

APPLICATION OF COMPUTER TOOLS IN PASSIVE SOLAR DESIGN

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ABSTRACT A course which implemented a computer tool "ASICLIMA", as an aid in passive solar design, was taught in the School of Architecture of the University of Zulia, in Maracaibo, Venezuela. ASICLIMA was designed by the author and used by students for the simulation of thermal conditions inside buildings. The students applied their creativity to generate ideas and the computer program to evaluate them, with the benefit of increased speed and precision over manual methods. Preliminary evaluation by grade comparison between students using the tool in their studio and others who didn't use it indicate satisfactory results. It is thought that acceptance of the computer tool by the students will be an indication of acceptance by practicing architects.

1 Introduction

Maracaibo, the second most important city of Venezuela, is located at 10°40' north latitude and 71°30' west longitude. It is characterized by a warm humid climate during all year. Temperature ranges from a mean maximum of 32.85 °C in August to a mean minimum of 23.12°C in January. Relative humidity oscillates between 50% and 95%. The annual average precipitation is 490 mm with a maximum of 105mm in 24 hours. The predominant winds are from the NNE and arrive loaded with humidity from the Lake of Maracaibo and the Gulf of Venezuela. The average wind speed is 3 m/s, with many calm periods. The average maximum solar irradiance on a horizontal plane is around 600 W/m² and the maximum is over 900 W/m². The values of diffuse radiation are close to 65% of the total received radiation (Quirios 1995).

Venezuela uses two to four times more energy than any Latin American country, occupying the sixth position in world, in per capita electric consumption. The city with the highest energy consumption in Venezuela is Maracaibo, mainly because of indiscriminate use of air conditioning and inadequate design and use of materials (La Roche et al 1997).

2 Class program

In the Faculty of Architecture of the University of Zulia, several departments undertook teaching and research in the field of Bioclimatic Architecture and energy conservation, at the undergraduate and graduate level. We proposed a course that integrated the concepts of passive solar architecture with the use of computer tools in the architectural design process.

The course "Computer Aided Bioclimatic Design" was designed and taught as an elective class for fourth and fifth year architecture students, by Pablo La Roche and Gaudi Bravo, during three semesters between 1994 and 1995 (La Roche & Bravo 1994). It was structured in two modules, a theoretical and a practical module. The theoretical module, introduced the student to the world of bioclimatic architecture, covering concepts, strategies,

recommendations, methods, and basic equations. In the second module, the student applied concepts taught in the first module and learned to use a computerized tool for the thermal analysis of buildings by a steady-state method: "ASICLIMA."

Each one of these modules was built around a series of topics and exercises that were developed in two hour classes (120 minutes), twice a week, with a total duration of 14 weeks, or 56 hours during the semester.

2.1 Theoretical module

In this module, the concepts of passive solar design were explained:

1. Bioclimatic architectural concepts. Definitions and theoretical positions.
2. Climate and its relationship with thermal comfort. The influence of climate on the development of society, human behavior, types of climate, climate variables, models of bioclimatic analysis, and the influence of the sun and wind.
3. Man and comfort. The mechanisms of heat exchange between man and his environment, variables that affect thermal well-being, thermal balance, mechanisms of thermal exchange, comfort zones developed by different authors, the psychrometric chart, Givoni's bioclimatic chart and Fanger's comfort method.
4. Thermophysical properties of materials. Thermal behavior, optical characteristics, heat transfer coefficients and thermal capacity.
5. Heat flows by conduction, radiation and convection.
6. Natural ventilation. Strategies to profit or protect from the wind. Architectural and natural elements that favor the circulation of air (urban and building levels).
7. Solar geometry. Sun, earth and their relationship to the building. Solar radiation.
8. Design guidelines for warm climates. Maximization of air movement and protection from solar radiation.
9. Thermal balance. Heat exchanges between the building and the environment, as the basis for the design of the computer tool that will be used in the course.

2.2 Practical module: ASICLIMA

The practical module explains the principles of the automated tool ASICLIMA (La Roche 1995). An automated tool is a program or group of programs that replace traditional manual or graphic tools, used during the design process. We proposed, a system that combines the creativity of the architect with the speed and information processing capacity of the computer. ASICLIMA is an automated aid for bioclimatic design, which acts as an analysis tool of the proposal, evaluating the building's capacity to regulate indoor conditions. It processes data from the site, climate and building in order to generate graphic and numerical information on the conditions of external comfort, incident radiation, thermal gain through the envelope and the energy costs to achieve the design temperature. ASICLIMA doesn't calculate heat exchanges by convection.

2.3 Exercises developed in the course.

The course includes four evaluations: a written test and three exercises. The written test covers theoretical concepts, while the exercises allow the application of theory and the program to solve specific design issues.

