Modern architecture as environmental construction - Methods and prototypes in Le Corbusier's work

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Abstract. *The irruption of concepts such as ecology and sustainability in the world of architecture is generating a new language to understand our building's ambiances. Once again, the separation of structural and environmental issues advocated by modern architecture is being challenged. Nevertheless, a broader look of modernity demonstrates pioneering of both technical and plastic approaches. By recalling the latest work of modern architects like Le Corbusier through current methods, such as monitoring and simulation, we can highlight its valuable environmental awareness.*

Keywords: Le Corbusier, energy, environment, monitoring, simulation

Introduction

Throughout history, communities have found their own languages[1] to analyze their particular reality. According to Rorty (1989), those new languages did not have more certainty than older ones, but they provided a better understanding of natural and cultural context. Moreover, the constant reconfiguration of languages has been the main path to innovation: "The method is to redescribe lots and lots of things in new ways, until you have created a pattern of linguistic behavior" (Rorty, 1989: 7).

Specifically, this process in the field of architecture has always been fed by technical and artistic preoccupations. However, during the 20th century technology and industry[2] have most influenced the emergence of new architectural languages. For instance, as Colomina (1994) noted, modern architecture has been conditioned by medical technology developments such as X-rays and by the expansion of mass media, giving rise to concepts of privacy and publicity.

Current concerns over sustainability are encouraging the development of new environmental technologies which simultaneously, are contributing to shape new architectural languages. Even so, the concepts of nature, ecology and environment were already present in the roots of architecture.

Modern architecture and environment

Up until the 19th century, the development of science throughout history generated different mechanical analogies in order to understand the nature's behavior. From that time the discovery of thermodynamics and the steam engine attracted scientific attention to the relevance of the internal energy of those natural or artificial machines.

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1. For example literary, technical, artistic or scientific languages.

2. Architecture has been mainly influenced by aeronautics, automobile industries and medical search.

Thus, the architecture understood as human construction, has always been considered as a "thermodynamic machine" that manages both, ambiance and human energy. This is evidenced, for example, by ancient constructions such as patios, loggias or roman thermaes which illustrate complex hygrothermal systems.
It was Banham (1969) who pointed out the false division created by the historiography of modern architecture. On the one hand, form and structure were subjected by the classical statics physics of the last centuries. On the other hand, facilities and environmental matters could only be dealt with simplifications like the "isothermal building"[3] scheme.
As the first approach was best consolidated, the modern architects and their engineers focused on the material and visible side of buildings, leaving behind their environmental and invisible side (Fernández-Galiano, 1991).
Nevertheless, this well-known process was not totally generalized. At the end of the 30's, the architects from the called "second modernity", started turning towards the integration of local climate and cultural conditions into their projects. Consequently, the environmental approach started being included in architecture.

Le Corbusier. From tectonics to ambiances

The two worlds identified by Banham, were evident in the work progression of the Swiss architect Le Corbusier. During the 20's he was an outstanding figure in the vanguards of the modern movement. Yet, years later he reformulated its original objectives improving and expanding his perspective.
In the 20's, technique as a way of subjecting nature, turned the modern architecture into a real *"machine à habiter"* (Le Corbusier, 1998: 73). It promoted the idea of universality in architecture by limiting a standard inhabitant to his anthropometric, hygrothermal and social parameters, hence renouncing his individuality. As a result, Le Corbusier designed the *Respiration Exacte* (1928), an air conditioning system developed to achieve a standard ambiance[4] for all users in the world. In conjunction with the *Dom-Ino system* (1914) as structural mechanism, they represent the most advanced model of the international architecture proposed by Le Corbusier, which was culminated in the *"Grands Travaux"* works of the late 20's. However, their progress revealed the technical incapability of the building industry to solve the modern utopia (Torres, 2004: 145).
By the early 30's, the study of other construction cultures and their previous difficulties, led him to change his course of research, therefore his architecture, which can be broadly classified into two periods. The first stage (1930-50) was focused on solar radiation control, implementing new techniques to his design process which led to the origin of the *brise-soleil*. Subsequently, sunlight and heat were the main tools to develop ambiances transitions from inside (isolated spaces) to outside (outdoor spaces).
Towards the second stage (1950-65), Le Corbusier looked back at lessons learnt from traditional construction and redefined them with the modern theories and design methods. His interests increased in matters of ventilation control, environmental moisture and thermal inertia. Therefore, he used the climatic parameters to develop specific ambiances in architecture taking advantage of the environmental resources.

