International Journal of Ambient Energy

An experimental assessment of shading and shadowing strategy, case of facade's cantilevered volumes. Reference to dwellings in arid lands

A. Belakehal & A. K. Tabet

Institut d'Architecture, USTO Oran, Algeria

Published online: 30 Mar 2011.


To link to this article: http://dx.doi.org/10.1080/01430750.2000.9675372

PLEASE SCROLL DOWN FOR ARTICLE
An experimental assessment of shading and shadowing strategy, case of facade's cantilevered volumes. Reference to dwellings in arid lands

A. Belakehal*, and A. K. Tabet**

SYNOPSIS
This paper describes the methods and the findings of experimental research assessing the quantitative and the qualitative efficiency of shading and shadowing as a direct solar control strategy. The case study is the contemporary individual urban dwelling facade in arid regions. The investigated facade component is the cantilevered volume. A heliodon is used for this simulation. Computation and graphic methods assess the studied facade variants. This work describes a classification of optimal variants of facade and allows recommendations for a shading strategy optimisation according to solar orientation.

INTRODUCTION
In the traditional towns of arid and warm lands, the streets are narrow and the buildings high, in such a way as to provide cooler air through the shade reaching them. Further, by shading each together the buildings protect themselves against the intense solar radiation and then allows a certain comfort level inside the buildings.

In the contemporary urban areas of arid lands, the streets are excessively wide to allow for mechanical circulation and are thus reached by solar radiation (Figure 1). In such a situation, not only the external physical environment is affected, but also the internal environment. Indeed, the facades are highly exposed to solar radiation and with less protection against them. In addition, the thermally inefficient materials of construction, used nowadays, make this situation worse. So, whatever are the constraints, an alternative to improve the outdoor and indoor physical environment comfort is necessary. Thus, the facade as a component of the urban form has to assure its own self-protection against the intense solar radiation. To do this, shading the facade with its own components is a strategy to be adopted [1].

Effectively, for the case of the facade, shading is an efficient natural strategy for solar radiation control. Elsewhere, shading also provides an ultimate aesthetic value for the facade, which is the principal entity upon which aesthetic judgements are made [2]. The aesthetic qualities of shading are of various natures (psychological, social, cultural and religious). The aesthetic aspect of shading is a qualitative parameter different from its climatic one, which is quantitative. The reconciliation of these two aspects at the facade level was the aim of an experimental study [3]. Its objective is the outcome of a comfortable indoor and outdoor thermal environment, and then responding to the environmental problems observed in the contemporary urban fabric of the arid regions of Islamic countries.

The case study of this investigation is the contemporary individual urban dwelling facade of the arid region of Algeria, which is representative of the Islamic countries. In this paper, the quantitative
An experimental assessment of shading and shadowing strategy

Belakehal, Tabet

The facade, an architectural and urban object. According to a morphological approach, the facade may be described as a vertical succession of storeys superimposed to a horizontal succession of span [4]. Within the grid resultant of this superimposition, the different components of the facade move conformably to three directions: (i) vertically, (ii) horizontally, parallel to the facade plan, and (iii) perpendicularly to the plan of the facade (depth). The intrinsic formal properties of the facade are submissive to the impact of the following extrinsic factors: (i) urban regulations, (ii) construction materials, (iii) dwelling evolutivity, and (iv) climate.

In this survey, the cantilevered volume is morphologically reduced to a parallelepiped, and is the single case of the facade components of which the impact is investigated.

Shading, a solar control strategy. In arid zones, the protection of a facade from direct solar radiation induces an important reduction of the absorbed solar energy. Then, a shaded facade will have only to sustain the diffuse and reflected radiation (Figure 2) [5, 6]. The diffuse radiation is small due to the local sky conditions, and the reflected, depending on the surrounding environment, can be reduced with the judicious use of vegetation, water, colour and surface texture. Hence in this study, only the direct solar radiations are considered.

Elsewhere, for a difference of more or less one degree of latitude, the geometric move of shade is nearly the same and without energetic incidence. Thus, the Algerian territory is divided in to ten geometric zones from 18° to 36° N [7].

THE CASE STUDY

The case study is a facade of four storeys (groundfloor, two intermediate storeys and the...
terrace roof) and three spans. The investigated variants of facades are aesthetically and energetically optimal [3]. They are descended from a single case of types determined through a generative morphological typology applied to this case of facade. The climatic context of this investigation is the 32°N solar geometric zone of the Algerian territory, which includes several representative urban regions of southern Algeria. Two periods are chosen for this investigation: (i) the month of July for the hottest period of the year, and (ii) January for the coldest period.

THE SIMULATION TOOL
The simulation tool used for this investigation is a low cost model stand and sunpath simulator [8]. This tool allows the simulation of the shading effects upon a model, during the necessary periods for this experimentation. In addition, the model is a familiar instrument for architects. It provides for this case study two advantages: (i) The ease of modifications applied to the model by simple manipulation of its components, and thus the possibility of simulating quickly several variants, and (ii) the satisfactory visual perception of the model, and the possibility to assess visually the shading impact.

