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ADAPTATION AND USE OF CASAMO-CLIM, A MICRO-COMPUTER PROGRAM FOR BUILDING THERMAL DESIGN IN HOT CLIMATES

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1 - OBJECTIVES

Improving the thermal comfort of buildings while limiting additional investment and operating costs is a genuine concern for designers in hot-climate countries. Whereas up until now architects and heat engineers have had at their disposal qualitative results for this purpose, the development of microcomputers now offers them additional help. By using designing aid tools, it is possible to quantify how various building and functional parameters affect comfort conditions.

CASAMO-CLIM was designed and written by the Centre d'Energétique to meet this objective. It incorporates the results of research conducted on simplified calculation methods of building thermal behaviour (*). Distributed in a portable version for PC-compatible microcomputers, CASAMO-CLIM evaluates the comfort conditions of a building and calculates cooling loads, if any. Easy to use, it enables designers to compare several variants of a project.

2 - THE CASAMO-CLIM SOFTWARE

The modular structure of the program is shown in figure 1. Comments are based on the analysis of "input", "functions" and "output".

Input

The site is defined by climatic data representative of a typical day (outside temperature, humidity, wind velocity and direction, sky overcast), the soil albedo and the characteristics of any obstacles to solar radiation in the form of relief, vegetation or nearby buildings. Weather data entry is simplified through the use of typical day libraries.

(*) CASAMO-CLIM was developed with financial aid from the French Ministry of Foreign Relations and the Association Française pour la Maîtrise de l'Energie (French Association for Energy Control) within the framework of the consultation on "Habitats climatiques" (Climatic Buildings) part of the interministerial programme REXCOOP, and in relation with the Centre d'Etudes et de Recherches sur les Energies Renouvelables (Research and Development Center for Renewable Energies) in Dakar.

The description of the building - assumed to correspond to a major thermal zone - is made by entering the thermo-physical and geometric characteristics of opaque walls, openings, ventilation, additional internal heat input dissipated by the occupants, the lighting systems and household appliances. The environments contiguous to the building must also be specified.

Data libraries for materials, walls, internal input profiles, all handled by the user, make it easy to key in the characteristics of a project.

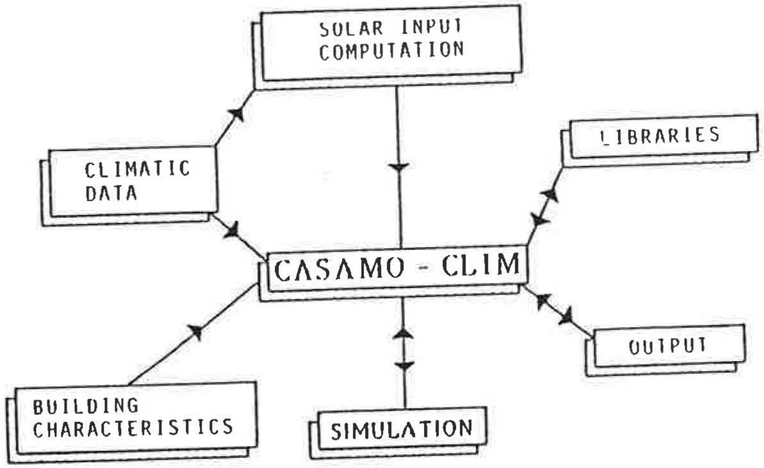

Fig. 1 - Structure of CASAMO-CLIM

Functions and Output

The software first evaluates solar input affecting the various facades of the building and the solar input transmitted (while accounting for any shading effects) for each hour of the period considered. The designer is provided with graphs and figures of results which help him choose the best location for the site in order to limit solar input as much as possible and which enable him to assess how shading features such as roof overhangs or side recesses can protect against solar radiation.

The software then computes on an hour by hour basis dry-bulb air and radiance temperatures as well as humidity in the building under study and, if necessary, the hourly cooling load for a given set temperature.

Changes in ambient conditions can be entered on a psychrometric diagram to display the level of thermal comfort. A synthetic comfort index, representing the superheat integral value weighted by the total time of occupation, is an additional element provided.

Lastly, input variation curves of solar gains and computed temperatures are proposed on an hourly basis.

3 - COMPUTATION MODEL

The computation method built into CASAMO-CLIM is based on a dynamic model which simulates the thermal behaviour of the envelope in half-hour intervals. The variable rates are processed by an implicit-type numerical method with finite differences.

Without going into the details of the mathematical formulae of the algorithms (1), here are the main hypotheses on which they are based.

At each time interval, the direct, diffuse and reflected components of solar radiations affecting opaque walls and transmitted to the building through openings are reconstituted. Diffuse isotropic radiation was assumed.

