INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 2, Issue 2, 2011 pp.261-266

Journal homepage: www.IJEE.IEEFoundation.org

Building thermal performance in Saharan climate

Brahim BELGAID

Department of architecture, University of Batna, 05000- Batna, Algeria.

Abstract

The aim of this study is to present an analytical method of the contribution of the building's shape and orientation in the definition of a comfortable microclimate for the inhabitants of the warm regions of Algerian Sahara.

Study is made by using the overheating Δt_m , a concept allowing a fast estimation of the level of internal temperature. Calculations were performed for summer hot period for Biskra (a city of southern Algeria), situated in Sahara and characterized with a hot and dry climate.

The influence of the shape and the orientation of the building are examined as a solution to improve the building's thermal performance.

Keywords: Dry regions, Thermal comfort, Solar radiation, Building form, Building orientation.

1. Introduction

Vitruvius said that 'we must take note of the countries and climates in which buildings are built' [1].

Modern constructions offer the technical possibilities of reaching an acceptable level of comfort by heating, cooling or other kinds of air conditioning.

This easy access to active solutions had the effect of making forget all the knowledge accumulated during centuries concerning passive solutions, and which countered today furthermore there exceeded.

In southern Algeria, traditional buildings often eased the outside climate, even though comfort was not always realized all the time of day or in any seasons.

Solar radiation intensity on a major part of the Algerian territory during period rather long the year, requires most of the time the use of installations of air conditioning, to improve the internal conditions of comfort. The objective is to assure new behaviour during the building design in these regions.

2. The Algerian context

Sahara represents about 87 % of the global surface of Algeria, what represents the major part of the Algerian territory, situated between latitudes 20°N and 34°N. It is constituted by regions with hot and dry climate (in Sahara annual precipitation does not exceed generally 150 mm/year).

Algerian territory is divided into 5 different climatic summer zones, from North to South, with a wide variety of climatic conditions for every zone as shown in Figure 1 [2].

The climatic environment of the Saharan regions is characterized by large temperature swings during the warm season, and the intense solar radiation as well as the aridity of the atmosphere.

In the dry and semi-arid areas (climatic summer zones E3, E4 and E5) which constitute the major part of the Algerian territory, the climate harshness during the summer period causes thermal discomfort conditions inside buildings.

Several solutions can be envisaged to remedy this problem, among which the exploitation of effects of the shape and building orientation.
This solution will allow so to avoid (or at least limiting) appeal to the solutions of artificial air conditioning, with all that it implies of running costs and maintaining problems.
An ignorance of this problem implies a lack of appreciation of energy savings and economic profits realized by the user. Consequently, the energy consumption by the buildings is higher than the necessary energy for their exploitation.

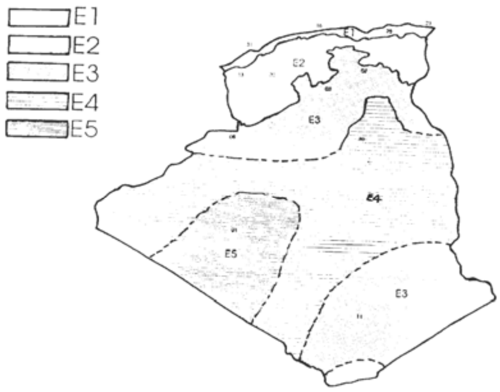

Figure 1. Climatic summer zones of Algeria

3. Comfort in the Saharan regions

In the desert climates, providing indoor thermal comfort constitutes a main objective.
Among solutions contributing to the improvement of the thermal comfort in these regions, natural ventilation plays an original role. However, it is also the most difficult parameter to measure and control.
In the cities of the desert, the warm and dry climate imposes mostly to have closed façades, with openings of small dimensions and introverted towards the courtyard.
Warm and dry air during the daytime imposes reduction of the amount of ventilation at its minimum (to keep internal coolness), and an increase of the renewal of air at the maximum during the night because of the evening cool air (at least 4 volumes / hour).
The roof, as a horizontal surface, realizes the biggest amount of solar gains realized by the building envelope as seen in Figure 2, and would benefit for this reason of particular treatment, in order to reduce these loads [3].
A study of the CTC (building supervision office - Algeria, 1986) proposed solutions to design appropriate roofs for the warm and dry regions of southern Algeria. These solutions recommended especially using local materials for the realization of heat insulation and rain protection of roofs for eight provinces of southern Algeria [4].

