Automatic procedures for bio-climatic control of architectural project

Abstract

The experiences illustrated here are related to the new regulation of teaching architecture in Italy and these ones in particular have been concentrated on the technological aspects of teaching architecture.

We can consider the evolution of the architect from the individual operator to the manager of multi-disciplinary aspects of the building process (building process manager) as a reality today.

Information technology, specifically applied to bio-climatic architecture and environmental control, can be of great importance for this professional role, and for this reason it is very useful to include these topics at the beginning of the teaching design process.

This paper describes a particular approach to bio-climatic problems of the architectural project. An experimental course has been performed by the second year students of the "Laboratorio di Costruzione dell'Architettura", at the School of Architecture of the Second University of Naples, in Aversa. Analysing old and new buildings, they used some flow charts for the evaluation and representation of energetic behaviour of buildings regarding their climatic and geographical environment.

In the flow charts the decisions are represented by boxes that allow to determine "rightness index" related to: morphological characters of the site and environment, typology and particular organisation of the inside spaces, shape of building, technological solution of the building "skin".

The navigation through the decision boxes is made with simple options like, "winds: protected or exposed site", "shape of building; free, close or cross plane", "presence of shields: yes or not", "presence of trees n the south: - yes or not"; it shows the students the bio-climatic quality of the building and, through numeric value assigned to each option, determines the "weight" of its climatic comfort.

Introduction

The bio-climatic approach to the architectural design has been characterised, in the last 30 years by an alternate fortune in modern architecture movements.

The lack of concern in design for the variations of climate among different parts of the world, was a general tendency of the professional attitude after the second world war as a consequent degeneration of the International Style of the '30s. The new technology of steel and glass, cement and glass, with external walls light-weight, without sufficient insulation, has often exposed the buildings to excessive amount of solar radiation during the day (especially in summer) and rapid loss of heat during the night (especially in winter).

At the beginning of the'70s., in connection with the energy crisis, there were many movements and studies concentrated on the use of alternative sources of energy in order to diminish the consumption of fossil fuels. Direct or indirect use of sun energy, wind power, water power, waste treatment systems applied to the building design, with a consequent new attention to the local climate and environment.
These movements were inspired not only by the traditional materials, typologies and techniques of using natural sources, but also by the new opportunities given by industrialised products and spatial technologies applied to civic use.

Very soon the care of environmental and energetic control in design buildings was confined to a very restrict circle of experts and their projects were defined bio-climatic architecture as specialised type of architecture.

Nowadays, after many impressive environmental accidents occurred in some country with serious consequences for many other countries, it rise a new consideration for the importance of environmental respect. As a consequence, in architecture the idea and movement of sustainable technology offers the opportunity for bringing together experts of different fields. The general aim is to realise a common, global level of quality life in building and a better respect for the environment, in order to select new technologies which are reversible and compatible with natural cycles of life, from an ecological point of view.

This involves the concept of human needs related on one hand to the new quality of building and on the other hand to the environmental quality of cities and their surroundings.

At the same time, we can observe as a reality today the evolution of the architect from an individual operator to a manager of the multidisciplinary aspects of the building process. Especially in complex design firms we can observe that projects are carried on with a multiple structure, which involves architects, economists, engineers, and experts of environmental, energetic and micro-climatic indoor control.

Because of these new ways of designing architecture, in the School of Architecture, students should be accustomed to link together architectural design and environmental need in order to obtain a high quality of building skills; contemporary they should develop their attitude of working in a multidisciplinary team of experts, taking care of the different professional languages and approaches.

Going on with the experiment we have presented last year at the ECAADE Conference in Palermo, we tried to develop a tutorial program specifically designed for the first cycle of Italian studies of Architecture, due to the general design approach.

Our experience concerns Building Technology Teaching and the first application of students in dealing with computer sciences, both practice and logic theory. So we decided to concentrate on a simple automatic procedure applied to the bio-climatic control of architectural design; we decided to use case-studies selected from the ancient villages of our region with the purpose of designing new buildings or rehabilitating existent buildings.

Our efforts were also concentrated on developing in students the consciousness that the present discomfort of urban life is related on one hand to the indifference of the modern buildings to the features of the site which they are destined to, on the other hand on the very poor consideration of the traditional culture and architecture. Especially in the South of Italy, cities and villages were built in past with a careful consideration for the environment and the houses were conceived as a protection against the extreme natural climatic elements, both to keep out wind, rain, excessive sun, great heat and cold, and to keep the inside warm or cool according to the season.

