one, it is important to verify the pertaining of school constructions and their interaction with the natural and built urban spaces, in four categories:

- **functional** - evaluation of the planning process and the attendance to the architectural requirements, as well as the pedagogical and psychological requirements of occupants;
- **indoor comfort** - the issues related to acoustics, lighting and thermal performance, in the scope of the indoor and outdoor spaces and the urban tissue;
- **energy** - to measure the costs of HVAC, artificial lighting, water consumption, people and materials transportation, amongst others, and still incorporating the maintenance and the construction costs;
- **environment** - includes variables such as the changes in microclimate conditions (temperature, humidity, winds) and the production of waste and emission of pollutants in air, soil and water.

Following other methods such as the criteria elaborated by UPC Environmental Plan [1], the benchmarks of GBTool [3] and even considering the POE methodology [4], this research proposes an approach to the Brazilian specific characteristics on the categories aforementioned (see Table 1). Some of those items, of course, are related to other ones or even with another category.

The concepts are also in accordance with those principles adopted in recent initiatives of the British eco-schools [5] in which the commitment to include the sustainable practice in the school planning and curriculum are considered, with the aim of developing all factors that appear in the insertion of the school in the social, cultural and environmental context, identifying itself with the proposal of this study.

2. DESIGN METHOD AND ENVIRONMENTAL CONTROL

According to Elvan Silva [6] the use of a method during the design process results in a sequence of transparent steps that make possible the definition and the materialization of referring concepts considered during the design stage.

Applying a design methodology that includes the environment control in the architecture [7], a draft exercise was developed for a community library, identified with schools typology, in Barcelona, as a project integrated of spring assignments of the doctorate program at ETSAB-UPC (Architecture and Natural Energy, Sustainable Architecture and Lighting Design). This exercise had the aim of integrating the architectural proposal with the urban and climatic context, so that the building presented alternative energy solutions, with the self-sufficiency to an indoor comfort proper to the local Mediterranean climate and to illumination using energy from photovoltaic panels, characterizing it, thus, as a building of “0-energy” for its operation and maintenance. Still, a proposal integrated to the concepts of sustainable construction,
or either, of low impact on environment, meeting the goals of this work.

**EXISTING SURROUNDING** ← ENVIRONMENTAL VOLITIONS  
DESIGN PROCESS

*Figure 1: Environmental design concepts [7]*.

The proposal of environment control deals with some particularities, such as a strong intention to link the design decisions to the conditioners (Figure 1): on the one hand the climate and existing surrounding analysis, on the other hand to what Serra and Coch [7] define as environmental “volitions” (from Latin volere, as an expression of the will), which set of desires or trends originated by the users' requirements, according to the spatial, climatic and acoustic appearances that characterize the spaces as an energy approach.

However, it is important to point out that the design process adopting a method allows an easy and fast reevaluation of concepts and design decisions, since it is not a simple succession of steps to follow, but its systematization [8]. The design must be considered as a holistic process, as a result of the structural relations of all the areas of knowledge that define the Architecture, where environmental issues and its implications should be included on all phases.

The community library that exemplifies the design method is located on the transition area formed by an old industrial zone (Poblenou) in recent and increasing process of transformation, the Barcelonian traditional Eixample, the new zone of Forum Barcelona'2004 and the Mediterraneo, as shown in Figure 2.

From the concretion of those intentions in a preliminary or schematic design, the information can be used to predict indoor temperatures and energy consumption by ARCHISUN [9], a building simulation computer program, whose inputs are related to the location (Figure 4), shape, skin and indoor characteristics of the building; such performance simulation constitutes a tool of preliminary design phase, allowing adjustments in factors such as the surround correction by creating or suppressing barriers or vegetation; adjustments of capacity index, slenderness, porosity, weight and color, mentioning the characteristics of shape and skin; or even in internal aspects as connection, geometry, weight and color. The program may also be used for assessing completed projects or already existing buildings, and for that reason it also allows the entry of detailed data.
Already in the phase of drawing itself, the preliminary proposal represented for a transversal cut (Figure 5) applies bioclimatic strategies as the indirect passive solar heating by water panels, located below the windows sills south-oriented, cross-ventilation, shading in hot periods by brises-soleil, light-self to improve the daylighting and photovoltaic panels integrated to the covering shape, taking care of the general objectives of the exercise.

Figure 5: Transversal cut of the preliminary design.

On the constructive aspects, the proposal adopts the concepts of sustainable construction: a. efficient - the ideal sections of structural elements; b. low environment impact of extraction and production (LCA); c. dry constructive system in order to reduce water consumption during construction; d. light - minimize the substance employed; e. multi-layer system, allowing a high potential of recycling by the end of its useful life. In this way it uses a sustainable wood construction system, guaranteeing equally the requirements of thermal resistance for the internal ambient conditioning.