Two types of exercises were done:

- Analysis of simple parametric models (thermal behavior of materials in roofs and walls, proportions of volumes, orientation of buildings, compactness, performance of sloped surfaces, etc.) This permitted the validation or determination of bioclimatic principles to be applied in architectural design, while it taught students how to use an analysis tool.
- Application of ASICLIMA in the studio projects. This generally involved the following steps:
 1. Analysis of climate variables in relation to the comfort zone and the strategies to achieve thermal comfort inside the building.

2. Application of passive solar principles in the preliminary design of the building.
3. Evaluation of the design with a thermal simulation program (ASICLIMA).
4. Improvement of the project and correction of the errors depending on the evaluation.

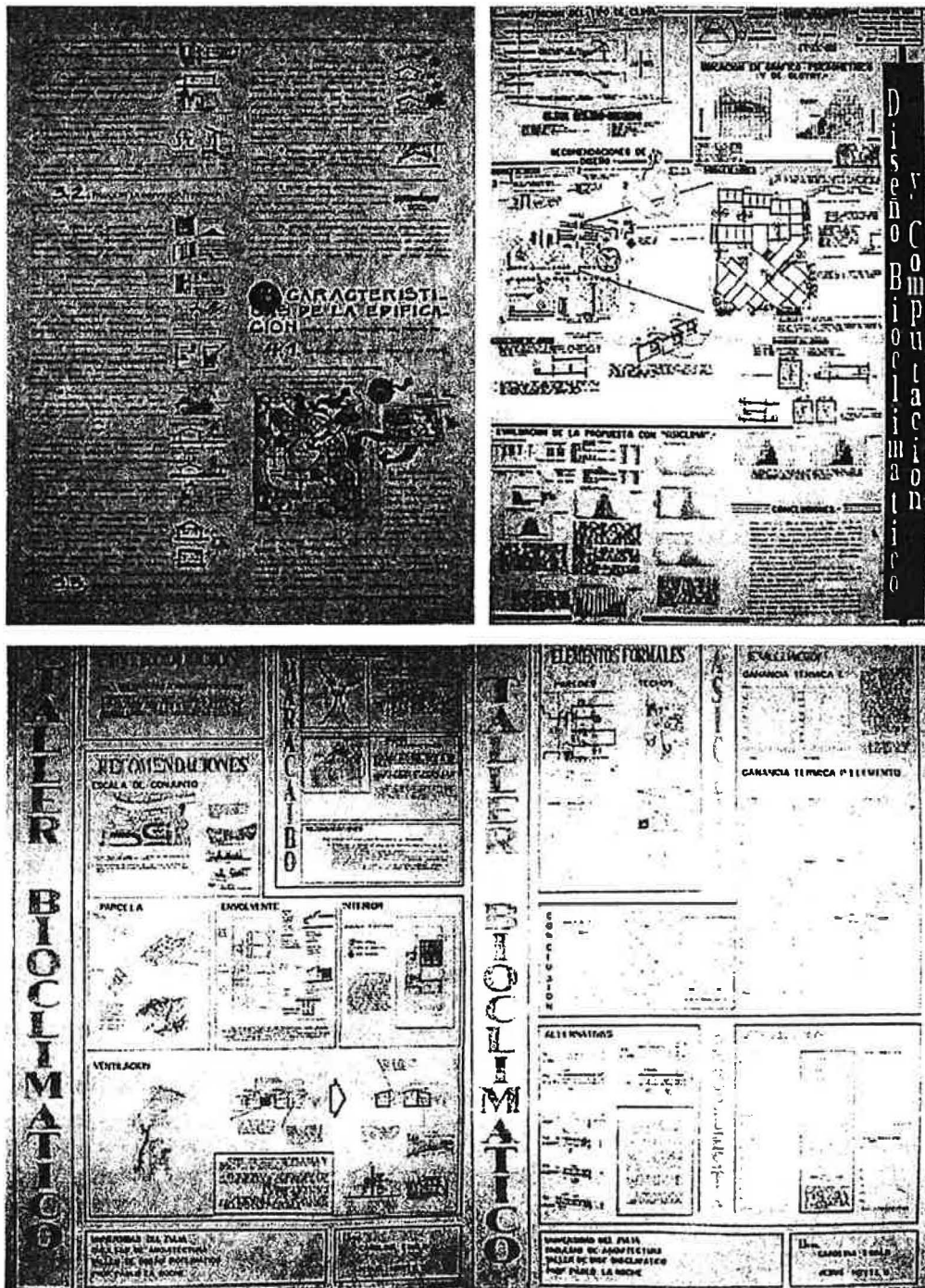


Fig.1 Application of ASICLIMA in the studio projects. Posters

These exercises permitted the students to discover multiple forms of use of the program. Some examples are:

- In the evaluation of the thermal behaviour of roofs, walls and windows using materials with different U values, absorptances, surface resistances, etc. In this case they should have the same orientation and inclination, to compare the results under equal conditions.
- In the analysis of heat flows through facades. Orientations and slopes of the facade, the proportions between opaque and transparent areas, the external colors of the facades, the dimensions of the overhangs, will all affect the results. This analysis is more detailed and allows to correct specific details.
- In the analysis of orientations, slopes of roofs and volumetric relationships (width, length, height). It is possible to evaluate the same facade under different orientations and/or inclinations, in order to determine which is the more efficient insulation/cost relationship in function of the radiation; in this case the facades with less radiation need less insulation.