The heliotechnique prototype (1930-50)

The solar charts, which combine gnomonics and geometry knowledge applied to architecture, were popularized by Atkinson (1912) in USA and by Körte (1932) in Europe.

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3. A building's scheme for climates in the world supported on air conditioning systems.
4. This proceeding uses the environmental comfort parameters (air temperature, radiant temperature, humidity and air velocity) to define the "ambiances" in architecture.

Le Corbusier started using solar charts in the mid-30's to solve sunlight problems. He used it to calculate sunpaths and projected shadows in urban masterplanning and individual buildings. Thus, he researched further and incorporated the solar radiation calculation method into projects such as the *Sanatorium* (Zurich, 1934) and the *Stade de 100.000 places* (Paris, 1936). However, it was not until the *Gratte-ciel Quartier La Marine* (Algiers, 1938) project that he found his own technical and plastic device to deal with solar radiation: the first *brise-soleil* (Siret, 2004).

Le Corbusier along with other collaborators founded in 1943 the Atelier des Bâtisseurs (AtBat). It mainly focused on the *Unité d'habitation* projects and it was the technical support for the *brise-soleil*. In this sense, the AtBat studied and defined the proportion and shadowing efficiency of the *brise-soleil* while calculating the illuminance levels achieved in the protected interior space. The above considerations are reflected in the plans of the projects: *Usine Duval* (Saint-Dié, 1946) and *Unité d'habitation* (Marseilles, 1947).

These two examples show evidence of how the *brise-soleil* was shaped as a whole with the aforementioned *Dom-Ino* system, resulting on the first prototype to address the local climate condition. The “open floor plan” was limited by the modulation[5] of both, the concrete structure and the apartment layouts. The *brise-soleil* was a part of this structure; built simultaneously and moreover with the same in situ concrete as walls, pillars and slabs. Besides, the remaining elements (parapets, lattices and jambs) were honed finished in precast concrete. Furthermore, the *brise-soleil* was a functional extension of the interior space and it became a characteristic feature of Le Corbusier's collective housing.

In addition, the public spaces were addressed with a second type of façade system: *the pan de verre ondulatoire*. It referred to a glass wall supported by precast concrete posts, arranged in a variable modulation. However, its fundament was representative rather than technical.

The combination of both facades configured the heliotechnique prototype scheme. It was used as basis for the *Unité d'habitation* (Marseilles, 1947; Firminy, 1960), the *Maison du Brésil* (Paris, 1952) and the *Couvent de la Tourette* (Éveux-sur-l'Arbresle, 1953). All of them were designed and built in Central European climates.

The environmental method (1950-65)

The complexity of Indian projects, in which the Atelier 35S[6] was involved in the 50's, forced to systematize the analysis, design and building processes. One of the main troubles they dealt with was the climate difference between Ahmedabad and Chandigarh compared to the Central European climate. Furthermore, they struggled while trying to combine form and function with their previous design techniques. Thus, they modified and improved previous methods in two ways.

The former was the development, in 1951 by the Atelier's employee Xenakis[7], of a geometrical method which allowed summarizing the heliotechnique calculation in a single drawing called the *Épure du Soleil*. There was a specific diagram to each defined location from which the solar aimuth and height angles were obtained. Thereby, architects could understand and use solar charts since early stages of design.

