STUDY OF THE SHADING SYSTEMS FOR A SOUTHWARD BIOCLIMATIC BUILDING FACADE

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Abstract – The bioclimatic buildings and some their characteristics, such as the geometric configuration, the orientation, the reflectance values of the materials, the use of particular capturing and distribution systems of sunlight are very interesting in the study of the potentiality of daylighting in buildings.

As the light propagation is independent of the building dimension several studies uses scale model to carry out their analysis on the building of the case study. Moreover the use of scale model allows to foresee the behaviour of the several design solutions that influence the illuminance conditions. The last one must be controlled to avoid discomfort condition inside the building.

In this work are showed the numerical and experimental results about a daylighting analysis realised on an existing bioclimatic building located in the centre of Italy near to the Adriatic coast. The study has the goal to value the efficiency of some shadow strategy to control the exposition to the solar radiation of the south facade. The necessity is to decrease the penetration of the sun in the months between October and March.

The experimental results have been obtained with the use of a 1:25 scale model. The model was tested under a sky simulator of Losanna Polytechnic with the aim to reach the daylight data without meteorological interference.

The theoretical analysis on numerical model was realised with the Adeline software.

The results allowed to evaluate the illumination performances of the building in terms of daylight factor, illuminance and luminance distribution in relationship with the several adopted strategies.

1. INTRODUCTION

In this last years a lot of headquarters, office or commercial buildings outlines a particular attention to daylight design. The majority of daylighting experimental studies is for atria-buildings but it’s interesting also considers the orientation and the fenestration to have a daylong solar heat gain factor during sunny days throughout the year. According to S. Daryanani (1984), fenestration must have adequate glare control in order to insure occupant comfort. Otherwise, daylighting savings will not be realized, as the occupants are likely to close blinds or curtains and not benefit from daylighting. In fact, the excessive window glare could even increase energy consumption if additional artificial lighting is required to counterbalance the unwanted glare at the perimeter.

In the search for comfort and maximal energy efficiency in commercial and residential buildings there is a possibility to select exact glass type or combination to suit any situation. Various techniques are available to control the amount of solar radiation coming through windows, including the use of external and internal shading and solar control glasses.

When the availability of solar radiation coincides with the demand for light, a use of daylight could give a significant contribution to the global performance of a building, both in terms of energy savings and comfort of occupant.

An important example of daylighting design in transparent facade is The Institute of the Arab World building in Paris (Jean Nouvel Architect): the treatment of light in the sud facade is realised by means of frames and filters. These are mobile diaphragms very much like those of a camera. The building of Thomas Herzog in Hanover is another example of daylighting technologies. In this trade fair pavilion the natural lighting in the hall is achieved by large nord facing glazed areas in the region of main steel structures. By means of light deflection elements, the daylight is directed via the “major reflector” (i.e. the roof of the hall) into the public areas.

In the LOG ID Dresden office, the interior is provided with sliding translucent panels with which glare and radiant heat from the glass can be combated. Moreover a scale model could be considered a tool of great interest since the behaviour of daylight penetrating into and inter-reflecting within a scale model is considered similar to how it would be in a full scale building.

The scale model was made in order to enable the reproduction of every interior or exterior details that influence the daylight penetration into the building and its distribution. In this work a scale model and an artificial sky simulator are using to foresee the daylight penetration and distribution into a real building.

We have compared the experimental results with computer simulation of the daylight system by means the program package ADELINE (Advanced Daylight and Electric Lighting Integrated New Environment).

At last we are going to reconsider the shadow system with the application of glazing film to eliminate the high glare in particular for the winter season.

2. THE EXPERIMENTAL DAYLIGHTING MEASUREMENTS AND RESULTS UNDER AN ARTIFICIAL SKY SIMULATION

A 1:25 scale model of the new iGuzzini Illuminazione headquarters building was made in order to enable the reproduction of every interior or exterior details that influence the daylight penetration into the building and its distribution to simulate its real behaviour. E. Francis outlines that this building that MCA architects have designed, is an example of an innovative office building where ways of reducing energy consumption and environmental quality have been considered throughout the design process.
The building is rectangular in plan, with overall dimensions of 40 m x 19.3m and a volume of 10,000 m$^3$. It provides office accommodation on four floors, located around a central atrium with circulation and service facilities incorporated into the link to an adjacent existing building. The south facade (Fig. 1) is entirely glazed. It is set forward 0.780 m from the concrete structure and passes in front of it. The east and west facades are opaque.

In Recanati we have Mediterranean climatic characteristics and in summer it can reaches high temperatures (Latitude 43.47°N, Longitude 13.31°E, Altitude 100m, facade orientation N-S).

To avoid overheating and glare due to such a large area of glazing, a shading roof was designed to protect the south façade in summer.

The shading roof was designed with shading extending horizontally 6.7 m, in front of the building and then dropping down vertically for 3.7 m. The shading is provided by 0.330 m. aluminium louvres fixed at a 45° angle to the beams. The orientation of the louvres varies according to the need for shading. The shading is most dense in the center of the roof as this the area that shades the facade in summer. The louvres here are oriented against the rays of the sun and are 0.400 m apart whereas the louvres on the vertical shading structure are fixed horizontally at 0.500 m centers.