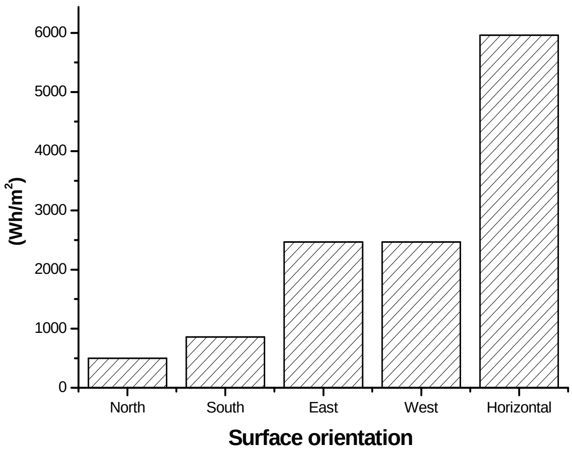

Figure 2. Direct insolation according to different orientations in July at Biskra

4. Impact of building materials

The traditional materials used in these regions are the stone, the brick of raw earth, the lime and the filler of lime. Walls realized with these materials are very thick (0.40 m to 0.50 m), and roofs are flat or vaulted.
For example, an external wall altogether of earth of 0.20 m of thickness realizes a thermal delay of about 9 hours and a decrement factor of 0.13 which is satisfactory.
Hassan Fathy, through his experience of Gourna, maintains the use of the mud's brick as building's material having made the object of serious studies at the university of California and Texas (United States) [5].
The colour and reflective properties of the external surface of walls and roofs influence the thermal behaviour of the building.
Actually, the mode of realization of constructions in southern Algeria is not so different from that practised in the North of the country where exist more clement climatic conditions, in spite of existence of several attempts to elaborate specific requirements for these regions.
The same building materials are mostly used (brick, parpen, concrete), besides the traditional materials (stone, lime, plaster, earth…) commonly used previously, and whose custom is today more and more reduced.
The rehabilitation of these traditional materials will require an inventory of the various materials, a detailed study and a critical analysis of their mechanical and thermal characteristics, as well as a definition of the fields of use.
If we consider the case of a region with desert climate, for example a warm climate as that of the countries of the Arabic Gulf, a requirement was adopted for use for building's thermal insulation, which imposes minimum levels of thermal resistances of 1.35 $m^2.K/W$ and 1.75 $m^2.K/W$ for walls and roofs respectively [6].
Note that for the most part of cases, thermal resistance of the external walls and the roofs in southern Algeria is weak (for our study, the thermal resistance for external walls and roof is respectively of 0.65 $m^2.K/W$ and 0.41 $m^2.K/W$).

5. Thermal comfort criterion

If we consider that the internal atmosphere of the building for an average uniform temperature is t_{im} , and that outside environment is for an average temperature t_{em} , it exists a difference of temperature Δt_m expressed by equation (1).

$$\Delta t_m = t_{im} - t_{em} \tag{1}$$

This difference of temperature Δt_m results from a thermal balance between various thermal quantities given by equation (2), expressing gains (solar contributions by opaque and glazed surfaces of the building's envelope, in addition of internal contributions), as well as losses (through the envelope and by renewal of air).

$$\Delta t_m = \frac{P_i + P_{cv} + P_{co}}{k_T + A.q} \tag{2}$$

where:
P_i = heat dissipated inside the building by users (cooking, lighting …) (W).
P_{cv} = benefits through the building glazing, following various orientations (W).
P_{co} = heat lost through the opaque surfaces of the building (external walls and roof) (W).
k_T = total conductance of the building (W/K).
$A.q$ = heat exchanged by renewal of air (W/K).

The method of the overheating Δt_m [7] calculated according to equation (2), is a way of estimating the indoor comfort level with regard to internal and external average temperatures, and allows having an appreciation of the value of overheating during the warm summer months.

So, for a building located at Biskra (southern Algeria), with a floor area equal to $144\,m^2$ and glazing on the northern and southern facades of surface S = $6\,m^2$, we will study 2 different cases following the ratio of the building's proportions, according to Figure 3:

- ✓ square shape ($L/l = 1$),
- ✓ rectangular shape ($L/l = 1.5$), building axis oriented $E-W$.

