Passive solar design in Antonio Gaudi's domestic architecture

E. Usón Guardiola
Escuela Técnica Superior de Arquitectura de Barcelona, Spain

E. Cunill de la Puente
Escuela Técnica Superior de Arquitectura de Barcelona, Spain

ABSTRACT

The objective of this paper is to show the importance of the solar passive design principles in Antonio Gaudi's Architectural Work from the analysis of one of his domestic buildings constructed in Barcelona in the turn of the XX century: The Batlló House. The paper utilizes a qualitative analyses that are based on accepted Architectural design strategies. The results demonstrate that Antonio Gaudi's Architecture not only is producing an enormous aesthetic emotion but also is a relevant example of environmental conscious design.

1. ANTONIO GAUDÍ AND THE ENVIRONMENTAL SENSIBILITY

Antonio Gaudí (1852-1926), *"Art Nouveau"*'s most important architect in Catalonia, is worldwide known because of his creative ability, based on nature's imitation among other inspiration sources. The fact is evident considering not only the natural motives which shape his decorative language, but also regarding in the same way his environmental sensibility appreciated in the wise use he makes of natural energies to achieve comfort in the Mediterranean climate. Concerned for the appropriate orientation of his buildings, his refined regulation systems of solar radiation and the exploitation of natural lighting and ventilation is habitual in Gaudí's works. On account of this, in most of his projects we can perceive the importance of section not only because it creates space, but also because it is the place where all the environmental tensions focus; light suits space illuminating it properly and air runs through sophisticated itineraries cooling the rooms which surround a central area, adopting the typology of the *"casa con patio"* in the Mediterranean tradition originated in the classical world. The façade of the building turns out to be a highly developed skin that wraps the building with exuberant adornments that are permeable to breezes and measures out the solar rays in all the rooms open both to the outside and to the inside.

We can find these basic principles in Gaudí's whole works, *"Palacio Güell, Casa Batlló, la Pedrera, el convento de las Teresianas, el Palacio Episcopal de Astorga, la Sagrada Familia"* ...etc..., but it is in his domestic architecture where his interest to achieve the user's comfort and wellfare by means of the appropriate use of natural energies is notably shown. The "Casa Batlló" (1904-1906), located in the" Paseo de Gracia" in Barcelona, is a building midst party walls of modernist style, designed as a plurifamiliar house. It consists of seven floors; basement, semibasement, ground floor, main floor plus balcony, four floors, attic and roof. In the Barcelona district designed by the engineer Ildefons Cerdà in the second half of the nineteenth century, the residential plots constitute blocks with a large inner courtyard and a building depth of 28 metres. The edification bylaws provided in this urban plan require the construction of a new intermediate courtyard for ventilation and lighting of the inner rooms. The "Casa Batlló" is not built as a new building, but as a result of the modifications to a remaining building: We do not know if the original building, built in 1877 and known as *"Casa de Luís Sala Sánchez"* was in such a bad condition to make the new

proprietor, Mr Batlló demand its demolition in 1901. It was a typical construction of that time, fitting the bylaws of Cerdà district: building depth of 28 metres and two façades: the front one facing the Paseo de Gracia and the back one facing the large inner courtyard of the block, with a central courtyard for ventilation. Its façade was composite in an irrelevant academic language.

Gaudí carried out a total remodelling (1904-1906) restyling the façades, reforming the central staircase and the main floor, which will be given independent access and will be the future residence of the new proprietors of the building.To improve the environmental functioning of the building, Gaudí will take advantage of the courtyard existing in the already built house and will enlarge it happening to be the principal part of his passive solar design.

2. A HOUSE WITH A COURTYARD IN THE MEDITERRANEAN CLIMATE IN BARCELONA

The building is located in Barcelona, at latitude N41º 23’, climatic area B-W (UNE 240445/6). We could make a valuation of the temperature in the house asserting that the outside average temperature in winter is of 10ºC and the inner of 18ºC, whereas in summer it is of about 31ºC in the outside with a 68% of relative humidity (RH) and an inner temperature of about 24ºC +/-1ºC and a 55% of RH+/-5%.Temperature and humidity standard of the Mediterranean climate, moderated by the marine influence, soft temperatures in winter and hot summers, with a stable running rate of breezes. The wind blows from inland to the sea during the day and the night sea breezes blow from the sea to inland, thus enabling to cool the interior ambience in buildings.

