THERMAL SIMULATION IN RESIDENTIAL BUILDING WITHIN COMPUTER AIDED ARCHITECTURAL DESIGN

Integrated model

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Abstract. Nowadays, the architectural profession is seeking a better energy saving in the design of buildings. The fear of energy shortage in the very near future, together with the rapid rise in energy prices, put pressure on researchers on this field to develop buildings with more efficient heating systems and energy systems. This work is concerned mainly with the development of a software program analyzing comfort in buildings integrated in CAD architectural systems. The problem of presenting the computer with information concerning the building itself has been overcome through integration of thermal analysis with the building capabilities of CAD system. Mainly, such experience concerns the rules for calculating heat loss and heat gain of buildings in Algeria, The program has been developed in order to demonstrate the importance of the innovation of the computer aided-architectural-design field (CAAD) in the technology of buildings such as the three dimensional modeling offering environmental thermal analysis. CAAD is an integrated architectural design system which can be used to carry out many tasks such as working drawings, perspectives and thermal studies, etc., all from the same data. Results are obtained in tabular form or in graphical output on the visual display. The principle of this program is that all input data should be readily available to the designer at the early stages of the design before the user starts to run the integrated model. Particular attention is given to the analysis of thermal aspects including solar radiation gains. Average monthly energy requirement predictions have been estimated depending on the building design aspect. So, this integrated model (CAAD and simulation comfort) is supposed to help architects to decide on the best options for improving the design of buildings. Some of these options may be included at the early design stages analysis. Indications may also be given on how to improve the design. The model stored on CAAD system provides a valuable data base for all sort analytical programs to be integrated into the system. The amount of time and expertise required to use complex analytical methods in architectural practice can be successfully overcome by integration with CAAD system.

1. Introduction

In Algeria, a large number of residential constructions do not seem responding to thermal comfort and energy savings needs. This can be explained by the absence of specific thermal regulations for the habitat and, also, by the lack of know-how and insufficient knowledge on the topic by the builders. The improvement of the techniques permits today to achieve the buildings that gather aesthetic and thermal qualities that offer a setting of more comfortable life at a time, while being a small consumer of energy. A thermal calculation method has been developed in order to reduce to the minimum the cost of energy used to heat new or existing buildings. The recommendations of the CNERIB developed for the Algerian climate are taken as references in the choice of the computer model elaborated in our study. A personal program, named "SimulArch", (registered at the National office of Copyright of Algeria, (ONDA) – N° 009/06 of 18/02/2006) that models both outside and interior parameters acting on the building, has essentially been developed to verify the data base of SONELGAZ (National Society of electricity and gas, Algeria) while using the thermal simulation of the architectural parameters and the climatic factors of the region. This program has allowed us to reach savings of active energy from 10% to 20% by household depending on the applications of the construction materials recommended (Theoretical principles of construction Mediterranean Bioclimatic in Algeria).

2. The application of Thermal simulation in CAAD

The practical limitation is the use of computers by designers and engineers in thermal simulation process at the same time. Before a design stage can be started, information has to be gathered from the design of building, thermal properties, dimensions, etc. This process is inevitable and time wasting for the designer who is asked to change his traditional approach to the design. Fortunately architects have recently become more aware of the facilities that models can offer, Lawson (1982). This thermal analysis programs would affect the design approach and environment as well as the nature of information they yield and its impact on the designer's decision making.

Until now the theoretical studies of the environmental behavior of buildings does not appeared on CAAD systems. These theories require specific data, such as the characteristics of building materials, which is not always available. This lack of suitable data has delayed the development of large scale computer application. In our research work a computer model is being developed to simulate the thermal performance of a building designed in CAD. This model can be used by architects to perform integrated environmental analysis building. During the sketch design stage, the architect can examine the performance of different building shapes. At the detailed design stage, the architect can make checks on a room by room basis. This system operates in both interactive graphics and automatic processing modes with input – output facility, (M.I. Husaunndee, 1999).

3. The structure of the integrated model

The architect starts from a broad concept and converges towards the details of the project. The data is arranged in such a way as to evolve with the design. The data is organized in four main files (Lawson BR, 1987).

