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NATURAL AND ARTIFICIAL LIGHTING IN ARCHITECTURE: ITALIAN CASE STUDIES

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Abstract
ABITA interuniversity research centre - University of Florence - is involved in several case studies at European level with focus on *daylight in buildings*.
The paper presents three Italian case studies with EU financial support focusing on visual comfort, daylight factor, daylight distribution, integration of artificial light; these are themes that focus on conscious and sustainable projects of architecture, giving answers to questions related to the possibility to design with light in architecture. The research gives the opportunity to design, to simulate and monitor daylighting in buildings and to reach interesting results minimizing artificial light for energy saving.
Case studies:
1. daylighting in New Meyer Children Hospital in Florence; the study has been done during the project of the building with simulation of the effect of installation of sun pipes.
2. daylight distribution in rooms with/without roof windows, in a simple model located in Rome; the case study is related to a residential family house with unutilised buffer zone that is converted in a room with vertical and roof windows.
3. daylight distribution in a historical building (1836): the Museo Bardini, Florence; the Museum was restructured with special attention to daylight, in order to avoid destructive effects on the organic materials that constitute the work of art

Each of them is presented with adopted methodology, aims and results.

Keywords: case studies, daylight, architecture, energy saving.

1. Meyer Children Hospital (Florence)

It has adopted few but efficient energy saving strategies with the EU financial support (Project HOSPITALS -Contract N: NNE5-2001-00295). Strategies adopted aim especially to the reduction of heating/cooling consumption and to the reduction of using artificial light with the installation of sun-pipes in corridors and roof-light in halls. Also, good insulation materials are adopted for most of the building structure.
The hospital is located in a outskirts of Florence, in an existing hospital complex area. It's distributed in three storeys, about 31.000 m² and has 150 beds. The site was chosen on the basis of being the most sheltered of various options, having good communications with existing hospital buildings to the north, and having excellent access and view to south.

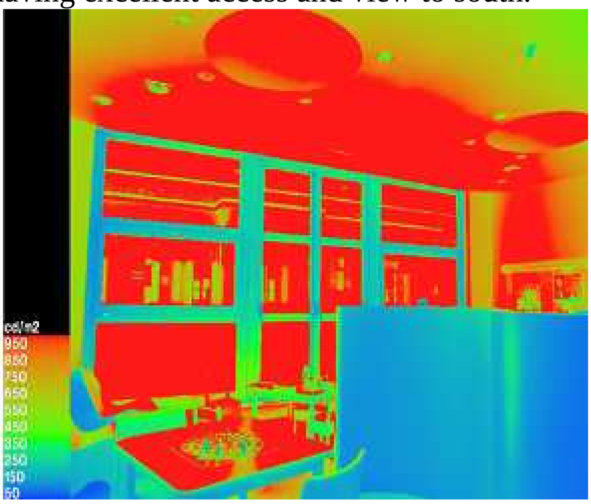


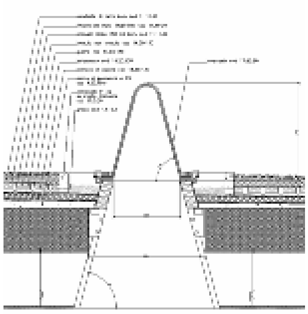
Image HDR: the image is the results elaborated by a software that reads pictures of the analysed space. Pictures are taken by a digital camera.

The architectural design has been focused on the detailed planning and design of the healthcare environment and, particularly, the

psychological effects of environment. This approach has been considered essential for neonatal intensive care environment and its subsequent effect on babies, their families and caretakers.
Special attention to interior rooms and surrounding view are achieved in order to obtain a better confinement period and to stimulate beneficial effects on patient's health.

Adopted methodology. Sun pipes and light ducts were suggested during the design phase to improve daylight in corridors and halls.
Simulations in Relux and Radiance were done to evaluate benefits of installations measuring daylight factor and illuminance level in corridors and hall. Also, during the design phase we have evaluated the contribution of solar pipes installed into corridors in front of patient's room window, to measure the daylight-benefit into patient rooms. The simulations were done in two models: with and without solar pipes and light duct (roof light).
Also we have simulated the difference due to bright or not colours in walls and floors, in patient rooms.

