Building envelope design for a zero energy response

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ABSTRACT: New ideas that include sustainability as an integral quality of the whole design concept contribute to set higher standards, tending to the world sustainable development. Variety of solutions of high quality design must be presented and discussed as the conception of a whole design idea is not restricted to one solution when projecting sustainability.

Great importance is given to the analysis of the treatment of the building's envelope, understood as a dynamic and selective limit between interior and exterior, were the main passive strategies can be conceived. The interior-exterior transition may be done through intermediate spaces that have the quality to function as environmental barriers and connectors acting as "filters" and becoming "environmental regulators".

It is presented a zero energy project of a thematic library for the Jardí Botànic de Barcelona in which early decisions favoring passive techniques gave form: compactness, slenderness and porosity to the project. Thermal balance for winter and summer has been studied using ARCHISUN and average daylight levels were simulated with RAFIS. NIF levels go from 10 to 15\%. Internal temperatures are, in winter between 20\°- 24\°, and in summer between 23\° - 28\°; been the external temperature's range from 0\° to 15\° and from 22\° to 40\°, respectively.

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1. INTRODUCTION

New ideas that include sustainability as an integral quality of the whole design concept contribute to set higher standards among professionals of the built environment tending to the so called world sustainable development.

The buildings' energy performance and environmental impact must be thought in combination with other architectural values (comfort, climate, history, context, culture, desires of the owner...) that will enclose the whole presence of the dwelling in its site. It is very important to take these factors into account in the first steps of design as they must be integrated with each other to conceive a solution that could not lack one of its parts to be complete.

The evolution of environmental consciousness in the recent past together with the developments of design tools and methods of predictions and assessments have started to change the traditional approach to architectural design thus generating a new architectural language. [1]

The question arises, however, whether and to what extend solar systems engender novel building solutions, and what their contribution might be to the cultural quality of architecture. [2]

The desire and the possibility to fully recover the architect’s point of view does exist; and in this dialogue with the site and its cultural and historical context, to create new forms. To concrete in a creative way the result of this dialogue in which both parts discover and discover themselves in something new, different, that each one assumes its own way and that enriches the totality in which it is implanted. Since the ecological and environmental responsibility that worries the architect that follows this effort does not suppose, must not suppose, a drying, a limitation of the creative capacity or the invention of new forms. [3]

As we put into the board of discussion projects and ideas that renew the concept of environmentally conscious architecture, we show that there are no restrictions to creativity and that instead it is an great opportunity to create wonderful and comfortable buildings most desirable to live in.
A variety of solutions of high quality design must be presented and discussed as the conception of a whole design idea is not restricted to one solution when projecting sustainability. This can be seen in Figure 1, where two sustainable houses, adopt completely different architectural responses to the same climate.

![Figure 1: Same architectural theme solved with a very diverse architectural sustainable solution. Source: J. Wines. Green Architecture.](image)

2. ENVELOPE DESIGN

Great importance is given to the analysis of the treatment of the building’s envelope, understood as a dynamic and selective limit between interior and exterior, were the main passive strategies can be conceived. Moreover, it presents opportunities to respond to two very important objectives in a project:

A. The interior environment situation of comfort. The environmental regulation of the zero energy response.

Steven Szokolay describes the building envelope as a fuzzy line often dissolving into various transitional spaces. And emphasizes the role of the envelope as a selective filter, to admit desirable and exclude adverse influences (energy flows) from and to the indoor environment. [4]

Helena Coch analyses the ways in which intermediate spaces (considered integral parts of the envelope) function as environmental barriers and connectors. In her work, the author demonstrated that, in enabling them to act simultaneously as a barrier to one phenomena and a connection to another, they act as “filters”. Moreover, this is not all they do. By using the possibilities for manipulation and variation that they provide, they may also become effective environmental regulators. It may even be stated that, as the possibilities for manipulation increase, the quality of the architectural space also increases, because the space fulfils a broader range of uses and environmental conditions.[5]

![Figure 2: The symbolic role of intermediate spaces in the envelope. Climatic and cultural interior-exterior transition.](image)

B. The exterior relationship with the inside inhabitant and the outside observer. The image of the zero energy response.

Christian Schittich states that it is the building skin that allows us to experience architecture and architectural design in the public space – in the street, square or urban quarter.[2]

Helena Coch refers to the symbolic desires that human beings must satisfy that are also more significant than is usually thought, and it is in this respect that intermediate spaces (conforming the envelope) may have a highly influential role to play, as a result of their ability to adapt and to become the showcase that users wish to display... They allow for a climatic and cultural transition, which is in the end what justifies their interior or perimeter location. [5] Some examples can be seen in Figure 2.

