C Conference and 28th AIVC Conference

Building Low Energy
g and Advanced Ventilation
ologies in the 21st Century

27-29 September 2007, Crete island, Greec

BOOK OF PROCEEDING
Volume

Table of Contents

Passive solar energy management strategies in shopping centres

L. Jesus, M. Almeida
University of Minho, Portugal

A. Almeida
Chamartín Real State, Portugal

ABSTRACT

The objective of this work is to demonstrate through a case study of a Shopping Centre in Portugal how daylighting and Passive Solar Strategies can be efficient in this kind of buildings, always characterized by large transparent areas and, in consequence, with enormous heat gains that cause overheating problems, especially in summer. Different strategies will be showed applied to a real case. The Shopping Centre in analysis has considered, since the first phase of the design process, natural ventilation, daylighting and others efficient strategies. The efficiency of the actions applied into the building also contributed for the accomplishment of the very recent national law (RSECE - Decree-Law 79/2006) that emerged from the recent implementation of the EPBD (Energy Performance Building Directive) in Portugal.
In conclusion, this paper shows that it is possible to achieve a balance between the Shopping Centre concept (defined as an attractive space, comfortable, transparent, pleasant, bright, which are factors that promote the selling) and the low energy consumption concern.

1. INTRODUCTION

The shopping centres tend to produce a strong impact on the "triple bottom line" factors (Environmental, Economical and Social). Since the eighties, a rapid growth of shopping centres has been observed in Portugal, and this new reality has been responsible for significant changes. These changes have been responsible for a significant impact in the use of resources, such as energy, the central theme of this discussion. This study focused on energy consumption components linked to lighting and cooling as they account for, on average, 80% of the total energy consumption in shopping centres. (Internal Reports of the company, 2006)
Taking into consideration this fact, some passive strategies to minimize demands on these component costs will be reviewed. The referred strategies were applied in a real case - study of a shopping centre in Portugal. This shopping centre, the product of a brand concept, "Dolce Vita", and named "Dolce Vita Porto" (DVP) is an important project belonging to Chamartín SGPS, SA (International Real State Company). This shopping centre is located in the city of Porto and won an international award (The *ICSC - best European Shopping centre in 2007, in its category)*.The DVP was inaugurated in 2005 with a GLA – (Gross Leasable Area) of 37.818m²
and it consists of four floors, car parking, lecture spaces, supermarket, stores, cinemas and others.
Therefore, this study will focus on passive strategies for lighting and cooling in shopping centres to demonstrate how these passive measures can help promoters achieve better energy efficiency as specified in the objectives of the new legislation for buildings (EPBD - Energy Performance Building Directive). Thereby, this study will be structured with basis on the following methodology:
1st – Concept of passive measures (daylighting and cooling strategies);
2nd - Measures applied on the case study (DVP);
3rd - Finally, it will be presented a table summary with passive measures (applied and not applied on DVP), which are a decisive contribution for the accomplishment of the EPBD- Energy Performance Building Directive.

2. PASSIVE STRATEGIES - CONCEPTS

2.1 Daylighting

The Daylighting concept is related to the use of passive solar measures for lighting, to take advantages of the available sunlight instead of using electrical sources, which are more expensive and environmentally unfriendly. The advantages of the daylighting concept in shopping centres can be demonstrated considering the optimal relation between lighting demand at "peak hours" period (from 14:00 to 17:00) and the larger period of solar radiation.
The Daylighting measures and the management of lighting systems are very important for energy efficiency in shopping centres. As indoor lighting is responsible for about 30% of the energy demand, this measure can decrease more than 2/3 of a mall's lighting needs (Enermodal Engineering, 2002).
Therefore, it is possible to evidence economical and environmental advantages that can be obtained through

the use of "daylighting" measures. Just as mentioned, the decrease of artificial lighting needs and its thermal loads cause a consequent reduction in $C0_2$ emissions.
In the meanwhile, other advantages relating to human comfort and consequent client satisfaction, generates an increase in sales productivity. According to the results obtained in several studies, shops which used daylighting measures had higher benefits (an average of 40% increase in sales) compared to shops without daylighting (EBN, 1999). This factor provides evidence on how natural lighting influences people's behaviour, as alterations in moods (state of mind) are directly associated with the lighting level. An example of this is how people react during the different seasons (winter and summer). The phenomenon is known as "Seasonal Affective Disorder" (SAD). It is the reduction in the secretion of a hormone known as "Melatonin" and is recognized by its symptoms of fatigue, depression and insomnia (Rusak et al, 1995).