3.1 THE CLIMATOLOGICAL FILE

The climatological file contains standard yearly climatological data which represent the localities. The consumer may use his own data when it is about an unusual climate or other considerations.

Once the data is prepared in the previous files, the energy performance can then be tested and results obtained. The results can be displayed graphically or numerically on the screen and the user may see if the design is appropriate or not, otherwise he can modify the data files to obtain others results.

3.2 THE GEOMETRY FILE

The geometry file defines the form of the building and the positions of the internal partitions, windows, doors etc. The structure of the geometry file allows the moving and reorienting of buildings on site with the minimum of data change. It is also an interactive and graphical database; it accepts data specifications of building plans. The main characteristics of this module are that it develops visualization of building model to be sent to be exploited by the thermal simulation performance module. This program is particularly suitable for the analysis of various types of passive solar buildings. Special provisions would be made for instance for analysis of attached sun-spaces, rock bin, thermal storage, and vented trombe walls, (Menezes and Lawson, 2006).

3.3 THE PROJECT FILE

The project file contains the latitude of the site and other heat gains from internal sources such as occupancy, lighting, etc.

3.4 THE THERMAL PROPERTIES FILE

The thermal properties file contains the building materials characteristics, such as density, specific heat and conductivity. They are used to estimate heat flow through the building fabric, the amount of sunlight, the thermal lag of the fabric, etc.

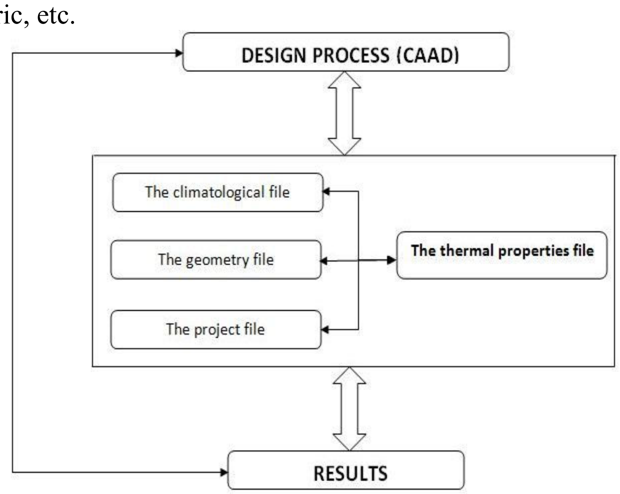

Figure 1, Relationship - Control Flow between the main Modules

One of the designer's task is to predict, from the general and the micro climate knowledge of a site, how the placing of a particular building on that site would alter the micro climate. The main objective of designing a building remains a satisfactory indoor environment; and obvious questions which face designers are what would be the seasonal energy requirement for heating and what would be the maximum demand at any time. Figure 1 shows how is the importance of the amount geometrical data gathered on the design process stage and shows the different parameters of the construction which would affect the results, (Lawson, B. R. (1990).

4. Algorithms for CAAD

The most important aim of this research work remains the structuring and organizing of the algorithms' theory within CAAD system implemented on a simple personnel computer. A logic-structure is proposed which comprises aspects of CAAD based-systems, such as input data, output data, permanent and temporary databases. A number of subroutines developed in this work will be presented.

The algorithms are designed to answer specific questions such as: What would be the effect of design changes (within the integrated CAAD Model) in areas such as increasing wall insulation, changing the glazing type or changing the orientation of the building? In other words, providing a better understanding of the simulation program results, is interpreting them in architectural terms, which also leads to good decisions in relation to the simulation.

Some of the variables which would have an effect on the building's comfort are: Climate, Building site, Building shape, Building fabric and Thermal mass, Building fenestration, Building ventilation, Occupancy, Natural Environment, and Building Environment.

5. Energy Modeling Program

SimulArch program contains several energy modules which are the interface between all data files, subroutines, building model and the user. Each of these offers a range of program modules such as solar geometry, solar radiation and regulation of the CNERIB energy code (CNERIB, 1998). Also the present modules of evaluating the thermal performance of buildings may be added to the Simularch, (Foura and Zerouala, 2007)

If these modules have to be build within the Simularch energy program, it would provide a better understanding of the simulation program results by interpreting them in architectural terms and leads to good decisions in relation to this simulation. Some variables that would have an effect on the thermal performance of the building which are quoted in section 5**,** (Jean-Louis Izard, 1993).