This tool is composed by five components (Figure 3): (i) moving light source, (ii) base board, (iii) tilted board, (iv) sundial and, (v) the model.

The model. The model used for the simulation presents the facade (the investigated variant) in an urban context (a street). Thus, the variant is situated in front of a flat facade (opposite).

The facades are both of twelve metres height and the width of the street, in respect to the local urban regulation, is the same (Figure 4). These facades can be positioned and fixed upon the support of the model stand accordingly to the considered orientation (Figure 5).

The materials used for the construction of the model are: (i) paste board for models of 0.1 mm of thickness for the facade opposite; (ii) graphic (squared) paper of 0.1 mm of thickness for the experimented variant. With this paper, each cantilevered volume is constructed independently of the others, in order to translate them easily in depth. A mould in squared paper of 0.1 mm of thickness borders all these volumes. This apparatus is working as a system of horizontal and vertical superimposed drawers (Figure 6).

The use of the squared paper allows calculating, through the squares, the shaded and exposed surfaces. The model is constructed at the scale of 1/100. Thus, each square of the graphic paper represents a unity of an area of 0.25 m².

THE EXPERIMENTATION PROCESS
This experimentation is done in two steps: (i) the simulation, and (ii) the evaluation, which is composed by two methods: computation and graphic.

The simulation. The optimisation of each variant was assessed for the hottest and the coldest months of the year. The assessment is done relatively to the meteorological data indicating the quantities of direct solar radiation for each hour and per m². During the simulation, for each variant and each hour, a memocard is established including, (i) the elevation of the variant, (ii) its
Figure 4
A cross section of the urban street silhouette used for the experimentation.

Figure 5
The various possible positions of the simulated model upon the tilted board according to the solar orientation.
An experimental assessment of shading and shadowing strategy

Belakehal, Tabet

Figure 6 The cantilevered volumes are constructed independently of one another. The whole is working as a system of horizontal and vertical superimposed drawers.

code, (iii) the period (month) and time (hour) of the simulation, and (iv) the number of shaded units for both principal and secondary orientation.

The three faces of the cantilevered volume are considered in this study. Indeed, when the principal face is oriented to the north in order to receive the minimum amount of solar radiation, the secondary faces are oriented to east and west and thus receive a considerable quantity of these radiations. Upon the variant elevation, the shading of the opposite facade and the cantilevered volumes are reported differently: (i) dis-continuous lines for the first and (ii) a black surfacing for the second.

The computation method. For every variant, a table compiling the experimentation results is established and includes (Table 1):

(i) In columns: the time (hours) of the simulation.

(ii) In rows, are indicated:
- The area (m²) of the surface A, representing the same facade without cantilevered volumes and giving on the same principal orientation. Thus, its transmission factor is 100%. However, the variant is situated within an urban context, and the reduction of this factor caused by the shading of the opposite side is then considered. According to the simulated variant, this factor is the referential one for every time whatever its value.
- The values B1, B2 and B3 (W h/m²) representing the direct solar radiation amount according respectively to the principal and secondary faces of the cantilevered volumes. The values used for this study are the Ghardaia town ones, representatives of the other urban cities of the context study.
- The values C1, C2 and C3 (m²) of the exposed surfaces of the principal and secondary faces of the volume. A previous computation of the shaded units from the variant elevations registered in the memocards, allows the determination of these values.
- The product I = A x B1, summed at the end of the column (Total 1).
- The product C1 x B1, represented by II, summed at the end of the column (Total 2).
- The product C2 x B2, represented by III.
- The product C3 x B3, represented by IV.
- The total V = D + E + F summed at the end of the column (Total 3).

At the top of the table are indicated: (i) the orientation, (ii) the month, and (iii) the code of the variant. At its bottom, the following quotients are given: (i) total 3/total 1, where the secondary faces of the cantilevered volumes are taken into account and (ii) total 2/total 1 where the secondary faces of the cantilevered volumes are not considered.

The graphic method. This assessment is graphic and consists of a cumulative series of the facade variants elevations. The analysis of these series,
Table 1 The computation method for the quantitative assessment. Case of the variant 3B3C North-east, July.

