475: DAYLIGHTING DESIGN FOR LOW ENERGY BUILDINGS IN SOUTH ITALY

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Abstract

The preliminary study for two low energy buildings are presented. The buildings will be built in South Italy, and their design process has taken into account all those measure related to energy savings: Italian regulation on building energy performance, the renewable energy employment, both thermal and photovoltaic systems, and finally a comprehensive study of daylight impact on architectural choices; to this aim have been considered both the direct solar radiation and the sky vault contribution. In particular the daylighting analysis has been performed by models and software simulation used throughout the architectural design process to help make decisions about the natural lighting conditions and for studying distribution of daylight across spaces, luminance evaluation and quantitative measurement of daylight levels.

The research developed at the Built Environment Control Laboratory RiAS, at Architecture Faculty of Seconda Università di Napoli, has involved, by several steps, the available "tools" for the assessment of daylighting contribution in a lighted environment.

The first step has considered the models physical simulation by means of ECOTECT and RADIANCE daylighting analysis; this "tools" have carried out the design of solar shading devices and fenestration optimization in terms of size and position.

Successively have been considered scale models that were tested inside a mirror sky box (3m x 3m) with banks of fluorescent lamps behind a translucent ceiling; this was used to reproduce the CIE standard overcast sky distribution, under which have been acquire data on internal illuminance levels, the related daylight factor and luminance distribution of internal surface. To this aim the acquisition was performed by photometric heads for scale model and luminance measuring camera; the acquired data were then compared with the physically accurate software simulation results to validate the simulation procedure and to determine the daylighting features of the architectonical solutions proposed and the potential savings due to daylight.

Keywords: daylighting, daylight factor, shading device, Ecotect, artificial sky, scale model.

1. Introduction

The use of daylight in buildings is widely accepted as one of the important strategies to reduce overall energy use. Apart from its numerous positive health and psychological effects, daylight is a free, renewable natural resource and a high efficacy light source. Daylight also provides a continuous spectrum of light, which enhances visual performance. People tolerate much lower illuminance levels of daylight than artificial light, particularly in diminishing daylight conditions at the end of the day [1].

On the other hand modern building design is a complex and demanding process. To add to a quite extensive list of design considerations, there are increasing client and regulatory pressures to produce higher performing and more energy efficient buildings. To this aim decisions made at the very earliest stages often have the greatest impact on the overall performance of a project. In our work we have considered two case studies related at two low energy buildings that will be built in south Italy, the first in Casaldianni (BN) and the second one in Pomigliano d' Arco (NA).

For such localities, the climatic conditions during all the period of the year remain mild, becoming rigorous climate only in the extreme seasons like December o July.

In this case the bioclimatic planning plays a fundamental role, because through appropriate architectonic choices and using strategies for the exploitation of resources tied to territorial characteristics it is possible to achieve energy savings. So, the design process has taken into account all those measure related to energy savings: Italian regulation on building energy performance, the renewable energy employment, both thermal and photovoltaic systems, and finally a comprehensive study of daylight impact on architectural choices. To this aim have been considered both the direct solar radiation and the sky dome contribution. In particular the daylighting analysis has been performed by models and software simulation used throughout the architectural design process to help make decisions about the natural lighting conditions and studying distribution of daylight across spaces, luminance evaluation and quantitative measurement of daylight levels. The research has involved, by several steps, the available tools for the assessment of daylighting contribution in a lighted environment and for optimization of the solar shading strategy on exposed walls in sunlight, where the balance between thermal and lighting optimization is critical to the success of the project, based on bioclimatic strategies.

Moreover, the simulation tools were especially developed for the analysis of the physical phenomena to reinforce the architectural application of passive solar design strategies.

The ECOTECT and RADIANCE software was used for daylighting and overshadowing analysis. Successively have been considered scale models that were tested inside a mirror sky box available at the Built Environment Control Laboratory RiAS, at Architecture Faculty of Seconda Università di Napoli. As the final step, when the buildings will be really constructed, we further will compare the preliminary analysis results described in this paper to the in-situ acquisitions. This is a useful process to evaluate the accuracy for both software and model simulation as a design tools.