The latter was developed the same year by Xenakis, Doshi and Missenard[8]. It was called the *Grille Climatique* and its objective was to widen the range of previous climate analysis. It introduced new parameters with regard to human comfort and ambiance: air temperature,

5. Measures that was determined with the Modulor as an anthropometric rule in architecture.

6. Le Corbusier office's name- Atelier of the 35 Rue de Sèvres.

7. Iannis Xenakis (1922-2001), Greek engineer who focused his creative thought in probabilistic models for musical composition and also applied it in architecture.

8. André Missenard (1901-1989), french engineer who researched on human comfort, operative temperature and radiant heating since the 20's.

radiant temperature, relative humidity and air velocity. At the end of the analysis, the grid related numerical parameters to bioclimatic architectural solutions.

As a consequence, changes in the architectural language of Atelier 35S were implemented. These included: the *aérateur*, a slender blind door specific for natural ventilation purposes; the building thermal inertia as a way of isolating the interior space from exterior temperature fluctuations; the incorporation of vegetation and water to roof and façade systems for hygrothermal regulation.

The interior proportions, exterior walls scheme and construction system, were all defined under a new environmental design criteria. It allowed Le Corbusier's architecture to adapt better to climate. Examples of this are: *Tour d'ombres* (Chandigarh, 1950), *Villa Shodhan* (Ahmedabad, 1951), *Chandigarh's Capitol* (Chandigarh, 1952), *Carpenter Center for Visual Arts* (Boston, 1961) or the project for *Olivetti Electronic Center* (Rho, 1963).

In summary, Le Corbusier dissected the relationship between architecture and the environment just as vernacular architecture did, but using rational thinking instead of traditional empirical knowledge. Moreover, his researches were prior to Olgyay's studies about sun-shading, hygrothermal effects and air movement which were published in the manual of bioclimatism “Design with climate” in 1963 (Olgyay, 1998).

The solar and bioclimatic charts developed by Missenard and Atelier 35S are in fact, the origin of methods we use today. All are based on the same scientific patterns, but current methods have the accuracy of computer calculation and new meteorological and comfort models.

Towards an ambiances concept in architecture

Environmental and comfort techniques have been present in architecture throughout history. Missenard's scientific approach to comfort nomograms, radiating heating studies and natural ventilation design, must be emphasized. In collaboration with Le Corbusier, they analyzed and managed to draw the physics of ambiances. The *Grille Climatique* schemes[9] are evidence of this challenge.

There are several examples of heliodon and wind tunnel use since the 50's, and computational fluid dynamics use since the 70's. They predicted and represented the energy exchange between the inside and outside of the buildings. In other words, these have the same approach that Missenard and Le Corbusier had, but improved with the evolution of scientific knowledge in this field.

Accordingly, our current monitoring and simulation techniques, by means of environmental engineering and meteorology, allow buildings to be designed as thermodynamic machines.

Measuring and drawing ambiances

By analyzing the building's thermal response to solar radiation and the average weather data progression, we can appreciate two types of physics performance in ambiances. A short-term performance, with great variations in temperature and luminance, which depends on daylight hours and maximum and minimum outside temperatures. A long-term performance, with slow and progressive variations, which depends on seasonal average values like diffuse radiation or thermal mass. The spatial distribution of these performances reveals two different interior “sub-spaces” or ambiances. The first one is located just behind the building envelope achieving short-term performance. The second one lies at the heart of the building and thus, achieves the long-term performance.

Le Corbusier, who sensed the existence of these two ambiances and understood their relation to the function, suggested an interior distribution based on daylighting, hygrothermal

9. Documents FLC 5627A to FLC 5627P found at Fondation Le Corbusier's catalog.

and ventilation requirements. He used the first zone to confine daytime functions that required daylight and thermal comfort. Whereas the remaining functions were situated on the second zone. The *Maison du Brésil* and *Couvent de la Tourette* are illustrative examples of the above.