2.2 The cooling Strategies for the Shopping Centre

As well as the lighting, the cooling process consumes quite a large amount of energy in a shopping centre.
This fact is due to indoor heat gains (generated by the visitors, lighting and equipment) in enclosed acclimatized spaces.
As mentioned, shopping centres dating from the mid-twentieth century are defined as "acclimatized" spaces, where all areas are cooled or conditioned by mechanical systems. This mentality has been maintained since the seventies, reflecting the expansion in the marketplace of air conditioning. However, after the eighties due to the fuel crisis, the signing of the Kyoto Protocol and the subsequent European environmental policy, this concept is being changed.
Today, it is impossible to think about buildings without integrating passive measures or "hybrid systems" that reduces the dependence on HVAC systems.
In addition to the advantages associated to the reduction of initial and operational costs, the passive cooling systems tend to increase indoor air quality and productivity, as well as decrease diseases if compared to mechanical systems. Due to these benefits, these new systems are being applied more and more to Shopping Centres. As such, the advantages of natural ventilation and other passive cooling strategies will be demonstrated, as well as the use of efficient cooling strategies.

3. CASE STUDY - APLICATION

Since the DVP` s design phase, one of the main concerns of the project team was on how to optimise daylighting and cooling strategies in the mall area with the aim of reducing energy consumption.
Therefore, before the application of passive measures, it was necessary to consider the site's climatic characteristics, orientation and building shape, coating materials to be used as well as the heat loads from equipment, occupants and lighting. Heat gains are extremely high in Shopping Centres and, in some cases, depending on geographical location; the use of heating systems in winter is inexistent.
The case study is situated in a climate area I2-V1 (defined by RCCTE - Decree-Law nº 80/2006 -The Thermal Regulation for Building) with strong maritime influences making winter more harsh than summer. As such, as a first thought, it would be advisable to use solar energy in heating seasons which is, however, strongly not recommended for shopping centres due to the high heat gains observable in this kind of buildings, as previously mentioned.
About daylighting, the DVP had the perfect conditions to support the implementation of important measures as the area totalled 13.000 m² with a ceiling height of 24 meters and it had two large atriums opened to the shopping area facing the south facade.
So, some of the measures applied on DVP were the following:

- Maximization of southern exposure and glazing properties;
- Implementation of toplighting methods;
- Atrium use;
- Prevention measures and solar protection;
- Use of night ventilation in summer;
- Use of evaporative cooling strategies.

The measures above mentioned will be exemplified:
- *Maximization of southern exposure and glazing properties*. The DVP benefits from large southern openings and minimal openings on the other exposures. To avoid overheating resulting from the overexposure to sunlight, a triple glass with the following characteristics was selected. This can be compared to the common double glass (see table2).

Table1: Glazing System

Glazing system (Clear glass)	Solar Factor	U-Value (W/m²ºC)
Double glass (6+4+6) mm	0.75	3.3
Triple, low-e + argon	0.24	1.7

The graph below compares the two air cooling histograms (power needs for DVP cooling) in the summer season using the two different glass types (see figure 1 and 2).

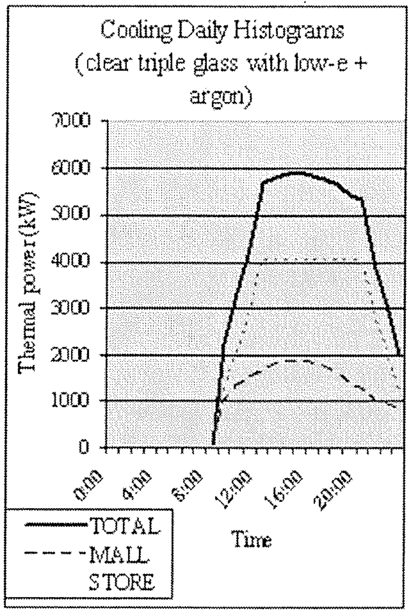

Figure1: Comparison among histograms (triple glass)