2. Methodology

2.1 Buildings features

The first building under study is a Cultural Centre with offices located in the southern part of Italy; Casaldianni a small town located inland about 50 miles north-east of Naples in the middle between Benevento and Campobasso (latitude: 41° 10' and longitude 14° 70'). The climate of Casaldianni is slightly different than Naples coast. Instead of a hot such as Mediterranean coastal weather, it is separated from Naples by hills that become the Apennine Mountains, and its weather is comparatively a bit cooler and similar to that Campobasso (one of the nearest big city).

Fig 1. Render building in Casaldianni (BN)

The idea of the shape definition is the concept of protection of energy. The gesture of hands that protect the energy generate the circular space (the heart of the project), on two levels, that receive the hall on the ground floor and a library on the first floor. To this, it's grafted the trapezoidal block which is subdivided in two under areas: the offices, on the north façade, and a corridor-greenhouse that distributes the flows to the laboratories, on the south façade.

For its exposure and its form it carries out in winter also a function of "thermal barrier" towards the back. Both the library and the offices have a flat roofs instead the greenhouse has a pitched roof. In Figure 1 it's possible to see a render of the building seen in front of the south façade. It shows the great glazing walls on the circular block and greenhouse.

The second building under study is a Sportive Centre located in the southern part of Italy too and just in Pomigliano d'Arco (latitude: 40° 90' and longitude 14° 38'). This city is situated near Naples (few kilometres) and for this reason its climate is much similar to Naples. The plan allows two separate blocks connected through a pedestrian passage completely enclosed from glazing. The simulations have been carried out on the block that accommodates a dressing room area and a child-plays area too (ludoteca). A covered public square is between the two areas. All the block is covered by pitched roof with maximum height like 10,0 m and minimum height like 3,4 m. Figure 2 shows a render of the building.

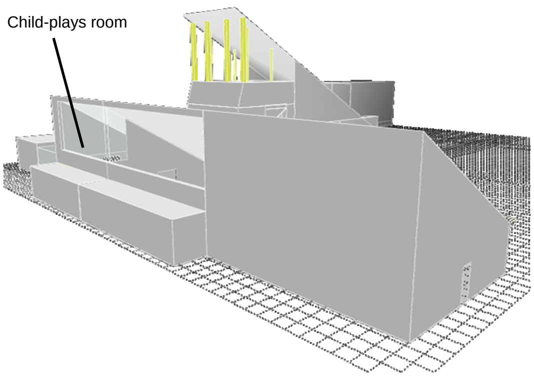

Fig 2. Render building in Pomigliano (NA)

2.2 Daylighting study

In the first step ECOTECT software has been used to preliminary daylighting analysis. In the last years it's an industry leading building analysis program that allows designers to work easily in 3D and apply all the tools necessary for an energy efficient and sustainable planning.

It's offers a wide range of different analysis and simulation options that concur to the energetic performances of the buildings, in order to supply indications and possible modifications to the preliminary plan. In Figure 3 below it's possible to see the model of the Cultural Centre built directly in the application software.

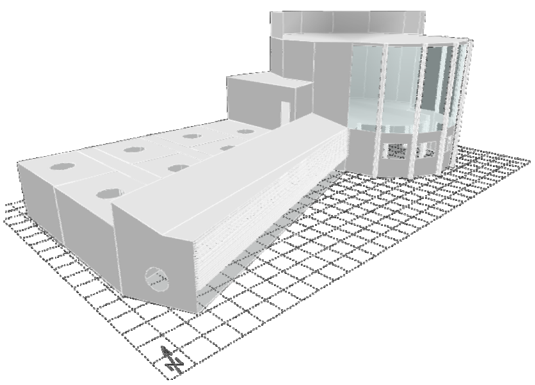

Fig 3. Model developed in ECOTECT (Cultural Centre)

The geometric model has been subdivided in three main blocks for the analysis as shows in Figure 4 below:

- office's block with a several number of small rooms that get daylight by skylight (identified with the red line in Figure 4);
- greenhouse, overlooking the office's block, and it's a capacitive element during the winter period (identified with the blue line in Figure 4);
- hall, like a open-space, in which there is a loft (identified with the yellow line in Figure 4).