Results. Sun pipes are installed in corridors in front of patient room windows: they give a low contribution in terms of daylight factor in the rooms themselves (the benefit is evaluated in 0,65 % of DF into a patient room) but it was established by doctors that they should have a positive impact on patients in terms of psychological effects.
The use of sun-pipes allows switching off artificial light in corridors during the morning, throughout the year.
Despite simulations in relation to walls and floors colour, patient rooms have no light colours: the aim is realize the most comfortable paediatric patient room: drawings and brilliant colour of the room could help little patient to a faster recovery in hospital.
After the construction, measure on site of DF has been done: simulations and results gave very similar results.
Solar-tubes and roof-lights in corridors and halls give a good level of daylight. During an overcast day, we reach a DF of 2.95% in the principal corridors, 1,5% in the others without windows; this means that in several spaces during the morning it shouldn't be necessary to use artificial light.



Light ducts called "Cappelli di Pinocchio"

We have to specify that for the Daylight calculation it is necessary to consider an overcast sky but in the analysed climatic area there is a lower percentage of cloudy days than sunny days.
In fact we had to wait a few days to have the more appropriate climatic conditions for our monitoring activity.
The corridor's Average Daylight Factor is higher than the simulation's one (DF = 2.6 %) because in the simulation model we have built solar-tubes like simple glazed openings on the roof.
The transmittance property of the solar-tubes' internal coating determines higher illuminance values in the corridor. This led to a good level of energy saving for lighting system.
All installed lamps are high efficiency and the total annual electricity demand is 12.3 kWh/m2. Compared to the energy demand in which all these features are not applied, the energy saving is of about 35%.
Possible future replication of installation is certainly possible, and the large dissemination activity carried out and carried on is very

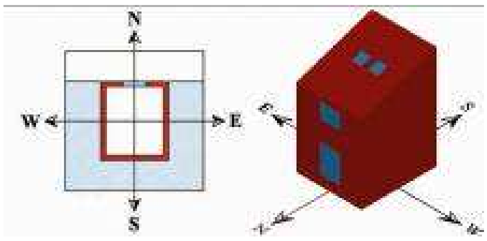
important if it is supported by energy saving value.
At an Italian level, the experience is very interesting and it is developing strong interest also at a politician level.

Conclusions. Performance base building is the concept of the experiment; end-users need to stay in comfortable rooms for a faster recovery, to alleviate their *staying-out-home*. Comfort is not only thermal, visual and indoor: it is living in a very nice, coloured, warm space, enjoying as much as possible their staying in hospital.

Sun pipes installed in corridors, in front of patient's room

2. The impact of different window configurations on the daylight conditions in simple rooms in Rome – in the period October to April.

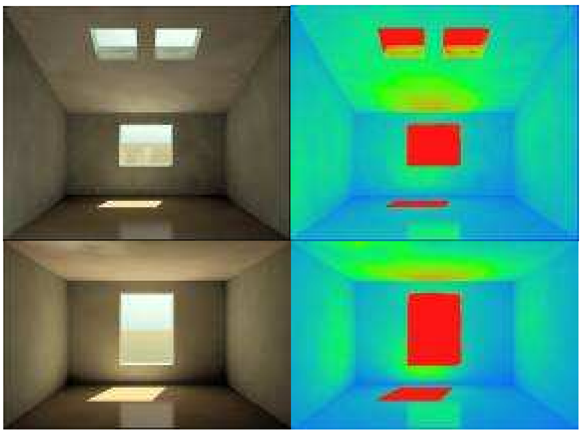
The case studied is related to a residential family house, which is a typical residential building in the South Mediterranean Sea. The house type is also representative for second home. It is a two-storey house that is assumed to be located in Rome.
The objective of this research was to compare the daylight conditions of two rooms with different window configurations.
The comparisons were done for several time of day and year, as well as different orientations. We did not consider the summer situations given the fact that it's a common practice in these regions to use shutters to block the light and solar radiation during daytime in this period.
A three dimensional model of the rooms has been elaborated with both rooms having the same floor area and the same total glass area. One room (lower room at ground floor) has a facade window only; and the other room (upper room at first floor) has a facade window and two roof windows. Both models have same windows area.
The simulations were performed using the Radiance Lighting Simulation System (Ward Larson & Shakespeare, 1998). A total of 52 simulations have been done, providing results in terms of daylight distribution, illuminance levels and daylight factor values. The simulation's output is presented using isolux contour render and a false colour scale showing the corresponding values.
This research project has been sponsored by VELUX A/S.