We have tried to reproduced all of the surfaces, furniture, fixture, texture, and materials exactly, it would be possible to simulate the real behavior of the building. The materials used have the reflectance levels close to those which were used in reality.

The model was screwed onto a 0.025 m wood-board base so that it could be easily fixed to the heliodon. The inside of the model is easily accessible through the open side to place and adjust the sensors. The Heliodon is an instrument that simulated the daily rotation of the earth about its polar axis and the changes in the solar declination (the angle the suns rays make with the equatorial plane) from season to season (Fig.2). The position of the earth relative to the sun at any time, day of the year and latitude can be simulated.

The Heliodon can be used to determinate light levels within a building, shadows cast by a building or interior reflectance due to materials. For the overcast condition, a daylight factor (DF) can be used to evaluate the efficiency of shadow system. The daylight factor inside was taken at the level of a work table although it can be taken at any point where we wish to know the daylight levels (Fig.3). In particular the transmission of light through glazing materials and the reflectance of light from surfaces, are determining factors of daylight quantity penetrating and inter-reflecting into the model.

The isotropic and overcast CIE sky are used to obtain a carefully controlled light distribution. This consists of a 5m. diameter hemisphere made from 145 luminous discs. Each lamp can be modified so a large variety of skies can be reproduced. The direct sunlight is simulated by means of a OSRM-HMI lamp situated 8m high from the mode (EFFL). The scale model was tested in an artificial sky simulator for the isotropic sky and CIE overcast sky (with a luminance of 4300 cd m$^{-2}$) with the aim of obtaining objective and reproducible measurements without interference from meteorological conditions. The sky simulator allows to reproduce the characteristic lumiance distributions of every type of sky and in particular the CIE standard sky distribution. the reproducibility of a sky luminance distribution, using the sky simulator, allows to make a comparison about functionality of daylighting strategies in different seasons. The diffuse sky allowed to determinate daylight factor while direct light to evaluate the efficiency of shadow system. The daylight factor inside was taken at the level of a work table although it can be taken at any point where we wish to know the daylight levels (Fig.3). In particular the transmission of light through glazing materials and the reflectance of light from surfaces, are determining factors of daylight quantity penetrating and inter-reflecting into the model.

For the overcast condition, a daylight factor (DF) can be used to estimate illuminance at any time of year from the measured
data. For the CIE sky the readings varies from 4.98 to 17.09% at 1st floor . While at the 2nd for the CIE sky the readings varies from 4.64 to 19.14%. Daylight levels of 350 lx ÷ 500 lx are considered sufficient in office buildings.

From the table 1 we can outline that if outside there are more than 3500 lx, the DF is too elevate in some positions like E and F.

Tab 1- DF on the scale model

<table>
<thead>
<tr>
<th></th>
<th>CIE overcast sky-1st floor</th>
<th>CIE overcast sky-2nd Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.92</td>
<td>8.36</td>
</tr>
<tr>
<td>B</td>
<td>6.95</td>
<td>7.84</td>
</tr>
<tr>
<td>C</td>
<td>6.09</td>
<td>6.91</td>
</tr>
<tr>
<td>D</td>
<td>5.66</td>
<td>7.03</td>
</tr>
<tr>
<td>E</td>
<td>17.09</td>
<td>19.14</td>
</tr>
<tr>
<td>F</td>
<td>12.45</td>
<td>14.69</td>
</tr>
<tr>
<td>G</td>
<td>4.98</td>
<td>14.29</td>
</tr>
<tr>
<td>H</td>
<td>4.97</td>
<td>4.64</td>
</tr>
</tbody>
</table>

The simulation with direct sun light would give a view of the performance of the building and the shading system for the two extreme (highest sun angle and lowest angle) and mid season. In the Fig.4 you can see that the external shadow system protects the buildings from the sunlight during the summer time exactly June 21(a) at 10 a.m. while in Fig. 5 is shown that in winter time at 10 a.m. the sunlight can reach the interior of the building and inside we have a discomfort situation in our climate.

3. NUMERICAL SIMULATION AND RESULTS

The behaviour of the 3D model was simulated with the Adeline computer program. Adeline stands for Advanced Daylighting and Electric Lighting Integrated New Enviroment and it is a package of programs that produce reliable lighting design result by processing a variety of data to perform light simulations and comprehensive numeric and graphic information. Daylighting analysis can take many forms but the diffuse indirect calculation to obtain the daylight factor at any points was particularly important for our research.

To make a visual comfort evaulation, we have obtained a frequency distribution of the indoor illuminance by daylight at various points, specified according to latitude, longitude, part of year, part of the day, geometry of the interior space and building's windows and materials characteristics of the existing buildings.