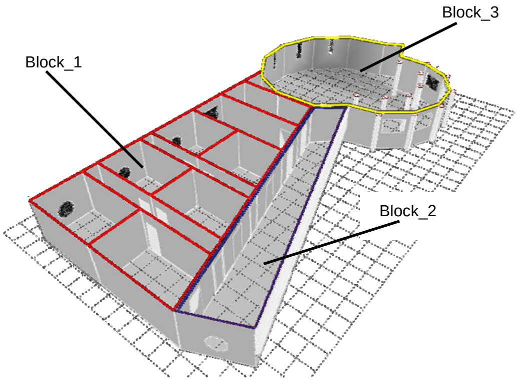

Fig 4. Subdivided model in three main blocks (Cultural Centre)

Successively the model in ECOTECT was exported to RADIANCE software for generating the best results and to improve the distribution of daylight across a space

The analysis of the natural lighting system is executed for the office's block and the hall, while the greenhouse has been performed to the solar analysis because it is necessary to account a shielding device.

A correct employment of transparent elements needs to specific characteristics in terms of solar shading and thermal insulation; in fact the glazing must be control, beyond the amount of visible light, the solar radiation inside the building for its comprehensive use. The glazing surface must therefore have the following characteristics:

- solar control, refers the amount of solar radiation that affect on thermal flow passing through the material. This information is available from all glass suppliers;
- thermal insulation control, that is the ability to reduce the thermal flow from outside to inside.

The first term refers to Solar Heating Gains Coefficient (SHGC) based on the fraction, in the range 0-1, of solar heat gain that passes through compared to either the incident solar radiation or the transmission of a reference glazing type, and a Luminous Transmission Coefficient (Tl) indicates the same relationship only for the visible radiation; instead the thermal insulation characteristics are based on the UNI regulations.

The used characteristic values in the lighting simulation are brought back in the Table 1 below.

Table 1: Solar Heating Gains Coefficient (SHGC) and Luminous Transmission (Tl) used.

Application	Layer	SHGC	Tl
Offices and skylights glass	Glass 6 mm; Air gap 3 mm; Glass 6 mm;	0.75	0.92
Hall glass	Glass 60 mm; Air gap 60 mm; Glass 40 mm;	0.56	0.42

ECOTECT uses the Building Research Establishment (BRE) Split-Flux method that is a widely recognised and very useful technique for calculating daylight factors in a preliminary study (it's defined as the ratio of the illuminance at a particular point inside a space to the simultaneous unobstructed outdoor illuminance under exactly the same sky conditions). This method is based on the assumption that, ignoring direct sunlight, there are three separate components of the natural light that reaches any point inside a building:

- Sky Component (SC) - Directly from the sky, through an opening such as a window;
- Externally Reflected Component (ERC) - Reflected off the ground, trees or other buildings;
- Internally Reflected Component (IRC) - The inter-reflection of 1 and 2 off surfaces within the room.

RADIANCE is a computer software package developed by the Lighting Systems Research group at Lawrence Berkeley Laboratory. It is a research tool for accurately calculating and predicting the visible radiation in a space by using a combination of raytracing and radiosity techniques (it take into account specular, directional-diffuse reflection of materials). The program uses three dimensional (3D) geometric models as input, that can be imported by ECOTECT, to generate spectral radiance values in the form of photo realistic images.

Moreover we exported the results again in ECOTECT for flexible display on the analysis grid.

The first step consist in the evaluation of the typical "daylight factor" values that are generally calculated using a standard "CIE OVERCAST" sky illuminance distribution in order to represent a worst-case scenario to be designed for [2]. This means that they will not change with different dates or times and will not be affected by rotating the North point. This makes it a property of the design itself, not the local environment. Thus, the only parameters that affect daylight factors are the geometry of the design and the materials it is made of. By assigning a design sky value, it is possible to obtain illuminance levels (in lux) for a particular location.