What is to be overcome in students’ mentality is the usual contrast between natural cycles and artificial ones, which should on the contrary be articulated as a flux of material modifications.

The aim could be to minimise the impact of subsequent transformations of the environment, to reduce energy consumption and resources waste, to avoid the use of noxious substances in the procedure of design process.

In order to develop a methodology of design sensible to the energetically behaviour of the buildings we divided the definition of the project in progressive steps, from the general to the particular ones.

The first step regards the relation of the project with the site environment and its characters (morphology, climate, urban design and so on); the second step concerns the typology of building, the inside organisation and life performances of the inner space and the relation between inside-outside spaces; finally the third step regards the choice of structural and technological aspects of the project such as materials, colours, grid, detail of the construction (window and window shutter, walls, insulation, roof) with particular consideration for the climatic performances of materials and systems.

According to the idea of involving the students in real and practical works, we decided to apply the Automatic Procedure for Bio-Climatic Control of Architectural Project, to the particular
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conditions of the region where our University is located, Terra di Lavoro (Campania), in the South of Italy.
Generally, in Southern Italy the constructive tradition is essentially based on conservative solutions. In order to provide both, cooling in summer and warming in winter, the utilisation of heavy structures in cold areas was allowed to obtain with very little fuel a relative comfort inside even at 0°C. In those areas, where summer weather provokes a remarkable discomfort, the architectural culture has been able to find some partially selective solutions, effective on the climate outline. These solutions, based on a rational and wise exploitation of sea breezes, vegetation and complementary dynamic elements of the houses, have produced a remarkable variety of architectural figures, directly related to local climate.
This is the case of Terra di Lavoro Region, the urban and climatic characteristics of which, we will describe in the third paragraph.

Knowledge Representation

From the previous paragraph it appears how difficult is to design and analyse correctly a building from the bio-climate point of view. To overcame this difficulty in teaching such topics to our students we adopted a Knowledge Representation Model which seems to work enough well. We divided the topic in three main sections each of which is formed by some sub-sections. Every sub-section has been discussed and analysed together the students and the knowledge has been represented by means a weighted directed graph. A node of such graph represents a single aspect of the problem and the connections to other nodes are determined on the basis of the logical consequences which from that situation may be derived. For instance suppose a node may represent the site form (a slope or a plain) on which the building is located. This node is connected to another node which represents one of the aspects which must be explored in order to evaluate the bio-climate goodness of the design. Than if our site is a slope we are interested in exploring the orientation of the building (see fig. 1). Otherwise we look for the direction of summer wind.
Each arc of the graph is denoted by a semantic label representing the meaning of the choice done by the designer and by a weight (in general 0, 1, -1) indicating the goodness of the choice.
In order to construct an algorithm for evaluating the bio-climate goodness of the building design this graph may be easily transformed in a flow chart from which an algorithm is immediately derived.
The flow-chart representation has proved to be very well understood by students and they easily evaluated their projects following the appropriate path on the diagram.
The use of this methodology introduces some advantages: a rationalisation in the bio-climate design process and a reduction on the number of errors derived from a not well organised knowledge. Moreover we have the possibility of implementing the procedure on a computer by means of a simple spread sheet.
Disadvantages may be introduced by the strong simplification of the design process but our representation has been provided only for teaching purposes and not for an actual design process. Moreover a mechanic application of the flow diagrams without a deepening from the students could be dangerous. To overcome this problem we request to our students to justify the choice represented on the diagram by means photos and graphics of the project they are studying.
A very simple implementation of our procedure was realised by means the spread sheet software Excel 5. This procedure has been implemented translating each node and the corresponding outgoing arcs in terms of propositional logic that is in terms of IF xxx & zzz & www THEN yyy clauses (see fig. 1). For instance if the SITE is plain and the ORIGIN OF SUMMER WIND is south then the evaluation of that part of the design is given by adding the evaluation-label of the arc plain (0) and the evaluation-label of the arc south (-1). The total evaluation is than equal to -1.

An example of our experience in teaching building technology design

In order to facilitate the comprehension of the whole design process for the students, we choose to select some old buildings as case studies which could be significant for their bio-climatic
IF (SITE = plain) & (ORIGIN OF SUMMER WIND = south)
THEN (EVAL = eval (plain) + eval (south))

Fig. 1 Graph and flow-chart representation
characteristics, located, as we just said, in Terra di Lavoro. This region is characterised by a temperate climate, but its configuration as an alluvial plain geological formed by the Volturno river, determines a constant very high level of humidity percentage in the atmosphere.