The model

Simulations were made to calculate the horizontal illuminance at a workplane height of 0.7m under known overcast sky condition. The simulation results show that, with the use of identical total glass area, the upper room window configuration produce higher DF levels on the workplane than the lower room window configuration. The upper room DF average is 3.85% and the lower room is 2.60%, this means a 48% increase in daylight availability for the room having using both facade and roof windows. According to CIBSE (1997), a minimal DF average of 2% is required for a space to be considered daylit, whereas values of 2-5% gives a predominantly

daylit space and 5% or more gives a strongly daylit space.
The simulation also shows that the lower room DF values change from very high to very low values over a limited area, whereas the upper room DF values range shows a less extreme distribution of values.
The following chart provides an overview of the daylight factor distribution in both rooms. The chart shows that the DF values in the lower room vary from 15% to 1%, and from 14% to 3% in the upper room.
The chart also shows that for the lower room, almost half of the DF values on the workplane are below 2%, whereas for the upper room, the DF values never drop below 3% and are mostly located between 4 and 6%.
It is not sufficient: with this study we arrived at the conclusion that it is often necessary daylight distribution during winter season to have good indoor daylight conditions, but also, as well as in case we use roof windows, we need to study the most appropriated shading devises to avoid overheating due to the introduction in the project of roof windows.
So that starting from the assumption that "daylight is good", we have simulated temperature and indoor thermal comfort during summer in 3 similar following models, with different shading in roof windows:

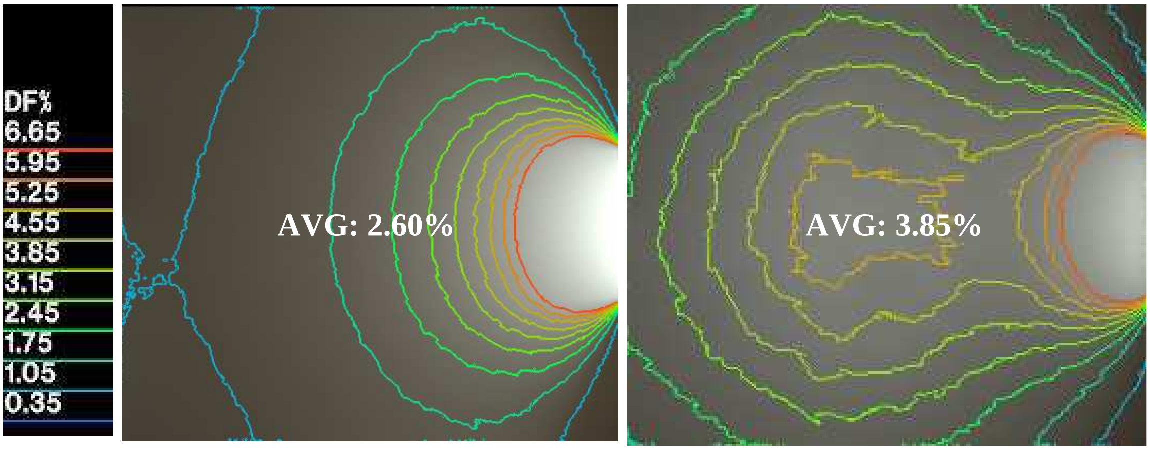


Front perspectives seen from the door at back end of the rooms, towards façade mimicking human vision + false colour - 21 March, 13:00, South, Sunny sky conditions

In this way, we verified that using buffer zones with vertical and roof windows, a better daylight distribution is reached during the period between October and April. Consequently: in a family house located in South Mediterranean area, when the designer needs to maximise daylighting in buildings, has he only to verify the daylight distribution?

Model a: comparison between two kitchens both at the upper room with different window configurations. One room has both a façade window and two roof windows and the other room has a facade window. Both rooms has same internal gains, floor area, windows area, ventilation strategy with occupant intervention, construction types (concrete/wood), insulation layers and 5% visual glass (double glass) during the daytime. Optical properties has been updated for roof windows with *external roller shutters in aluminium*.
Simulations are conducted in ESP-r tool.
Main findings: in the south orientation the hours with less than 10% PPD (Predicted Percentage of Dissatisfied) is significant higher for the room with roof windows.

Model b: comparison between upper and lower room with external solar screen on roof windows instead of roller shutters.
Both rooms has same internal gains, floor area, windows area, ventilation strategy with occupant intervention, construction types (concrete/wood), insulation layers and 5% visual glass (double glass) during the daytime. Optical properties has been updated for the external solar screen.
In roof windows, in order to consider a realistic air flow for the solar screen, during occupancy hours the bottom opening is whole opened (i.e. 5.5% of the glazing area), meanwhile the top opening is half opened (i.e. 50% of 5,5%).