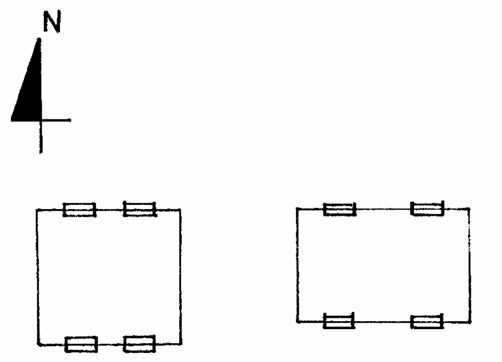

Figure 3. Square and rectangular building shapes

The corresponding values of Δt_m, following different ratios, for warm period are summarized in Figures 4 to 9 for different values of air change rates.

Modulated ventilation will vary from minimal rate during the day (minimal hygienic amount of air for $t_{em} \rangle\ t_{im}$) to maximal rate during the night ($t_{em} \langle\ t_{im}$).

6. Results

The change of building shape consists of a reduction of the building's proportions (ratio length / width), as well as a variation in exposed surfaces to solar radiation. For the square shape four faces exposed to the solar radiation have a surface equal to $36\,m^2$, whereas for the case of the rectangular shape the exposed surfaces to North and South are equal to $44.10\,m^2$, and those exposed to East and West are equal to $29.40\,m^2$, therefore a surface variation of closely 18 %.

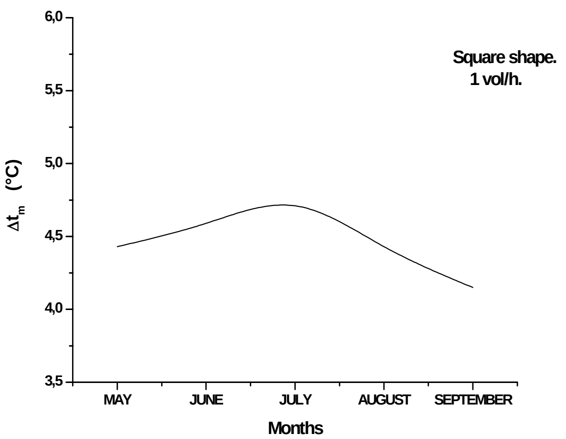

Figure 4. Variation of Δt_m for warm period, square shape (1 volume / hour)

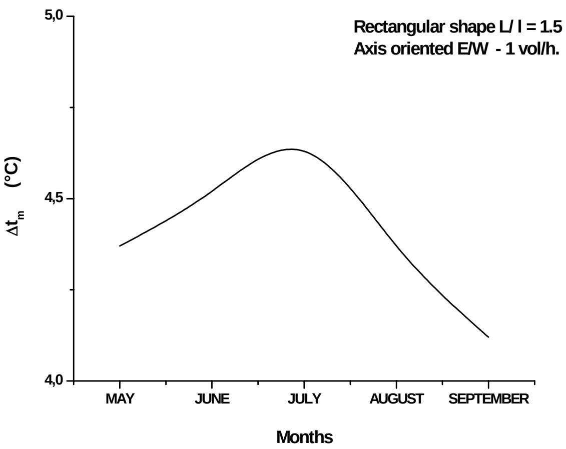

Figure 5. Variation of Δt_m for warm period, rectangular shape (1 volume / hour)

ISSN 2076-2895 (Print), ISSN 2076-2909 (Online)

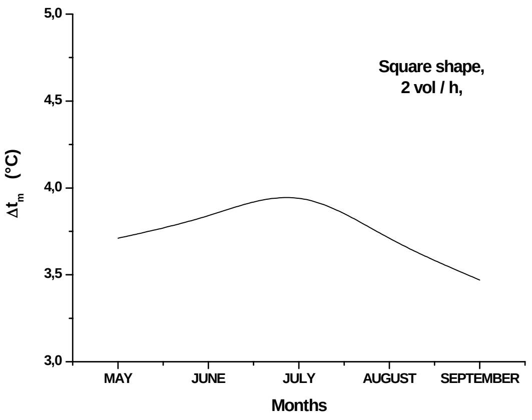

Figure 6. Variation of Δt_m for warm period, square shape (2 volumes / hour)