3 Evaluation of the computer tool

3.1 Method

The course was taught in three semesters between 1994 and 1995. 16, 13 and 10 students registered in each case. In order to determine the effectiveness of the classes in the design process, an analysis method based on the student's grade was proposed. Five different grade relationships were proposed.

1. The students who learned passive solar concepts satisfactorily. 15/20 points in the first exam is the reference. If the students obtained a mark higher than 15 points, it is assumed that they learned the topics satisfactorily and if it is lower, that they didn't. In Venezuela, a grade of 10/20 is sufficient to pass a course, so 15/20 is an average mark.
2. The students who learned to use the tool quickly. 15/20 in the second exam, which is the first one with the computer tool, is the reference.
3. The students who used the tool creatively. The reference is 15/20 on all the computer exercises.
4. The students who passed the class. The reference is 10/20 minimum on the class.
5. Relationship between the grades in the design studio and the previous and following design studio. The following options exist:
 - The number of students who increased the studio grade
 - The number of students who maintained the studio grade
 - The number of students who lowered the studio grade

4 Results

Table 1 Percentage of students with satisfactory learning of the theoretical topics

	1st 1994	2nd 1994	1st 1995	average
+15 POINTS	87%	62%	70%	73%
- 15 POINTS	13%	38%	30%	27%

Table 2 Percentage of students that learned how to use the tool quickly

	1st 1994	2nd 1994	1st 1995	average
+15 POINTS	87%	100%	100%	96%
- 15 POINTS	13%	0%	0%	4%

Table 3 Percentage of students with satisfactory and creative learning of ASICLIMA.

	1st 1994	2nd 1994	1st 1995	average
+15 POINTS	86%	69%	100%	85%
- 15 POINTS	14%	31%	0%	15%

Table 4 Percentage of students who passed the course.

	1 st 1994	2nd 1994	1st 1995	average
+15 POINTS	94%	85%	100%	93%
- 15 POINTS	6%	15%	6%	9%

Table 5 Grades in the design studio.

	1st 1994		2nd 1994		1st 1995	
Students	16		13		10	
	grade TAM	grade TAD	grade TAM	grade TAD	grade TAM	grade TAD
AVERAGE GRADES	16,125	16,6875	17,6	18	15,4444	17,2

T. A. M: Relationship between grades in the design studio during the ASICLIMA year and grades of the previous semester.

T. A. D: Relationship between the grades in the design studio during the ASICLIMA year and the grades of the following semester.

Table 6 Grade relationships in the design studio.

	1st 1994		2nd 1994		1st 1995	
Students	16		13		10	
	T. A. M.	T. A. D	T. A. M.	T. A. D	T. A. M.	T. A. D
=	19 %	63 %	24 %	46 %	30 %	0 %
+	38 %	6 %	31 %	39 %	50 %	80 %
-	43 %	31 %	45 %	15 %	20 %	20 %

The number of students who learned the theoretical topics (73%) is lower than the number of students who learned how to use the computer tool quickly (96%), or who used it creatively (85%), therefore learning to use the tool is probably easier than learning the basic concepts of passive solar design.

The relationship between the design studio grades during the ASICLIMA year in relation to the previous year didn't show a substantial improvement. We think that this might be due to the fact that in three of the four studios opened during that semester, no emphasis was made in the concepts of passive solar design. In spite of this, the percentage of students who maintained or increased their grades is above 50%. Also, more than 65% of the students who took the course maintained and increased their grade in the next semester's design studio. This could be due to the fact that 82% of the students were developing thesis projects, where more freedom is permitted.

5 Conclusions

The implementation of bioclimatic design courses using computer tools, permits the students to enlarge their knowledge in relation to traditional thermal evaluation tools. To learn to use computer tools, the students don't require special abilities. The students are generally eager to learn other strategies or methodologies different to the traditional ones.

Bioclimatic design classes are helpful during the student's design process. The use of this tool for thermal evaluation, is important in a country with the highest energy consumption in Latin America. Results indicate that this course is efficient in using teaching tools to improve energy efficiency in architectural designs.

If we assume that the positive results that were observed in the students' design process indicate positive results in the architectural profession, we can conclude that student grade analysis can be an effective tool to evaluate the performance of different design instruments in the architectural design process.

6 References

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