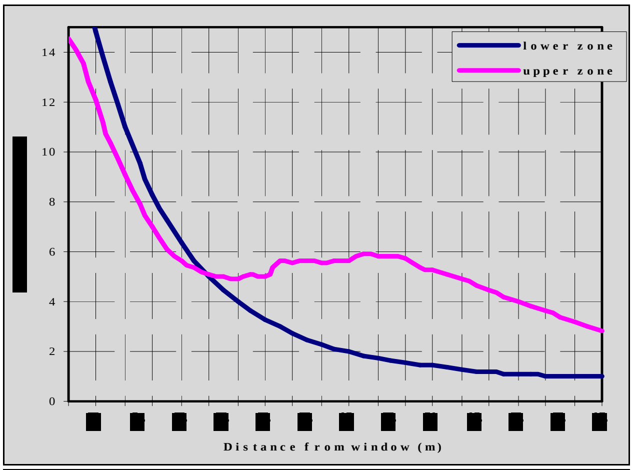
Lower room **Upper room**

IsoDFcontour lines + average value

Main findings:
- the upper rooms with the roof window with a external solar screen always have more hours with less than 10% PPD (Predicted Percentage of Dissatisfied) compared to lower room due to a better night cooling effect and due to a better ventilation during occupancy hours. This indicates a higher occupant satisfaction on the upper room with roof and façade windows.-In the south orientation the hours with less than 10% PPD (Predicted Percentage of Dissatisfied) is significant higher for the room with roof windows.

<u>Model c:</u> comparison between upper and lower room with roof windows with *sun protection glass* instead of shutters.
Both rooms has same internal gains, floor area, windows area, ventilation strategy V2 with occupant intervention, construction types (concrete/wood), insulation layers and 5% visual glass (roof window with sun protection glass and façade window with double glass) during the daytime as in the current study. Optical properties has been updated for the sun protection glass.
In roof windows, in order to consider a realistic air flow during occupancy hours the top and bottom opening is whole opened (both 5.5% of the glazing area).

Main findings:
-the upper rooms with the roof window with sun protection glass always have more hours with less than 10% PPD (Predicted Percentage of Dissatisfied) compared to lower room due to a better night cooling effect and due to a better ventilation during occupancy hours.
-in the south orientation the hours with less than 10% PPD (Predicted Percentage of Dissatisfied) is significant higher for the room with roof windows.



Daylight factor on workplane 0,7m above floor level along an axis perpendicular and centred about the façade window, overcast sky conditions.

<u>Conclusions</u>. In all models, roof windows guarantee a better daylighting distribution of light, during winter season. To avoid overheating during summer, shading devises strategies are applied in roof windows that guarantee better ventilation and consequently a better indoor comfort compared with the room without roof windows. Also, simulations show a very interesting results related to the application of sun protection glass instead of external

shutters and instead of external solar screen due to the overheating of the external roller shutter in aluminium

3. The Bardini Museum (Florence)

The light is radiant energy and as part of electromagnetic spectrum it produces destructive effects on the organic materials that constitute the work of art, as objects exposed in a Museum.

The study and the results of this case studied was supported by EU with the project MUSEUMS - Energy Efficiency and Sustainability in Retrofitted and New Museum Buildings (Contract NNE5-1999-2O).

Factors that regulate the deterioration times of a painting or any organic material are the followings:

- Spectral distribution of the radiation;
- exposition;
- duration of the exposition.

Simulations have been done in rooms that are considered interesting from the point of view of works exposed, and in days and hours with maximum and minimum insulation value with the aim to measure luminance and illuminance values.

Into studied cases with a high value in terms of natural light were introduced different screening systems, with the purpose to bring the illuminance values into limits specified by the normative.

In order to reduce the work of art's deterioration coming from the illumination, following conditions have to be verified:

-the bright source should contribute less possible the heat transmission to the exposed objects;