3. ENVIRONMENTAL REGULATION

To refer to the treatment of the envelope, as an environmental regulator, we must analyse the permeability of the skin in relation with the exterior energetic manifestations. This permeability depends basically on four groups of characteristics:

A. Relative relationship between the envelope and the built context and location.
   a. Climate and orientation
   b. Settlement
   c. Enclosure

This group refers to the building’s opportunity to access to radiation; and the amount of envelope exposed to the exterior environment in relation with possible energy flows’ exchange. In Figure 3 we can observe some examples referring to these characteristics: On one hand, a series of buildings located in a rather cold climate in contact with the ground and with each other leaving only two facades and the roof exposed to the exterior. This way the exchanges of in-out energy flows are limited. On the other hand, a building isolated and on “pilotis” separated from the ground to increase the amount of envelope exposed to six “façades”. Enlarging as much as possible interior-exterior exchanges of energy flows. This aspect is also related to open and compact typologies.
B. Relative relationship between the envelope and the general form of the building.

   a. Compactness
   b. Porosity
   c. Slenderness

In this case the principal equation is referred to determining the possible influence of the envelope in the internal behaviour of the building. It is about the relationship between the envelope’s area and the volume enclosed.

Figure 4 shows “La Geode”, de la Cité de Sciences et de l’Industrie de Paris. This building has the shape of an sphere, and this solid has the characteristic to enclose the maximum volume with the minimum envelope. This is an example where the skin plays less influence on the interior environment behavior. Any other shape has more possibilities to regulate its behaviour through the intervention of the envelope.

C. Specific particularities of the envelope.
   a. Mass
   b. Perforation
   c. Transparency
   d. Insulation
   e. Smoothness
   f. Texture
   g. Colour

This variations are the ones referred to the particularities in the envelope itself. Designing them we can choose to what extent we want to profit the opportunities the envelope-context and envelope-form relationships gave us. This characteristics are very important because they will inside directly not only in the behaviour of the building (heat gain, daylight, ventilation…), but also will have a lot of impact in its expression.

These particularities can be classified in three: (1) mass, perforations and transparency; (2) insulation; and (3) smoothness, colour and texture.

The first group distinguish mass and perforations, that means close and open parts of the envelope. And also distinguishes transparency that may be achieved by an open or a closed envelope. In figure 5 are shown the four possibilities: close and massive (opaque) and close and transparent. Open and opaque and open and transparent.

Insulation is a characteristic of the materials that compose the envelope. This concept gives an idea of the resistance that opposes the skin of the building to in-out energy flux exchanges given the difference of temperature from inside to outside.

Smoothness, colour and texture have a direct incidence in the absorption or reflection of the incident radiation and can modify its qualities (specular, diffuse). It does no only affects the internal behaviour but also the context of the building. Figure 6 displays examples of the different combinations between these three factors. Smoothness and textures can give different responses depending on the colour of the surface.
D. Variability and flexibility to adaptation.
   a. Modifiable elements
   b. Practicable elements
   c. Intermediate spaces

Up to this point we have established relationships between the relative context, the form and the materiality of the envelope. These studies had permitted us to understand the influence of different criteria of design decisions in the environmental response of buildings. But, we have considered this conditions as static, unchangeable and constant.

It is very important to take into account that as climate actions change during days and seasons, so do internal habitability demands from the users. It is an unavoidable need that the envelope has the ability to adapt to these two demands and satisfactory respond to them, specially in complex and changing climates as the temperate.

Rafael Serra and Helena Coch refer to this concept as: Solutions that have the principle to be flexible, that means, elements or groups of elements that can change easily its environmental action depending on the climatic circumstances, like:
- Movable shadow systems, that allow to control radiation admitting it only when we are interested.
- Movable isolation in openings (shutters, curtains, etc.), that permit to regulate at will the pass of energies through openings.
- Completely practicable openings, that allow to control ventilation, from a maximum that permits the total pass of the air, to a minimum in winter, that reduces heat losses.
- Intermediate spaces between interior and exterior, that can generate favourable microclimates and permit also its occupation, depending on the season and the hour of the day (court yards, porches, galleries, etc.).[6]

In Figure 7 shows examples of movable shadow and movable isolation systems, and completely practicable openings. Observe that the three are characteristics of the same element (window) that vary according to climate regulation requirements. Meaning that good envelope design must be a flexible and adaptable synthesis of treatments.

From the treatment of the skin, interior – exterior relationships are enriched with the appearance or intermediate spaces, barriers and modifier filters (movable and practicable) that contribute to the bioclimatic behaviour and make more interesting the architectural offer presented to the user.

Many times they present an additional attractive due to the presence of a new space, between public and private, where comfort exigencies are more flexible. Moreover, its use is seasonal and intermittent extending the activities that can be developed in the building and allowing the enjoyment of more broaden environmental conditions, been this, another contribution to their perceptive richness. Some examples of Intermediate spaces in buildings are shown in Figure 8.