Wall surface exchanges with the outside are considered to be either convective - which means they vary according to wind velocity and direction - or by long wavelength radiation which is related to the equivalent sky temperature and to wall emissivity.

Inside the building, the distinction was made between convective exchanges with inside air and long wavelength radiation exchanges among the walls.

Surface exchanges are linearized. Transfer coefficients which are associated with them allow two different values per day in order to account for distinct nighttime and daytime rates (ventilation profiles and wind velocity rates).

Based on the same principle as many detailed simulation models, the model uses a direct reduction of the number of spatial nodes (3 nodes per wall) which, due to its reasonable computation time for a designing aid tool (30 seconds per day of simulation on a standard IBM-PC configuration), means it can run on a microcomputer.

The accuracy of this simplified model is very satisfactory as shown by a study (2) which compares the results with the MINERVE model developed by the Ecole des Mines used as reference (6).

In the present state, the model uses only two uniform-temperature zones: the major zone which is being studied and a "secondary" zone such as a buffer space or contiguous unheated attic space.

The computation method was validated through experimentation by comparing simulated results with actual measurements taken on a test-cell of instrument-fitted buildings located in Senegal (3). Results matched up conclusively: observed temperature variances were between 0.5 and 1.5°C.

4 - USING THE SOFTWARE - A CASE STUDY

Below are several results from the "Etude du comportement thermique de logements et d'écoles au Sénégal" (4) highlighting the methodology used when studying the sensitivity of parameters.

4.1 - Choice of a climatic day

The thermal comfort study requires avoiding "average" climatic conditions in favor of climatic periods with a "risk of discomfort".

In the case of Senegal, the choice of typical days for each location site was made in two steps:

- based on mean monthly temperature and humidity curves, the two most contrasting months in the dry and wet seasons were determined, the months of May and October, respectively, for the TAMBACOUNDA site;
- an actual typical day for the above months was chosen from available weather files (dry bulb temperature of 26°C at 5am, 42°C at 3pm and relative humidity varying from 10% at 4pm to 50% at 7am on the day in the dry season).

4.2 - Characterizing comfort

For schools, which are occupied only part of the day, objective parameters such as air temperature and dry-bulb radiance temperature, were given priority. Humidity was not taken into account since during daylight hours, the levels of relative humidity remain reasonable even in the wet season (rarely above 80%).

The comfort index is the one mentioned above used for dry bulb air and radiance temperatures. (As an example, the index could be in the following form for a building occupied from 8 am to 12pm:

$$Icomf = \frac{1}{4} \int_{8}^{12} (Tair - 28)'dt$$

( )' indicates that only the positive values of the expression in parentheses are taken into account .

Moreover, additional criteria were used to highlight certain conclusions: the maximum air and radiance dry-bulb temperatures attained during the day.

4.3 - Reference case

The reference case was defined based on local building methods: classroom floor surface area 6 m x 9 m and ceiling 3 m high, built onto an identical building on the eastern side; the roof axis is oriented from east to west; thermal inertia is average (breeze-block walls 15 cm thick, concrete floor 12 cm thick, ceiling made of plywood 5 cm thick and roof made of galvanized sheet); average air exchange is estimated at 20 vol/hr. The room can hold 50 students.

The occupancy time used is 4 hr. in the morning (8 am to 12 pm) and 2 hr. in the afternoon (3 pm to 5 pm).

The solar diagram in figure 2 shows the periods of daylighting of the western side of the building.

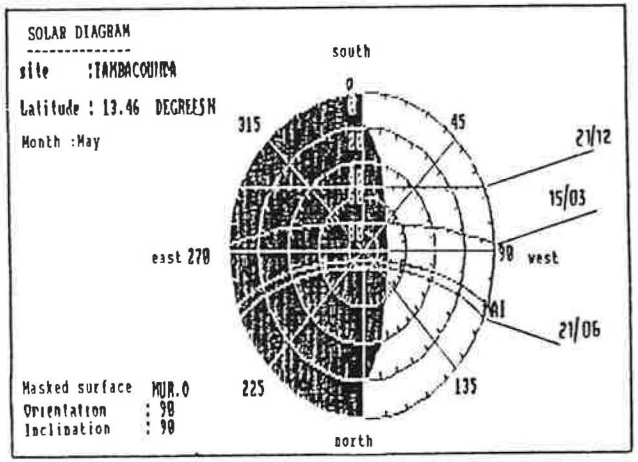

Fig. 2 - Display of Shading Effects on the Western Side (shaded area is the shaded side)

The main results of the reference case simulation are shown in figures 3 and 4. The following should be noted:

1) the inside temperature is very high during the day and the room's environment is outside the comfort zone according to the representation of Givoni (fig. 3);

2) the actual inside air temperature varies during the day from 37 to 41.5°C.