6. Detailed Operating Modules and Concepts of the Proposed model 'SimulArch'

SimulArch is an architectural design software which could be used in the very first stages of the design of buildings. It is a thermal simulation tool of building performance and decision support. And as we all know, it is in the early stages of the design that decisions related to building behaviour, energy consumption and rooms' comfort are taken. So it is very important to have a method and/or a tool to assist the designer in choosing the appropriate architectural solution. The organizational model, SimulArch, is presented below (Diagram of different relational modules of SimulArch).

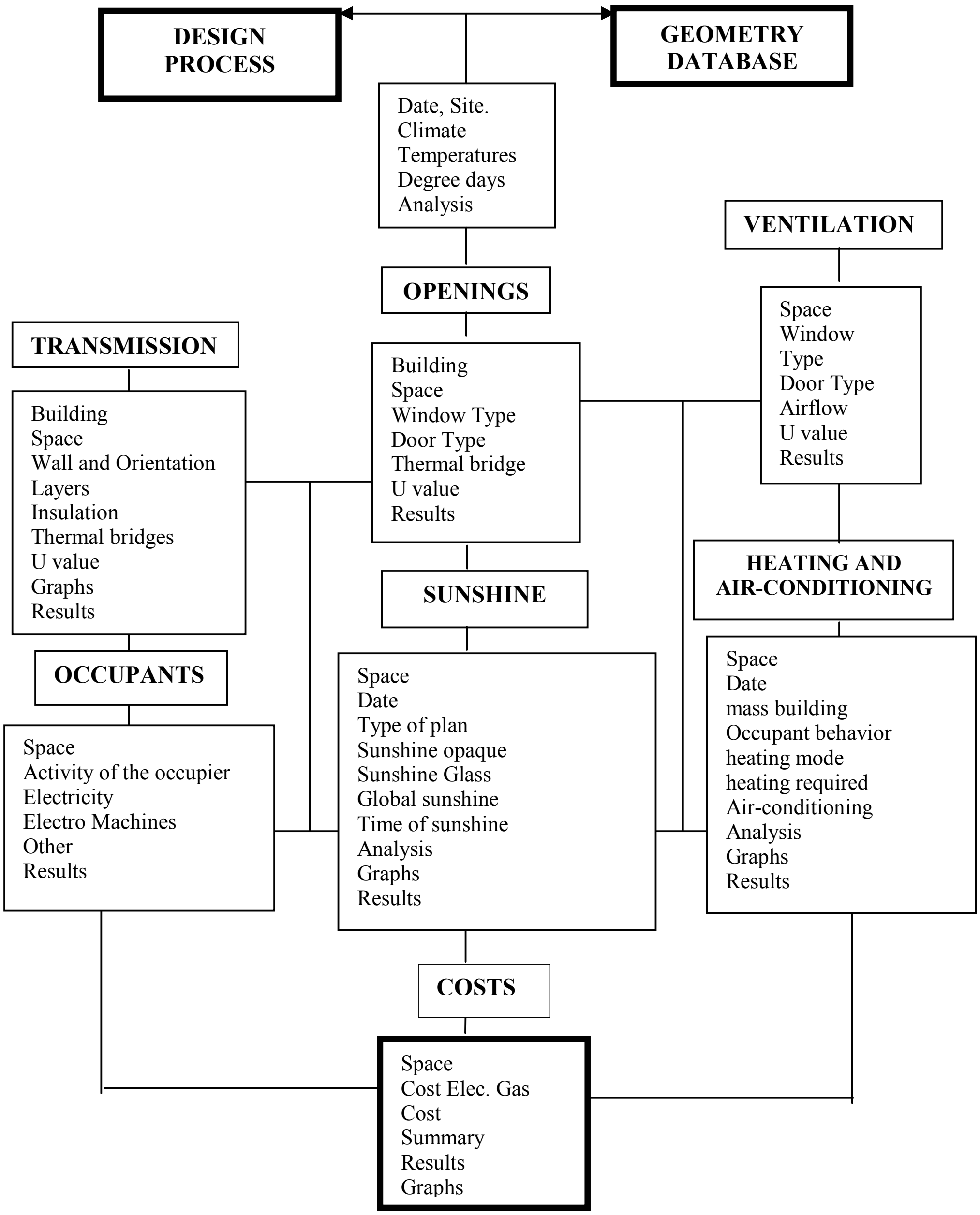

Figure 2, Diagram of SimulArch.