Applying the V. Olgyay bio-climatic diagram (that relates temperature, air humidity and wind variation during the year with human welfare) we have observed that in this region the diagram shows, during the whole year, need of protection against humid-cold conditions during the winter and against humid-hot conditions in summer months.

The responses of the traditional houses of this region were concentrate in massive building, made of local tufa stones and designed with a court-yard typology. The construction of heavy and thick walls gives the advantage of a system relative adaptable to alternative exigencies of protection against excessive hot or cold temperatures. The roofs are generally on wood and tile covering, normally completed by a garret used during the winter as a deposit of wheat or other provisions (or foodstuff) that have also the function of insulating the roof, and during the summer for the ventilation of the roof. All the inner and surrounding spaces are equipped with flexible finishing, for example the window hole are finished with the glass fixture for the daylight, the shutter for the winter insulation and the louver for the summer ventilation and shadow.

The urban structure has been characterised by buildings alternated with open spaces (court-yard, garden, orchard, arbour, little square), so this structure determines a lot of reciprocal shadows, opportunity of creating ventilation during the summer and a sufficient penetration of the sun during the winter.

After the selection of single case-studies, the students were invited to work twice to the graph; first they applied the entire graph to the building analysed, noting in single subsections characteristics, problems and lacks of the building and finally arguing about the reasons of the final weight of the graph.

During the second phase of their work, the students design the building rehabilitation or add new spaces to the buildings, in order to improve the bio-climatic performances.

Finally they verify the rightness of their choices, applying the graph to the renovated building, noting the improvement also from the final weight of the new graph.

Another tool we prepared was a specific list of oriented general bio-climatic principles that could guide the students in the comprehension of the diagram. It is based on clear simple definition illustrated with some examples or drawings based on real cases; for this part of the system we think of putting this tool in the computer as a large help or as a hypertext that could include a series of different cases.

Obviously, also these principles were divided into three sections, the first one called "Relationship between site and building", the second one "Typology and inside organisation of building", and the third one "Shape and materials of building envelope".

These principles are not equal all over the world, but they depend on local environmental and climatic conditions in each particular site, so the relative appropriateness of various solutions, such as building orientation, insulation, control of building shape and materials, areas, angles and orientation of glazing and many others factors, will vary region by region.

Thus one could create a sort of new regionalism, if strictly conceived as fixed rules, but could be, on the contrary, a new behaviour for architects, who start to be more conscious of the environment and of inside quality of life in designing buildings.

Particularly, in this experience, all these principles were strictly related to the characteristics, the sources and the need of Terra di Lavoro region, that is affected by a temperate hot-humid climate, only partially according with the four characteristic climatic regions defined by V. Olgyay in his book "Design with climate".

In order to show some works of the students, we now shortly summarise these principles and how they worked for the students.

1. "Relationship between site and building":

1.1. Site choice.

It is better to choose a slope site facing to South-East than a plain. If the building is on the slope the direct action of the prevailing winter winds is to avoid. If the building is on a plain site, we must consider the negative effects not only of the prevailing winter winds, but also the warmest summer wind from South. A different weight has been given to each aspect of the site choice, as is explained in fig. 1.
1.2. Urban structure and quality of public spaces

A compact design of town has to be avoided. It is better to have urban blocks with open-plan and large public spaces with trees for a good circulation of the summer air. It is better if the directions of the streets don't canalise the winter winds.

1.3. Typology, geometry, orientation and shape of the building

Open-plan or court-yard typologies are a better solution than compact blocks. If the building is rectangular, the two sides must be in the ratio of one to seven (or at least one to three), with the longer side oriented on the axis East-West. It is better if the outside spaces around the houses are in the shadow during the day in summer.

1.4. Evaluation of trees and plants use

Evergreen trees must be located on the North as a useful barrier against the winter winds. Deciduous trees are really useful on East and West sides of the building in order to provide shading in the summer days. Bushes near the houses must be avoided because of their effects of reducing the benefit of cooling breezes.