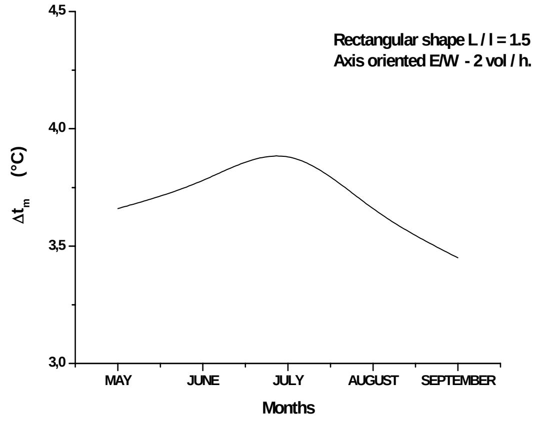

Figure 7. Variation of Δt_m for warm period, rectangular shape (2 volumes / hour)

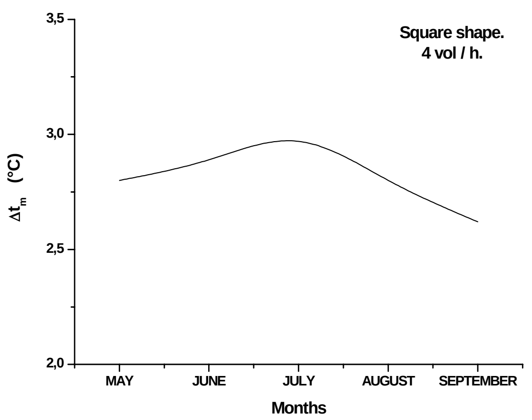

Figure 8. Variation of Δt_m for warm period, square shape (4 volumes / hour)

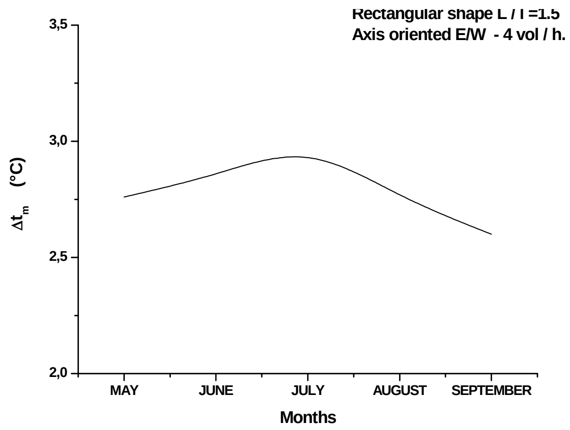

Figure 9. Variation of Δt_m for warm period, rectangular shape (4 volumes / hour)

According to the calculated values of the overheating for various studied cases, we notice that values of Δt_m are lower for the rectangular shape with regard to the building square shape, and that Δt_m could be reduced by the ventilation effect.
Note that the ventilation effect is considerable only from an air change rate of 4 volumes/hour or more, which is possible during the evening in fact that outside air will be at a temperature lower than the internal air. What would give possibility to obtain an efficient night cooling of the building thermal mass.

7. Conclusion
Building's geometry and orientation play a major role in determining building's thermal efficiency.
The Δt_m method presented here allows a good opportunity to evaluate influence of the building shape change on the solar collecting.
A priori, the objective of a study of the shape of the building from a thermal point of view, is a decrease of the surface of envelope exposed to the outdoor air, what would have decreasing effect of heat losses in winter, and also a reduction of gains (especially solar) in summer period.
Night-natural ventilation is an effective measure for the improvement of the thermal comfort in summer. However that a reduction of the exposed surface to the outside climate would limit possibilities or potential of envelope radiant cooling to night sky.

References
[1] Oktay, D. Design with the climate in housing environments: an analysis in Northern Cyprus. Building and Environment 2002, 37, 1003-1012.

[2] Recommandations architecturales. ENAG editions, Algiers, 1993.
[3] Capderou, M. Atlas solaire de l'Algérie. OPU editions, Algiers, 1985.
[4] C.T.C. Règles techniques pour la conception et la réalisation d'isolation et d'étanchéité des toitures en zone saharienne. O.P.U editions, Algiers, 1986.
[5] Fathy, H. Construire avec le peuple. Sindbad editions, Paris, 1970.
[6] Gulf Countries Electric Energy Conservation Committee. Thermal insulation regulations. First Meeting of Gulf Ministers of Electricity. Doha, Qatar, 30–31 October 1984.
[7] Lavigne, P., Brejon, P., Fernandez, P. Architecture climatique. EDISUD editions, 1994.