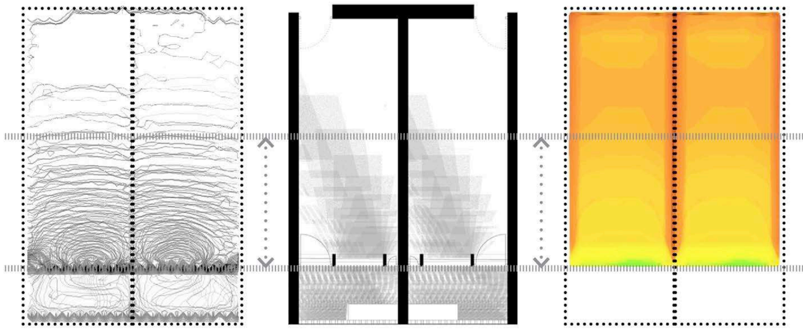

Figure 1. Maison du Brésil rooms. Ambiances performance using luminance, shadowing and temperature simulations (Requena, 2011)

Referring specifically to air movement, the *aérateur* proportions, spacing and quantity respond to the analysis of climate and function. Consequently, the *aérateur* was not designed as a single door, but a system of doors working together to manage building's air permeability. This system allowed inhabitants to regulate moisture and ventilation to achieve the desired comfort level.
In particular, the *aérateur* proportions determined by Missenard resulted in the so-called "air sheet" effect. Induced airflows through the door move both, upper and lower air layers and simultaneously, the air velocity increases improving comfort conditions.

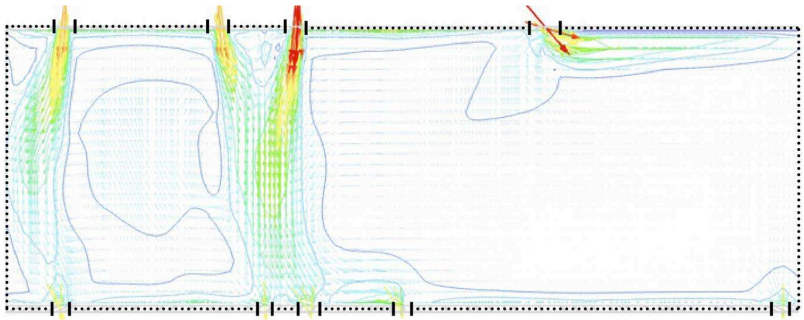

Figure 2. Couvent de la Tourette refectory. Ambiance performance using air movement simulations (Requena, 2011)

The *brise-soleil* environmental performance is due to its own daylighting, thermal and functional properties. Firstly, its depth – according to solar chart – controls solar penetration and hence, regulates temperatures and daylight levels of interior spaces. Secondly, its thermal inertia maximizes isolation of interior spaces. Lastly, it function as a transitional space extends the inside function towards the outside and the nature.
In summary, the *brise-soleil* recovers and improves the intermediate space concept, as an ambiance of transition, associated to traditional architecture – like in the *loggias* or

mashrabiyyas. Nevertheless, economic awareness somehow has always expressed a rejecting posture – that goes back to the 20's – against it.

Conclusion

The estrangement between the tectonic and the ambiances worlds specified by Banham, evidenced how engineering was not able to include environmental considerations into architecture.

Just like any other periods of changes in the 20th century, architecture is implementing the aforementioned technology, which was created for the military industry, later modified for medical research and now is being used in the art world. Techniques that are changing our point of view the architecture.

Currently they allow us to measure, draw and analyze architecture while developing a new language about energy and ambiances. Thereby, if we are able to design including these intangible matters and create thermodynamical machines, we will then generate a new vision that have yet to be explored. Nevertheless, we must not forget that these approaches are part of architecture's DNA throughout history and, particularly, in modernity.

Acknowledgments

Fondation Le Corbusier, I+D+i National Plan MES INNPACTO Project – Ministry of Science and Innovation – and supported by FEDER founds.

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