For example a group of students (G.Landolfi, M.Matrisciano e A.Pozzi), analysing a massive, residential building of XVI Century in Aversa, made the evaluation of the graph before the rehabilitation project discovering typology and climatic characters of the building, but also lacks and need of rehabilitation. Starting from the answer of the graph, they oriented the rehabilitation project with the aim of improving the comfort of the building without many changes. In this case, they discovered the relation between the site and the building analysed particularly good, with the exception of the neglected garden (fig. 2). After the project, a right use of evergreen and deciduous trees allows to improve the inside and outside circulation of the air, as the better weight of the graph strengthens (fig. 3).

2. "Typology and inside organisation of building"

2.1. Geometry and disposition of the planimetry

The building must be flexible to the alternative seasonal climatic conditions. It could be obtained designing in the right position court-yard, loggia, orchard, arbour, or external staircase, working with these elements in order to achieve the effects desired. Particularly shadow spaces are useful from east to west during the summer; a large amount of glass surfaces has to be avoided on the northern external walls because of the winter loss of heat. For the internal layout of the building, it is better to locate on the North bathroom, kitchen, toilet passages and deposits.

2.2. Performances of the inside spaces

Natural crossed ventilation of the single rooms is very important especially if the room is destined to contain a lot of people, because of the increase of heat and humidity of the air. It could be convenient to use movable walls and to connect spaces with different orientation, in order to reduce the high internal temperatures in the summer.

2.3. Performances of the outside spaces

The external spaces must be designed in order to avoid the increase of heat caused by absorption or reflection of the sun radiation during the summer. It is better to create lawns in front of the building and to protect the parking areas with arbours.

Referring to the same building previously described, the students noted that this building represents a typical example of a traditional building designed according with the local climate. So the evaluation of inside spaces performances before the rehabilitation project shows that this building doesn't need inside modifications (fig. 4).

3. "Shape and materials of building external walls"

3.1. Glazed areas

The orientation and the amount of the glazed areas on the external walls are of great importance for the thermal balance of the building. Glazed areas have a great capacity of absorbing heat during the day, but they loose the gained heat during the night if the windows aren't insulated. Glazed areas on the external walls, oriented to the South are really useful in winter, but they need shadow in summer. Windows shutters, defences, vertical or horizontal projections, loggia or external deciduous trees can be used as shading devices of the southern and western glazed areas. It is useful to minimise glazed areas on northern walls and it is better to provide them with insulation, doubled glass during the day and blinds or curtains during the night.
Fig. 2 Residential building of XVI Century in Aversa (Italy). 1.4 Evaluation of green and plant effects before the rehabilitation project.
Fig.4 Residential building of XVI Century in Aversa (Italy). 2.2 Evaluation of inside spaces performances before the rehabilitation project
Fig. 5 Residential building of XYI Century in Aversa (Italy) 3.3 Evaluation of the roof before the rehabilitation project.
Fig. 6 Residential building of XVI Century in Aversa (Italy). 3.3 Evaluation of the roof after the rehabilitation project.
3.2. Walls

Walls can be characterised by massive or lightweight construction. Massive walls, made of materials with high thermal mass, are really useful if oriented form East to West. Lightweight walls must have a sufficient insulation; the summer absorption of heat could be reduced through colouring these surfaces with light colours.

3.3. Roofs

Roof is the part of the building exposed to maximum swings of temperature. Roof made with material of high thermal mass, as the ancient vaults or the modern heart roofs, works very well all over the year. Lightweight roof needs a vapour barrier with these climatic conditions. Horizontal and plain lightweight roof must be insulated and coloured with light tints. Inclined and plain lightweight must be insulated and ventilated; it could be useful to create a garret naturally ventilated under the roof.

The group of students who have analysed the old building in Aversa, in the evaluation of this third sub-section, found the worst conditions and lacks of the building on the inclined wooden roofs (see fig. 5). In the rehabilitation design they decided to make a new roof, using the same structure, materials and shape of the old roof. Nevertheless after the insertion of vapour barrier, insulation and tiles in the new roof, the evaluation of its performance showed a serious increase of the graph weight and consequently a better quality of the rooms below fig. 6).

Conclusion

Working with some similar real cases, we can say that generally the students improved their consciousness of the bio-climatic problems and the need of saving the environment. Particularly they understood from practice the main problems of a correct climatic design. They also realised that the environment respect is not a limitation to their inventive power in designing and doesn't increase costs of the construction.

If they want to obtain these results, it is especially useful a good knowledge of the local climatic conditions and a correct use of systems and materials in relation with the environment.

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