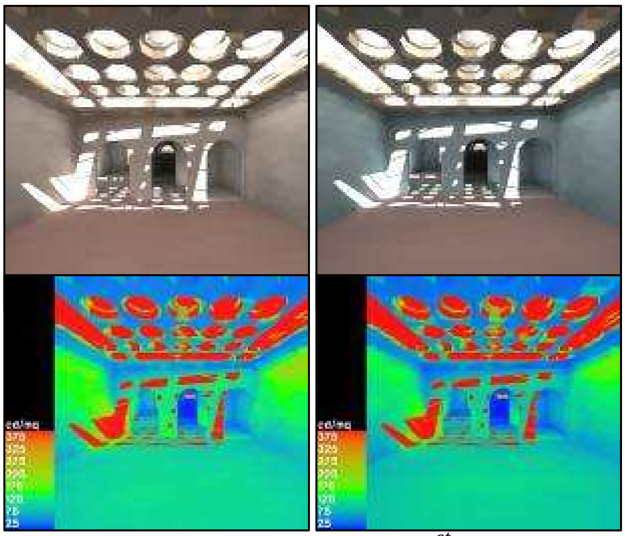
-all the ultraviolet radiations UVs should be stopped by special filters;

-the total exposure, in terms of lux per hour, should be less possible given that damages coming from the illumination are proportional to the sum of the illuminance values and its duration;

-daylight is potentially harmful, more than other types of artificial light; it should not strike directly the most sensitive materials and it has to be screened, filtered and checked, especially when it is of zenith type.

Abstract of UNI 10829, 1999 - Appendix A

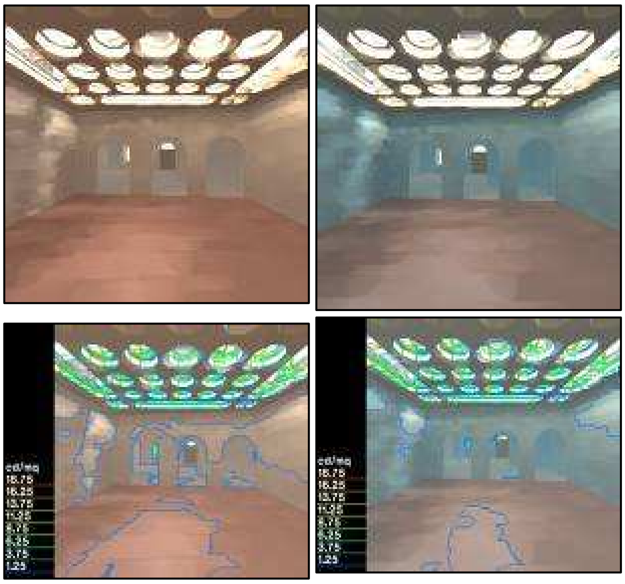
Goods of historical and artistic interest	E max
Woven, draperies, carpets, tapestries in cloth, tapestries, silk, customs, suits, religious hangings, material in natural fibre, sisal, jute	50
Sketches, water-colours, crayons and similar on papery support	50
Painted on cloth, paintings to oil on cloth and canvas, tempers	150 ÷ 200
Stones, rocks, mineral, meteorites	Not Relevant (NR)



Atrium: analysis in radiance 21st June, 10 am

<u>Atrium (work of art in stone)</u>. For work of art in stone there isn't a maximum value of illuminance and in this case a screened structure has not been designed and the evaluation of the luminance has been done. The actual state with walls dressed in a cream colour plaster, has a luminance value that is bigger compared to the colour used in the project. This means that in terms of visual comfort the actual state is better than the project.

During the winter season the ambient has a low luminance value and in this case the daylight has to be increased using artificial light, without particular prescriptions about the type of the source and with no a maximum illuminance value that has to be respected (just in this case in which the exposition is for stone material).



Atrium: analysis in radiance 21st December, 10 am

Atrium – work of art in stone	
Actual state	Project
• Cream colour plaster: ρ = 60% • N° 1 Skylight: - Safety glass climbed on the frame of the roof translucent glass climbed on “cassettonato” ceiling in wood with transmission coefficient of light of 70%	• Blue colour plaster: ρ = 35% • N° 1 Skylight: - Safety glass climbed on the frame of the roof diffuser in translucent polymer climbed on “cassettonato” ceiling in wood with a transmission coefficient of light of = 70% (model: ATENSIO-LUX - firm: DERK LUTH)

As far as it concerns the atrium and the ground floor, substantial changes have not been introduced since here the exposition is related to stone’s work and therefore there are not particular problems to the natural illumination. The only evident thing is that the luminance’s values are sensitively smaller compared to those of the actual state so that the use of a blue plaster colour reduces the luminance of around 18 ÷ 28 %. This is evident looking false pictures elaborated in RADIANCE and it implicates that, bringing the old and original colour, the environment results certainly less bright and therefore an integration of artificial illumination is necessary, as already discussed.
Clearly this contribution would be subsequently in demand in the winter period.