3. PASSIVE SOLAR DESIGN

3.1 Natural ventilation

To cool the “Casa Batlló”, Gaudí uses the two variants of natural ventilation: ventilation via pressure difference and thermoventilation. Ventilation generated by the sea breezes is given a direction through a complex system of openings set in the outside and inside façades of the building, thus making the air run all over the flats producing a crossed ventilation.

Although crossed ventilation is typical in the whole district, the “Casa Batlló” is, beyond doubt, the one that has the most sophisticated phonic systems of ventilation. It is full of openings all around to receive the cool summer night breezes in the low levels of each floor. Ventilation takes place through cracks, eastern gaps and wooden regulative openings, included both in the façade’s structural work and in the inside doors and windows, enabling the renewal of air in the whole house, even with the flats closed.

Altogether, and in his time, all the machinery system of easy working, conceived by Gaudí himself, constitutes a notable technological contribution which permits to regulate the amount, speed and direction of air to achieve the grade of comfort required by the users. Crossed ventilation is reinforced by solar radiation. The sun heats the air under the skylight that goes up until reaching the outside. This is possible with help of two openings strategically placed. It generates a depression in the courtyard that reinforces crossed ventilation in the flats.Additionally, in summer the inner courtyard is supplied with the air that comes from the street through the base of the façade that overlooks Paseo de Gracia, and that gets cool when it comes through some tubes which cross the basement. In the wintertime the system changes; the contribution of cold air is closed and the courtyard turns into a space that receives the heat cumulated inside due to the greenhouse effect through the upper skylight. The hot air goes into each flat through the windows by means of convection. For this reason Gaudí designed windows with directional opening and closing. They turn in the direction of the hot air to make its access inside easier.

3.2 Natural lighting

The central courtyard acts not only as a thermic regulator but also as a well. Observing the longitudinal section of the building we notice that in both inner courtyards one of the façades is displaced to enlarge the surface of the zenithal skylight. The diaphragmatic functioning of the courtyard’s hole, together

with the contribution of hot air, makes it possible to obtain +2/3ºC in the lowest part of the courtyard. This increases with the amount of light that goes down the courtyard.

Gaudí had a special interest in making the light get to the lowest floors. Thus, he works not only in the section of the building but he also takes profit of the effects that the colour of the light produces. The courtyard is covered with bright pottery, having relieves in blue tones. The intensity of colour lowers until reaching white tones on the ground floor. The interplay of the colours causes the reflection and diffusion of light in the whole courtyard, coming to a uniform end. The colourlight relationship is habitual in the whole house.

We find volumetric interplays of the colours in the access hall, where a gap of light appears. On the ground floor, colourful skylight with the shape of a turtle shell are evident. Anyway, it is on the main floor where Gaudí exhibits all kinds of skylight shapes. He uses circular stained glasses for doors and windows, emphasized the colour in the centre, which concentrically diminish to achieve uniformity and diffusion on the whole when light goes through them.

4. LIGHT MEASUREMENTS

Some measurements were done with a luxometer at a height off the ground of 70 cm. They went along the central courtyard, from the roof, including utility rooms and attics, going down the stairs until the ground floor and the two basements. The outcome is interesting. Some Daylight Factor (DF) were checked. The variation of Daylight Factor show us if the level of contribution of the light intensity taken "in situ" is optimal. From the results obtained, the following is proved:

- There is a certain difference of intensities in the zone of the original inner courtyard with regard to the one enlarged by Gaudí. Being the latter more spacious, the levels are slightly higher.
- Increase of lighting in the displaced stairs in relation to the ones which are not.
- The light intensity perceived in the courtyard is spectacularly uniform. Starting from an outside radiation of 17000 lux, half-way the landings of the fourth and third floor, it drops to 500 lux aprox. But starting from the landings half-way the third and second floor, it becomes stable between 140-120 lux until the ground floor. In proportion to the total height of the courtyard, the same illuminance are kept from halfway and downwards.
- DF in the attic of the catenary arches is of 3.2%. It is a diffused light, very much thought as space.
- The back façade, orientated south-west, receives the most direct radiation. The rooms in this sector have got a 10%DL. The problem is dazzling owing to excessive intensity. To solve it, Gaudí makes use of basically two passive solar solutions; louvers blinds of the Venetian type. They bring in natural diffused light coming from the inner courtyard.
- With Gaudí's skylight and thanks to the new central point of vertical access, a 3% DF is chieved in the two floors underneath the balcony, at the back part of the building.
- DL in the middle of the main lounge in suite for functions is also very good, with a rate of a 3.1%. This is because of on the one hand, the large window, and on the other, the depth of the room.
- With reference to the above mentioned paragraph, to get a 3%DF, present-day guidebooks about passive solar architecture design cut down this proportion to 6 metres of depth if light penetrates through a façade. If there is an entrance for light through an inner courtyard in the opposite façade, the distance augments to 12 or 6 metres per side. The main lounge has a depth of about 7.8m , until the inner courtyard, the adjoining room has about 4.5m. Total 12.3m.

5. SOLAR RADIATION PRODUCES THE SHAPE

Carrying out a study on the solar projection on an abstract diagram of the "Casa Batlló"'s lounge with its large window. Using the computerassisted design program Autocad, it is possible using the light that comes from the sun, the geographical location and latitude, date and a time. Rendering the sample space we obtain the projection of the shadows produced. Choosing the summer solstice in the morning, it

is in this season when the morning sun penetrates through the lounge. After several assays, with different hours, the angle that best focused the shadows towards the inside was fixed. Toning down later the intensities, the graphic result presented is achieved. The similitude between the shadows on the walls and the location and shape of the doors designed by Gaudí in this room is so amazing that one can think that maybe the genius used the sun as a tool to draw, as a pencil, producer of his shapes.

1700 LUX
600 LUX
140 LUX
120 LUX
120 LUX

6. CONCLUSIONS

The “Casa Batlló” embodies all the benefits of solar energy; with the help of thermal gains, thanks to direct solar radiation or by means of the exploitation of natural lighting, by virtue of diffuse radiation, with the benefits of Aeolian energy, since there is not any asymmetrical ventilation, creating a comfortable and energically efficient building. The results demonstrate that Antonio Gaudi’s Architecture not only is producing an enormous aesthetic emotion but also is a relevant example of environmental conscious design.

REFERENCES

Bassegoda i Nonell, Joan. *La Casa Batlló*. Barcelona, Publicaciones de la Real Cátedra Gaudí, 2001.

Edició commemorativa de l’Any Internacional Gaudí.

Gaudí 2002. Miscel.lània. Barcelona, Editorial Planeta/Ajuntament de Barcelona, 2002.

Edició commemorativa de l’Any Internacional Gaudí.

Gaudí. A la recerca de la forma. Barcelona, Lunwerg editores/ Ajuntament de Barcelona/Seacex, 2002.

Flores, Carlos. *La lección de Gaudí. The lesson of Gaudí.* Madrid, Editorial Espasa Calpe S.A, 2002.

Zerbst, Rainer. *Antoni Gaudí*. Alemania, Editorial Taschen.

Coleccionable de “el Periódico”. Gaudí. Casa Batlló. Capitol 11. Barcelona, Editorial Grupo Zeta, 2002.

Coleccionable de “la Vanguardia”. Catalunya desde el cielo. Barcelona, Generalitat de Catalunya/Editorial Planeta, 1995.

González Sandino, Rafael/ López de Asiain, Jaime. *Análisis Bioclimático de la Arquitectura*. Sevilla, Escuela Técnica Superior de Arquitectura de Sevilla,1994.

Müller, Werner; Vogel Gunther. *Atlas de arquitectura,1*. Madrid: Alianza Editoral, S.A. 1984-1999.