3. FINAL GOALS: INDICATORS AND PARAMETERS

The continuity of the research intends to consolidate the assessment methodology, developing it in order to establish instruments that allow the definition of criteria and the formulation of lines of planning and management integrated and responsive of intervention in the urban context.

The presentation of the results will have as objective to facilitate the interpretation and application, by means of graphs and tables that express "parameter-summary" or pointers of energy coefficient, environmental coefficient and coefficient of impact, using at this intermediate moment of the research what is considered by Serra [2], comparing the exterior (urban) and indoor conditions.

The energy coefficient attributes value to the amount of primary energy consumed by the different solutions of location and typology, enclosing the construction, the use, the maintenance and the recovery of the construction, i.e., during all the cycle of execution and use of the building, not only in architectural terms, but also in other concepts associates such as the waste and effluent treatment.

The objective environmental coefficient to characterize and to quantify the solutions in terms of contamination of air, quality of the consumption water, passing to the acoustics and lighting contamination, the ratio of green surfaces, the landscape, the visual amplitude, etc., results in a complex coefficient, when becoming related with the occupants' behavior and physiological components, complementing the previous analyses of the POE.

Finally, the impact coefficient summarizes the set of influences of the solutions on the environment, both of the construction and of the functioning, resulting in an "ecological evaluation", which is the final goal of the inquiry. These impacts can be represented by a self-sufficiency indicator of construction, or either, the degree of its dependence of outside energy, as previously called Ø-energy building.

Table 2 shows some aspects that appear in this analysis applied to the case study. The predicted energy consumption is 5.68 MJ/kg, considering 494 kg/m²; to a conventional construction of masonry and concrete, the energy computation is 2.12 MJ/kg to a 771 kg/m², considering only the walls and ceilings of a Spanish standard of 4-story residential building.

Table 2: Library at Barcelona: materials and environmental impacts.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Weight (kg/m²)</th>
<th>Energy (MJ/m²)</th>
<th>CO₂ (kg)</th>
<th>SO₂ (kg)</th>
<th>Waste (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>concrete</td>
<td>288</td>
<td>288</td>
<td>2.059</td>
<td>32</td>
<td>539</td>
</tr>
<tr>
<td>EPDM</td>
<td>10</td>
<td>714</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>wood framing</td>
<td>38</td>
<td>115</td>
<td>489</td>
<td>4</td>
<td>105</td>
</tr>
<tr>
<td>plywood</td>
<td>50</td>
<td>949</td>
<td>379</td>
<td>5</td>
<td>220</td>
</tr>
<tr>
<td>glass</td>
<td>13</td>
<td>107</td>
<td>838</td>
<td>65</td>
<td>?</td>
</tr>
<tr>
<td>recycled steel</td>
<td>9</td>
<td>92</td>
<td>564</td>
<td>3</td>
<td>?</td>
</tr>
<tr>
<td>water panels</td>
<td>19</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>mineral wool</td>
<td>33</td>
<td>360</td>
<td>3.874</td>
<td>22</td>
<td>1.152</td>
</tr>
<tr>
<td>plasterboard</td>
<td>36</td>
<td>180</td>
<td>1.052</td>
<td>12</td>
<td>32</td>
</tr>
</tbody>
</table>

TOTAL 494 2.806 9.253 143 2.048

Dealing with such information, the research intended to develop the assessment indicators or coefficients, to constitute their sequence, comparing them and evaluating their positive and negative aspects, in order to create a proper approach to Brazilian context.

CONCLUSIONS

Although the architecture and the construction in the environment could be considered as an oxymoron in relation to the sustainability, due to their original impacts upon the environment, it is very important to develop a practical methodology that allows one to evaluate and minimize these environmental impacts.

Since the urban development process in most Brazilian cities can be reverted, these methodologies
based on the sustainable development, in a global sense including economic, social and cultural way, becomes essential, not only in those big cities where its is urgent, but even in medium-sized ones, where the urban development tendency can be redirected to an alternative achievement. Thus, the assessment tool, even in the preliminary version presented, fulfills that purpose.

As the main research result, it means that even the design process takes into account the environmental issues in a global and dynamic way, the built correspondence indicates an energy efficiency, comfortable levels and a responsible interference on the environmental surroundings and even in a larger scale.

Despite being initially applied to school buildings, the use of a design method that considers the environment control as presented, during all its steps or phases (since predesign until advanced ones), suggests that this study can be extended to other typologies.

This systematic and integrated environmental approach on the architecture process is an important design tool to be used, in particular, in the academic process of undergraduate courses in Architecture and Urbanism, and thus, to gradually consolidate the principles of the "sustainable architecture" in the professional field.

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REFERENCES