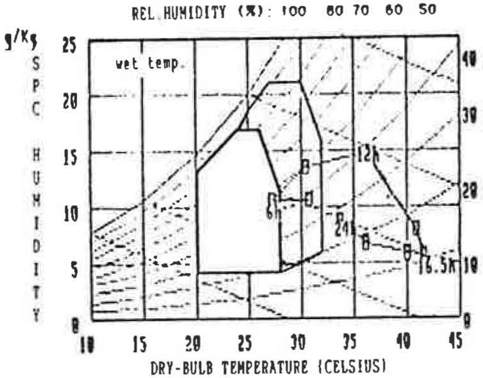

Fig. 3 - Diagram of Comfort Conditions (Classroom in Tambacounda, dry season)

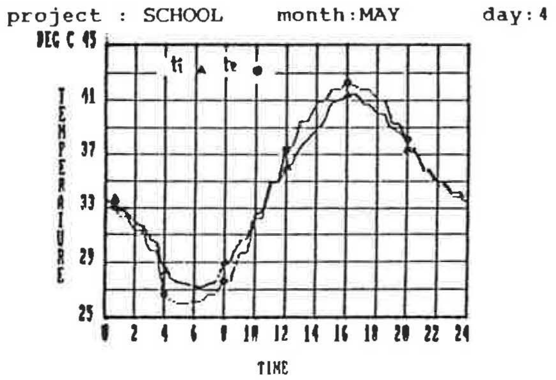

Fig. 4 - Changes in Inside and Outside Air Temperatures (same)

4.4 - Parameter Study

In order to improve thermal comfort conditions, the effect of various design parameters were studied: orientation, solar protection, building color, ventilation, wall composition, wall insulation, false ceiling and roof, false ceiling composition.

The following conclusions were arrived at:

relative importance of parameters

The table below combines the relative effect of the four main parameters on comfort indices (as compared with the reference case):

- the color of the walls (going from a dark to light color),
- inertia (going from 15 cm breeze-block to 100 cm earth wall),
- protection against inputs from the roof (insulation, aluminum foil on false ceiling, light-colored roof)
- day/night ventilation operation.

VARIANTS	Icomf1 (C)	Icomf2 (C)	Tmax (C)	TRmax (C)
COLORS	0.3	0.6	1	1
INERTIA	0.3	0.7	1	3
ROOF INS.	0.9	0.7	0.2	0.4
VENTIL.	0.6	0.4	0.5	0.3

NOTE: X: variation in X between the reference case and the variant studied

Icomf1,2: comfort index calculated from dry-bulb air or radiance temperature, respectively.

Tmax, TRmax: air and radiance temperature maxima.

accumulation effect limit

The interaction of functional or construction parameters of the building limit the effect of certain combinations. For example, a well selected orientation considerably lessens the need for solar shading or blanking the openings on the southern and northern sides.

Likewise, to protect against thermal input from the roof, a single method suffices:

- a light-colored fibrocement covering,
- or an insulating false ceiling (very thick wood),
- or a foil of aluminum on the false ceiling.

While these solutions are more or less equally efficient, combining them does not produce a greater improvement.

4.5 - Recommendations for passive cooling

As the above table shows, the different variants, taken, separately, do not considerably improve comfort conditions. However, judiciously combining these variants can lead to satisfactory results.

The following improvements were combined:

- white walls and light colored roof,
- high inertia (breeze-block or earth, thicker than 50 cm),
- ventilation (low during the day, high at night),
- and, as an example, outside insulation of walls and roof.

A solution combining thick walls, good solar protection and proper ventilation control leads to substantial gains, notably as concerns temperature maxima, with a 6°C drop in the maximum dry-bulb radiance temperature from 42°C to less than 37°C.

The same parameter sensitivity studies were conducted for the wet season and showed how the solutions recommended for comfort in the dry or wet season remain consistent. The main difference involves ventilation control and the part played by inertia which becomes secondary in the wet season.

5 - CONCLUSION

What is really innovative in CASAMO-CLIM ?

First, it belongs to a new generation of computer aided tools, which replaces the ancient and limited rules of thumb.

Designers can improve the sensitivity of the thermal behaviour of a building to the main design parameters : ventilation, radiative properties of materials, thermal inertia, solar protection, roof insulation ... If one knows empirically their individual effects, it becomes quite impossible to predict the consequences of their simultaneous variations without any computed calculations.

Secondly, micro-computer software appears as an appropriate mean of knowledge transfer from research laboratories to engineers and architects.

Lastly, we can point out the aid to the design of "passive" comfortable housings which can avoid expensive and unappropriate air-conditionning systems for developing countries.

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