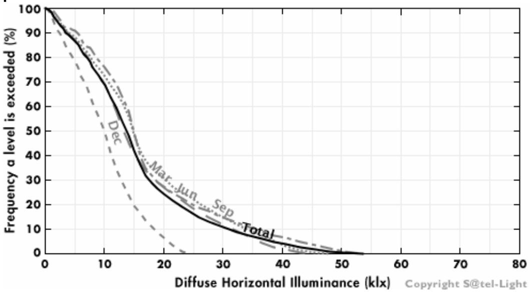

Fig 5. Diffuse horizontal illuminance, throughout the year, with an overcast sky (Campobasso, Lat 41°34'N – Lon 14°39' E)

The external illuminance value was derived from a S@tel-Light database that, according to the latitude of the site, provide the illuminances in a horizontal plane, throughout the year, with an overcast sky. It is show in Figure 5 above.
We have considered the value of outdoor illuminance that is exceeded 80% of the time between the hours of 9am and 5pm throughout the working year (7500 lux).
The simulation of daylight factor has been carried out on the plan at 0,85 m. from the floor. Successively, a lower limit of illuminance inside the rooms was set (300 lux) to perform the "daylight autonomy". It is given as the percentage of time throughout the year that each room will need no additional light to maintain the selected level. The relative data on the single zones are brought back in the Table 2 below.

Table 2: Average daylight factor and daylight autonomy on each zones of the building for Casaldianni (RADIANCE results).

Zone	Average Daylight Factor [%]	Average Daylight Autonomy [%]
Hall	3.5	89.9
Loft-Hall	3.5	94.1
Meeting room	11.9	99.5
Office A	10.2	99.2
Office B	8.9	98.9
Office C	10.3	99.3
Office D	8.9	99.0
Office E	9.8	99.2
Office F	7.8	98.5

In the same way the model of the Sportive Centre in Pomigliano was build directly in ECOTECT (Figure 6) and exported in RADIANCE. The CIE Overcast Sky was set too. Although the overall building was considered in the process of design and analysis, this paper mainly deals with the lighting design of the child-plays room.
In fact lighting contribution falling on in this space is accomplished by several hole improved at the earliest stage of the design:

- external door on south façade;
- semi-external doors on east and west façade;
- very large window on the north façade.

It's possible to see in Figure 6 that inside the child-plays room there are very high daylight factors with about 10% as a average value.

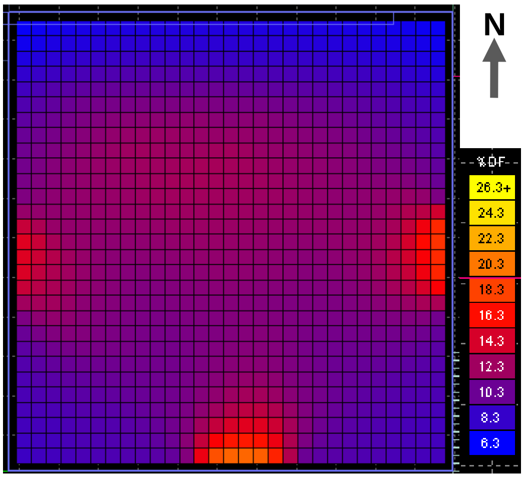

Fig 6. Daylight factor distribution in child-plays room (Sportive Centre)

2.3 Glare

The daylight study gives quite high results in all rooms of buildings performing a good energy savings, cutting a lot of electricity request for interior illuminating. Anyway, it is necessary to study glare exporting the model from ECOTECT to RADIANCE again for a comfortable visual performance. In this way we evaluated the internal surfaces luminance producing false colour renderings of the model knowing that they will inform us about light contrast within that space.

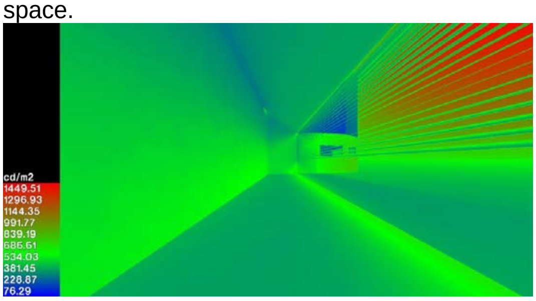

Fig 7. False colour image of greenhouse (Sportive Centre)

Once we obtained the false color image, we calculated the light contrast ratio by dividing the highest color number on that image by the lowest. We perform this study specially for greenhouse (Figure 7) and hall. The valid range for a comfortable light contrast we considered 1 to 20.

2.4 Shading design

The design of shading devices is an important part of many buildings. As anyone know from own personal experience, the most important characteristic of solar position is its seasonal variation. At the height of summer the sun rises much earlier and sets much later and in completely different positions than in winter.