Radiance software has also good capabilities for qualitative simulations that are important to predict the behaviour of a building and of its shadow system. In the Fig.6 e Fig.7 it was decided to record simulation at 10 a.m. in summer period and in winter period to compare with Fig. 4 – 5 about experimental simulations on the scale model.

The daylight factor in the point to analyse is the ratio of the interior illuminance at that point to the global horizontal illuminance, under Cie Standard overcast sky conditions. This kind of sky tends to be used for numerical work (Greg Ward Larson, 1998).

In this step we are trying to test how Radiance can be used to predict the daylighting performance of an architectural design.
4. COMPARISON AMONG THE EXPERIMENTAL AND NUMERICAL RESULTS

The data obtained from the computer simulation were compared with the measurements carried out on the scale model with the aim to verify the agreement between the results.

The above picture in Fig.3 referred to Fig.8, the following table 2 and graphics (fig 9 a-b) demonstrate the Adeline accurate predictions under a CIE overcast sky.

![Image](image_url)

**Tab.2**

<table>
<thead>
<tr>
<th></th>
<th>DF Scale model simulation</th>
<th>DF Numerical simulation</th>
<th>Δ%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.36</td>
<td>7.10</td>
<td>15.07</td>
</tr>
<tr>
<td>B</td>
<td>7.84</td>
<td>7.50</td>
<td>4.33</td>
</tr>
<tr>
<td>C</td>
<td>6.91</td>
<td>7.10</td>
<td>2.7</td>
</tr>
<tr>
<td>D</td>
<td>7.03</td>
<td>5.80</td>
<td>10.99</td>
</tr>
<tr>
<td>E</td>
<td>19.14</td>
<td>17.00</td>
<td>11.18</td>
</tr>
<tr>
<td>F</td>
<td>14.69</td>
<td>15.80</td>
<td>7.55</td>
</tr>
<tr>
<td>G</td>
<td>14.29</td>
<td>15.60</td>
<td>9.16</td>
</tr>
<tr>
<td>H</td>
<td>4.64</td>
<td>5.27</td>
<td>13.57</td>
</tr>
</tbody>
</table>

5. GLAZING FILMS

Always by means of radiance computer simulations (Adeline software package) you can predict some results to improve the interior visual comfort. Glare from the direct rays of the sun was creating uncomfortable viewing of the various Computer screens throughout the building.

The shadow system can be better in south façade extending the vertical brise soleil or applying solar control films on the louvres.

With the application of film you can eliminate the glare and reduce interior temperatures how is showed in fig.10 and fig 11 for a CIE clear sky with direct solar radiation.

![Image](image_url)
The figure 11 has a more uniform distribution of illuminance on the floor; the direct radiation is stopped on the curtain wall. The Radiance simulation allows to obtain the trend of the DF on a working plane inside the building. From table 3 is evident that the daylight factor with glazing film is much more less than that one without it in the condition of overcast sky. Using a films with visible light transmitted value of 24% and a medium neutral color, we obtain a better result to stop direct light for south facade. This solution provides unparalleled solar control and outward visibility, allowed freedom of design and increase in the comfort of the building occupants.

Tab.3

<table>
<thead>
<tr>
<th></th>
<th>DF Numerical simulation</th>
<th>DF Numerical simulation with films</th>
<th>Δ%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7.10</td>
<td>3</td>
<td>-57.74</td>
</tr>
<tr>
<td>B</td>
<td>7.50</td>
<td>3</td>
<td>-60</td>
</tr>
<tr>
<td>C</td>
<td>7.10</td>
<td>3</td>
<td>-57.74</td>
</tr>
<tr>
<td>D</td>
<td>5.80</td>
<td>3</td>
<td>-61.33</td>
</tr>
<tr>
<td>E</td>
<td>17.00</td>
<td>13</td>
<td>-23.6</td>
</tr>
<tr>
<td>F</td>
<td>15.80</td>
<td>9.12</td>
<td>-42.27</td>
</tr>
<tr>
<td>G</td>
<td>15.60</td>
<td>13</td>
<td>-16.67</td>
</tr>
<tr>
<td>H</td>
<td>5.27</td>
<td>13</td>
<td>-43.07</td>
</tr>
</tbody>
</table>

In figure 12 is shown the uniform distribution of illuminance under overcast condition to comparison with figure 8.

With the film you have the clarity of the view and noticeable absence of high glare (Fig. 13), its virtually eliminated and daylighting can be fully used as a design element.

6. CONCLUSIONS

Daylighting analysis can take many forms, we followed this path:
- A 1:25 scale model was made in order to enable the reproduction of every interior or exterior details that influence the daylight penetration into the building and its distribution.
- The scale model was tested in an artificial sky simulator with the aim of obtaining objective and reproducible measurements without interference from meteorological conditions.
- For the overcast condition, a daylight factor (DF) can be used to estimate illuminance at any time of year from the measured data.
- We compared the experimental results with computer simulation of the daylight system using Adeline program.
- After this first analysis we have reconsider the shadows system for winter season.
- A solution to eliminate the glare inside the offices is the application of glazing film. It was tested by means of Adeline to predict the building behaviour.

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