Sala dei quadri. This room is the most delicate to verify because it contains pictures in water-colour and carpets and it has been decided to limit the maximum value of the illuminance to 50 luxes. To get this results is necessary to decrease the entry of the solar light, over that clearly to filter it from UVs. In this case there are three images because two different solutions of project have been compared to the actual state:

Sala dei Quadri	
Actual state	Project
• Cream colour plaster: ρ = 60% • N° 1 windows in: - single glazing	• Blue colour plaster: ρ = 35% • N° 1 window composed as follow: **1st SOLUTION** - glass with a film to filter rays UV and coefficient of transmission of the visible light: τ= 19% (firm: SOLAR 2000) **2nd SOLUTION** single glazing with an external brise-soleil constituted by vertical elements directed according to the direction of the solar rays

- in the first one there is a glass with a fit film to reach this result;
- in the second a normal glass with a vertical brise-soleil climbed on to the outside of the window.

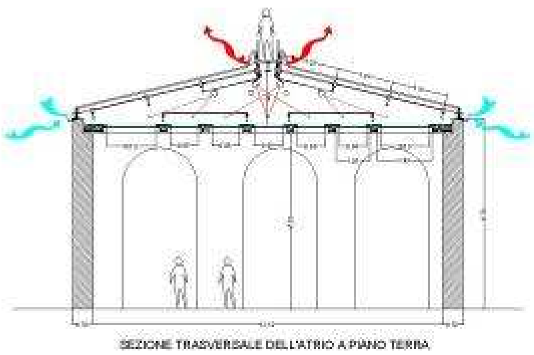
In reality the glass won't be never normal, but in this case we were looking for the effect introduced by the brise-soleil.
An enormous step can be noticed between the values of illuminance of the actual state and those of the two solution projects and like the two different screenings produce good results. Simulations show that the inside distribution of the solar light is made more uniform and limited by the glass film, rather than by the brise-soleil, however the brise-soleil allows a great versatility of control of the natural illumination compared to the glass film.
A negative, but inevitable effect, of the two screenings we have that, being the room very long, it is necessary introduce artificial light well filtered and calibrated.
Windows at the first floor have been screened heavily, especially in the Sala dei Quadri, to limit the penetration of the solar rays that in this case are particularly harmful for the exposed work of arts. Considering the calculation of the illuminance in the Sala del Terrazzo on 21st of June at 2 pm, the adoption of the new system of screening reduces the illuminance value of about 60 ÷ 70 %.

Into Sala dei Quadri are used two different screenings systems. Considering the simulation of the 21st of June at 10 am, the different effect of the two solutions adopted in the project can be noticed. Images give a light variation of colours between the simulation with the glass film and that with the brise-soleil owed to the reflection of the bright rays on the white foils of this last that is translates in a coldest environment, in terms of colour temperature.

As far as it concerns the inside distribution of the illuminance, it is noticed like the glass-film is able to control better and to spread in a more uniform manner the bright radiation without penalizing the adjacent walls to that one with window, while the brise-soleil, because of the multiple reflections, distributes the light not in a uniform manner penalizing the opposite wall to that is screened. How positive effect the greatest flexibility of bright regulation of the brise-soleil can be affirmed, in comparison to the glass film, thanks to the possibility to change the orientation of its foils and therefore to allow a great penetration of the natural light in the darkest periods of the year.
The reduction of the illuminance (comparing the actual state and those of project) is around 90 ÷ 94 %, in the case of the glass-film, and of 72 ÷ 82 % using the brise-soleil.
Conclusions. The Bardini Museum in Florence suffered from poor artificial lighting and a low transmittance rooflight structure with poor daylight control. For the artificial lighting, a variety of tungsten and poor efficacy fluorescent lamps with low utilisation fittings are being replaced with modern, high efficacy improved colour-rendering fluorescent with high reflectance, low brightness (low glare), high utilisation fittings.
The original glass superstructure of the rooflight had poor solar control and is being replaced by 30mm twin-walled polycarbonate of improved transmittance.
A wooden / glazed ceiling exists below the present superstructure. The bullet-proof glass is to be replaced by high-grade diffusing plastic, creating a more even illumination.
Simulations with RADIANCE have been carried out in order to compare the reflection coefficient of the original blue colour (0.35), which is intended for replication in the new museum rooms, with that of the cream colour (0.6) of the existing plastered walls.


Sala dei quadri: simulations in radiance, 21st June, 10 am

Internal view of atrium: the original roof "a cassettoni"



Section of the atrium: the new rooflight has also openings to control the evacuation of exhausted air.

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