The aim of good shading design is to utilise these characteristic to maximum advantage, typically to exclude as much solar radiation as possible in Summer whilst letting as much through as possible during winter.
The south façades of the Cultural and Sportive Centre are particular exposed to solar radiation during the period of air-conditioning, which was defined of March 21 to September 21. A study has determined the optimal solar configuration to control the solar gains. The normal angles of solar incident to the glazing were initially calculated in order to know the most critical periods to occult. Digital simulation using the ECOTECT software then enabled the determination of the optimal solar geometry [3,4]. A study of the critical angles of solar radiation from December to June was therefore performed, identifying a solar pergola for the greenhouse zone that needed to be avoided for solar gains. The shadows comparison is displayed between the winter solstice (Figure 8) and summer solstice (Figure 9).

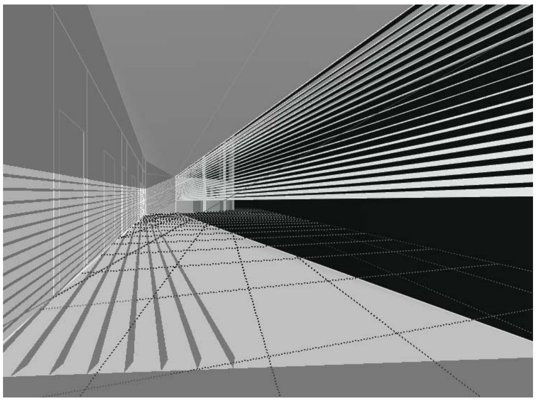

Fig 8. Shadows effect inside greenhouse (Winter solstice)

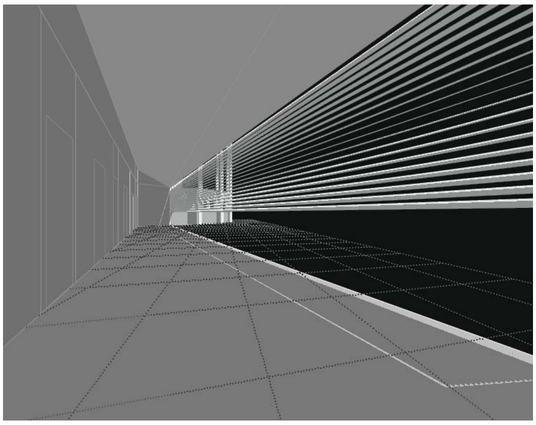

Fig 9. Shadows effect inside greenhouse (Summer solstice)

Another shading device was planned on the hall of the Cultural Center to cut off the solar gain away the hall. Using the sun-path diagram, we projected the shading on one object while interactively manipulating others in the model, making use of a shading mask like Figure 10 below.

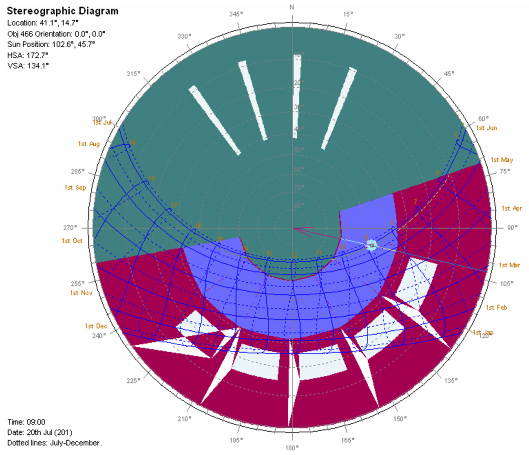

Fig 10. Shading mask of the hall

We can see on the horizontal plane of the hall the projection of the walls shadows (purple), the light penetration inside a small windows placed at the bottom of the walls (white hole) and the unobstructed area through which the direct solar radiation could affects inside the hall (blue) in function of solar position.
This last one happens above all the summer and usually around midday when the sun is higher.
As a result a grid of photovoltaic panels was apply as an external skin on the transparent surfaces. They are able to move vertically (Z axis) depending on the hours of a day and a monthly of a year. In this way we can block a direct solar radiation and store solar energy to electric use obscuring only a small portion of sky dome [5]. An example of a photovoltaic panels configuration is show in Figure 11 below.