7. Experimental Study: Application to an existing building

7.1 PRESENTATION OF THE SAMPLE

The site of 'A' is located in the western outskirts of Constantine and consisting of a large complex of four storey height buildings. The city of Constantine belongs to a zone B climate in Algeria (hot in summer and cold in winter, and is at an altitude of 640 meters above sea level); its latitude is 36.17 degrees and 6.37 ° of longitude.
The database concerning the geometry of the sample is gathered into a separate file project. Each one of those parameters (width, length, height, thickness, surface and volume) is exploited directly by the proposed energy model 'SimulArch' to calculate the cost of energy spent during either summer or winter season. The huge amount of geometric data obtained systematically (without input data) from this model (SimulArch) may contribute enormously to reduce the consumption of energy and consequently giving internal comfort to residential buildings.
Some results could be summarized below by running the model partially:
The presented sample is subject to weather conditions, either in terms of ventilation or heat transfer towards outside.

- Heat loss by transmission through opaque walls: 133 W/°C
- Heat loss by transmission through glass: 57 W/°C
- Heat loss by air renewal: 10 W/°C

As we already said, one of the research objectives is to reduce heat losses. After transformations the following values of heat losses were obtained:

TABLE 1, Simulation of total losses and average heat gains after simulation parameters - before and after transformation

Before transformations of fabric	**791.55 W/C°**	**Heat Gain**
Presence of polystyrene	590.68 W/C°	25%
Reducing the size of openings (17%+55%)	680.25 W/C°	14%
Double glazing	701.59 W/C°	11%
Strengthening the insulation and reducing the surface of windows.	553.67 W/C°	30%
Reorientation- front North-west to South- East	467.59 W/C°	41%

A number of thermal simulations can be made in order to make design decisions. A good analysis of the building envelope depends also on the accurate geometrical database items. The project files of several components of the construction are generated to provide precise information on the parts to be simulated. More the databases are structured and more the simulations of the thermal comfort give good results. Some of generated geometric database could be generated as follows:

TABLE 2, Example of a generated database from a design process

Project Level	Sub level	Group item	Code item	B.mat	Dim	Vol	S
L001	SL001	I0001	I0001- 111	CONC			
L002	SL002	I0002	I0001- 112	CONC			
L003	SL003	I0003	I0001- 113	CONC			
L004	SL004	I0004	I0001- 114	BRIC			
L005	SL005	I0005	I0001- 115	BRIC			
L006	SL006	I0006	I0001- 116	BRIC			
L00X	SL00X	I000X	I0001- 11X	GLA			

B.mat: building materials, Dim: Dimensions; Vol: Volume; S: Surface.

8. Conclusion

This research work is considering that the conception of system data processing for design project could be the most important developing program for this model. Once the dimension database of the project is systematically established, the simulation for a good thermal performance for example, could be very beneficial for researchers to take decisions on their design conception. In our case, the aim is to reach a low energy building consumption. The benefit and the advantage of this process is to minimize the cost of the building at the early stages of their design.

A module may be added to the structure of the program in order to give indications on how to improve the design. This module may locate large number of deficiency sources in the building which would require improvement. Each stage of the analysis could be made up of several suggestions or solutions, which are specific to the failure to meet the program module requirements.

It is possible to design a model which may reach a high degree of accuracy, for example the dynamic thermal network analysis such as GABLE (Flynn, 1997) system which is implemented on a high performance computer. This program requires very important quantity of data. For architects and designers this model must be relatively easy to use and requires little time in the preparation of data.

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