4. ZERO ENERGY RESPONSE

As an example of the zero energy possibilities by the envelope design, it is presented a project of a thematic library for the Jardí Botànic de Barcelona – JBB (Botanical Garden of Barcelona) located in the Montjüic Hill, south west of the city. (41° North Latitude, 2º East Longitude, 173 m.a.s.l)

It has a privilege position as it is located in the highest area of the Montjüic which orientation and access to radiation is optimum. As we can see in Figure 9, best views of the city of Barcelona are also available, though the site’s staggered disposition.
Temperatures belong to a typical Mediterranean temperate climate. The average annual temperature goes from 7°C to 24°C. Special attention must be given to certain periods in which temperatures can be as low as 0°C or high as 40°C. As for wind velocity the north west is leading, but the south west direction is predominant.

Been the general enclosure of the building open, as it is isolated from other constructions. The existing lot presented a north-south slope given to the staggered disposition of the park. This situation is profited by the settlement of the project that increases the contact surface with the soil reducing heat losses in the north façade.

The passive strategy starts with the reduction of thermal losses and gains; and follows with the flexible and user friendly environment regulation through the building's envelope and south space, also enriching diversity of spaces and uses within one space.

The ground plant of the library (Figure 11) shows the importance given to north, west and east façades' insulation; been north thermal resistance increased by the position of the bookshelves.

Early decisions favoring passive techniques gave form: compactness, slenderness and porosity to the project. It is a compact, one story high building without internal court yards. Been the relation between the volume and the envelope of 0.67.

In order to respond to the space requirements, two levels were created. This decision does not split the space as it is conceived as a whole environment but do separate activities and therefore energy requirements.

The upper level corresponds to the reading room that can not directly view the exterior but can indirectly see the connection with it. This way a silent environment, favouring concentration is created. The lower level, been the access level, has an straight view to the exterior and receives directly the energy flows through its transparent parapets when desired, been its envelope the environmental regulator of the whole.

This space and its south oriented envelope are the most important in relation with the building's performance. Every energy exchange in and out of the building will happen depending on the environmental regulation activity the skin will be performing. Solar energy will be allowed in winter through its transparent glazing and collected in its mass concrete floor slabs, sun shading movable devises will protect from the summer radiation; and it can be open to enjoy a breeze when needed by the complete practicable perforation of the south façade. This opening is complemented with smaller ones in the north façade to favour the summer air movement through the whole building. It proposes a more informal space where reading is allowed but its ambiance is not looked after to the optimal performance of this activity. It is perfect to stretch the legs, change the view, relax, and connect with the outside.

Figure 11 shows a partial section with the space disposition in two levels in relation with the possibility to regulate climate actions and see the outside Botanical Garden. It is also displayed the incidence angle of radiation for winter and summer; and the PV “two positions” movable device that covers specific electricity requirements.

Notice that the roof is also very important as part of the envelope. It accompanies the difference of levels in the floor by a difference in the roof that would allow an indirect illumination of the reading sector providing mostly diffuse daylighting working together with sunducts to complement an homogeneous distribution of light in the space.

Exterior surfaces are mostly smooth and with pale colours (not specular) to absorb little radiation. The interior reading ambiance is also pale tending to the diffuse distribution of light. In the lower space colours grow stronger and darker to absorb radiation when allowed in winter and heating the
whole space. **Textures** are thought in order to absorb and provide a quieter sensation within the building.

Thermal balance for winter and summer has been studied using ARCHISUM and average daylight levels were simulated with Rough Analysis For Illuminated Spaces (RAFIS). Both programmes are developments of the Universitat Politècnica de Catalunya (Polytechnic University of Catalunya).

Natural Illumination Factor levels, mainly diffuse to prevent shadows, in lecture and consulting areas are in the range between 10 and 15%. Figure 13 shows the result image from R.A.F.I.S.

![Figure 13. Simulation results by R.A.F.I.S. analysis](image)

Internal temperatures in winter are between 20° - 24°, been the external temperature’s range from 0° to 15°. Internal temperatures in summer are between 23° - 28° been the external temperature’s range from 22° to 40°. See ARCHISUN results for a theoretical average sequence of days in Figure 14.

![Figure 14. Simulation with ARCHISUM. Winter and Summer Temperature analyses.](image)

It is observed a the design is validated by these two evaluation systems and both analyses (temperature and daylight) give satisfactory results for the passive behaviour of the building and its specific needs as a library. The envelope treatment as an environmental regulator is very important in this type of buildings where its influence makes significant changes to the passive behaviour of the dwelling.

5. **CONCLUSIONS**

In this work where highlighted the possibilities that the treatment of the envelope provides as an environmental regulator. It also must be taken into account that it is an unavoidable need for the project to adapt to changing climate and users habitability demands. This is an issue in which the envelope, if studied intensively, can provide the flexibility to answer properly and satisfactory respond to these adaptations in order to success in the users’ acceptance of the project.

The emphases was also on the importance of high quality design for creating the image as well as the response of a zero energy project. As exposed in the theoretical analysis and then supported by the example, sustainable design is not restricted to one solution. It is about understanding and working with design elements to architectonically achieve it.

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