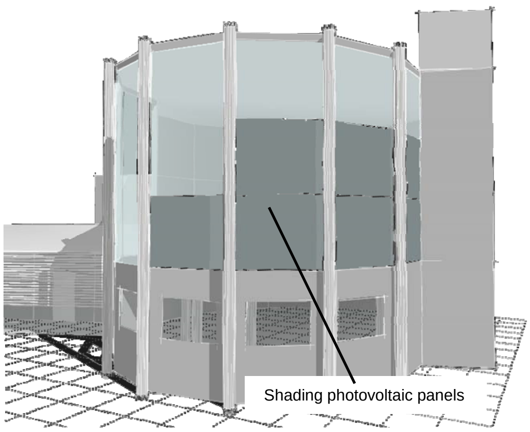

Fig 11. An example of a photovoltaic panels configuration (9am - 20th July)

Making in this way we obtained the multiple configuration wherewith we can shade the solar radiation during the whole year. Therefore a shading mask will correspond to each single configuration panels like in Figure 12 below.

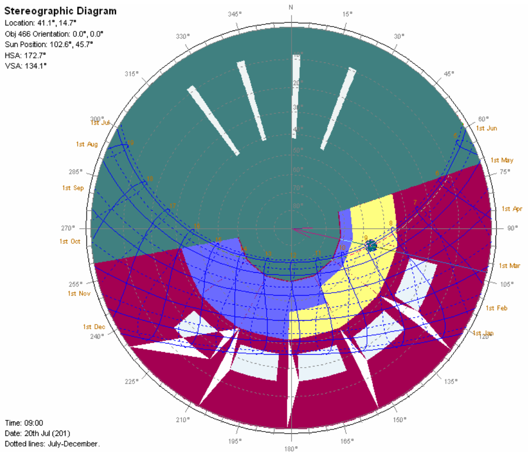

Fig 12. Corresponding shading mask of a photovoltaic panels configuration (9am - 20th July)

The yellow area represents the limited sky dome shaded of the single configuration panels as well as in Figure 11 above. This means that at 9am in 20th July we sideway shade the sun (through the yellow area) but in the other hand allow diffuse light penetration (through the blue area).

2.5 Daylighting model

In the coming months we will be able to evaluate the scale model under an artificial sky [6], It is a "mirror box" type, that was set-up for didactical purpose at the Built Environment Control Laboratory RiAS, at Architecture Faculty of Seconda Università di Napoli. The box is an aluminium cube of 3.0 m wide and 2.8 m in height with vertical walls covered by mirrors and ceiling arranged with diffuse opaline sheets and an assembly of 56 fluorescent lamps of 54 W each, with dimmerable ballast; each lamp (ballast) is tuned by a software for recalling light scenes, timer programs, single-circuit operation, On/Off and master dimming functions. An appropriate air conditioning plant avoids overheating that could occurs during lamps operation. The maximum illuminance range achievable on the work plane is up to 15000 lux, with good uniformity, for providing good internal measurement accuracy also for low daylight factor.

Wood was used for mock-up building and it results in a very robust model, but its weight grows rapidly [6]. After choosing the appropriate scale, the selection, the position of the sensors and the surface photometry of the scale model become a crucial point, which will be used to match the results with a computer simulation programmes: then several instruments will be employed for scale model experiments [7].

Fig 13. Daylight model inside the artificial sky (scale 1:30)

The illuminance measurements will be taken by miniature photometer cells made by PRC Krochmann Gmbh, furthermore the luminance distribution will be taken by the Techno Team LMK 98-3 colour CFA CCD videoluminancemeter.

3. Conclusions

Daylighting and solar shading should be integrated simultaneously, early in the design process. The case study presented in this paper identifies several issues that were tackled on daylighting and shading aspect throughout the design of the building. Simulations occurred at the various stages of the design, using basic rules of the thumb that were later tested with progressively more advanced simulation tools such as the artificial sky. A useful tools to solar shading optimization are the sun-path diagram and the shading mask and their implementation. In fact they offer a lot of information and insight to designers. Therefore they should be used within the building design process to optimise the use of shading and solar control glazings.

4. References

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