<table>
<thead>
<tr>
<th>Time</th>
<th>Area</th>
<th>Energy Exposed (m²)</th>
<th>Exposed Surfaces (m²)</th>
<th>I * B1</th>
<th>II * B1</th>
<th>III * B1</th>
<th>IV * B2</th>
<th>V * B3</th>
<th>II + III + IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>63</td>
<td>411</td>
<td>0</td>
<td>242</td>
<td>56.07</td>
<td>0</td>
<td>3.5</td>
<td>25,893</td>
<td>23,044.77</td>
</tr>
<tr>
<td>8</td>
<td>123.9</td>
<td>436</td>
<td>0</td>
<td>332</td>
<td>108.63</td>
<td>0</td>
<td>6.25</td>
<td>54,020.4</td>
<td>47,362.68</td>
</tr>
<tr>
<td>9</td>
<td>144</td>
<td>368</td>
<td>0</td>
<td>364</td>
<td>113.25</td>
<td>0</td>
<td>5.75</td>
<td>52,992</td>
<td>41,676</td>
</tr>
<tr>
<td>10</td>
<td>144</td>
<td>250</td>
<td>0</td>
<td>343</td>
<td>94.53</td>
<td>0</td>
<td>4.5</td>
<td>36,000</td>
<td>23,632.5</td>
</tr>
<tr>
<td>11</td>
<td>144</td>
<td>109</td>
<td>0</td>
<td>274</td>
<td>63</td>
<td>0</td>
<td>3.25</td>
<td>15,696</td>
<td>6867</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>168</td>
<td>144</td>
<td>6.75</td>
<td>3.25</td>
<td>0</td>
<td>546</td>
</tr>
</tbody>
</table>

Total 1 = 184,601.4
Total 2 = 143,447
Total 3 = 151,442

Total 3 / Total 1 = 0.82
Total 2 / Total 1 = 0.77

Table 1 reveals the shading impact of the facade opposite and the cantilevered volumes, as well as the visual appreciation of the shading move upon the surface of the facade.

RESULTS AND DISCUSSION

According to the objective of this study, the optimisation is the reduction of the transmission of direct solar radiation through the shading allowed by the cantilevered volumes of the facade.

**Tables.** For the summer period, the optimised quantity of energy is equal to the result of the subtraction of the calculated transmission factors from the total value of 100%.

\[
S.O.S.C. \% = 100 - \frac{T_1}{T_2} \tag{1}
\]

**(Summer Optimal Shading Coefficient)**

However, for the winter period, the optimal shading coefficient (W.O.S.C.) is equal to the calculated transmission factors.

\[
W.O.S.C. \% = \frac{T_1}{T_2} \tag{2}
\]

**(Winter Optimal Shading Coefficient)**

The analysis of the tables allows the classification of the variants in three categories according to their optimisation (Table 2).

The variants of the first category provide a positive optimisation, since the reduction of the direct solar radiation quantities during the summer period are of 12 to 19%. Equally, during the winter period the optimisation is of 100 to 765%, implying an additional quantity of energy when it is favourable.

Elsewhere, the variants of the second category provide a positive optimisation for the winter period, while it is unsatisfactory for the summer one. A value of -167% implies an additional quantity of energy conducive to an overheating inside the building during a period where cooling is needed.

The analysis of the shading impact of the secondary faces of the cantilevered volumes outlines the necessity of the protection of these surfaces against direct solar radiation to obtain a better optimisation. Neglecting their effects, the S.O.S.C has a minimum of 11% and a maximum of 22%.

The third category is the most deficient and includes a single variant. Its optimisation is of -9% for the hottest season and of 82% for the coldest one. Even, without the shading impact of the secondary faces of the volume, the results are still unsatisfactory (-7% for the hottest season).

**Graphics.** The analysis of the cumulative series of the variant elevations highlighted the following remarks: (i) For the coldest season, shading is assured during most of the time by the facade opposite (the urban profile action). (ii) During the hottest period, the action of the facade opposite is of little impact, in particular for south and west orientations. The action of the cantilevered volumes during this period has a big impact.

Hence, the major results of this experimentation are as follows:
The action of the cantilevered volumes for the optimisation of itself shading is satisfactory in the case of the W, N-E, S-W and N-W orientations.

Consequently to the over-exposition of their secondary faces, the volumes which the principal faces are orientated to S, N-E, S-E and N, cannot come up to a satisfactory optimisation, in particular during the summer period. Thus, for the case of these orientations, the shading impact study must be extended to include the other components of the facade (texture, decoration, . . .) in order to improve its optimisation.

For the east oriented facades, shading the principal and secondary faces of the cantilevered volumes is indispensable for a better optimisation.

**CONCLUSIONS**

Finally, this experimentation allows the conclusion that shading cannot be provided by a single component of the facade. Rather, it emanates efficiently from the hierarchical connected actions of the various facade components. These actions can constitute the basis of a support for a more complex and rich aesthetic system for the facade. Also, the shading impact study must be extended to the evaluation of its effects upon daylighting. Obviously, daylight is an inherent phenomenon to direct solar radiation in arid zones.

On the other hand, the urban form impact, referred in this work to the local regulations, recommends the study of the relationship between buildings height and street width in order to obtain a more satisfactory optimisation.
formalistic game revealed by the dark and clear moving contrast, allows the facade, at the perceptual level, to acquire a new dimension as a dynamic urban figure. It even revalues this contrast between light and shadow as an architectural character of the urban areas of the arid regions of Islamic countries. Thus, it provides for this context a new aesthetic value binding the perceptual and the social aspects to the climatic one at the level of an urban and architectural entity: the facade.

REFERENCES