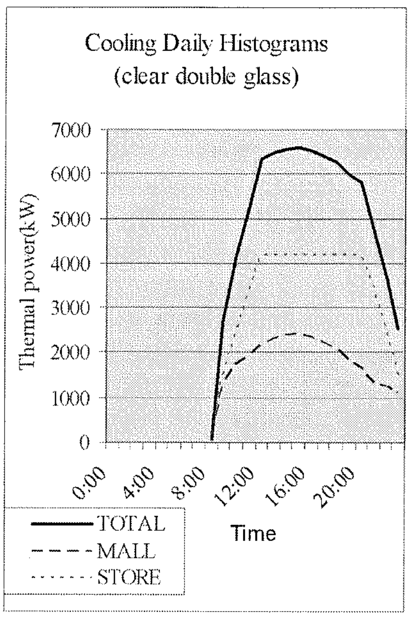

Figure 2: Comparison among histograms (double glass).

Theglazingselectioncancontributetothereductionofther-malloadandconsequentdecreaseofcoolingneeds,by30%.

- *Implementation of toplighting methods* - through this strategy, the DVP has reached high illumination levels with much more uniformity than using sidelighting. Despite these advantages, the overheating effect (mainly in summer), when the sun is high, could be extremely harmful to the increase of indoor temperatures. Therefore, skylights were inserted in strategic places, only in the atrium where, as mentioned, the ceiling height was superior to 10 meters, using triple e-low glass with the previously mentioned characteristics.

- *Atrium use* - with this strategy it was possible to obtain a better sunlight distribution among the indoor spaces of the Shopping Centre, especially for the shops and restaurants facing the atrium. This strategy has the same effect of facing exterior openings, albeit with an important difference, a decrease in thermal loads.

These measures obtained quite positive results in energy efficiency related to lighting. To prove such results it is possible to compare values from an energy audit carried out in another Shopping Centre belonging to the same company, known as Dolce Vita Douro (DVD). Similar construction methods were used in this shopping centre along with equivalent daylighting concepts. The audit concluded that the demand for lighting (except stores) was responsible for 27% of the total energy consumption (of that, 61% corresponded to the pedestrian area of the centre), evidencing that lighting costs would be quite higher without daylighting (Figure 3).

By optimizing the use of natural lighting (sunlight), in both DVP and DVD, it was sufficient to only use the of electrical lighting, on average, 7 hours per day (with the complete lighting system on), while the Portuguese average for shopping centres is 13 hours per day (See Figure 4) (RSECE, 2006).

For DVP, the difference in time consumption from 11.9 h (equivalent hours: 4,9 hours resulting from 10 am to 5 pm 70% ON, plus 7 hours 100% ON between 5 pm and 12 pm) to 13,5h (equivalent hours: 0,5 hours resulting from 11 pm to 12 pm 50% ON, plus 13 hours 100% ON between 10 am and 11 pm) would convey an increase of 13,5 % in lighting consumption per year.

Applying the 13,5% on the DVP, which had in 2006 a total energy consumption of 12.037.659 KWh (151Kwh/m²) and a lighting demand of 3.250.168 KWh, it would result in an equivalent increase of 436.997 KWh (5.48 Kwh/m²), €26.219 euros and 181Ton.in CO_2 emissions.

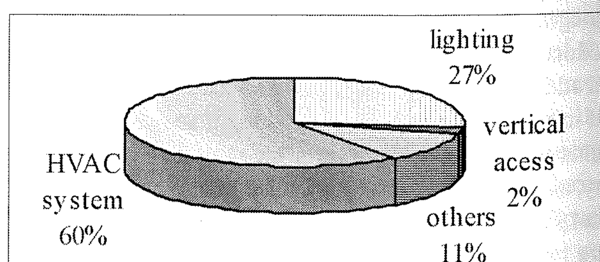

Figure 3: The total energy demand in the DVD.

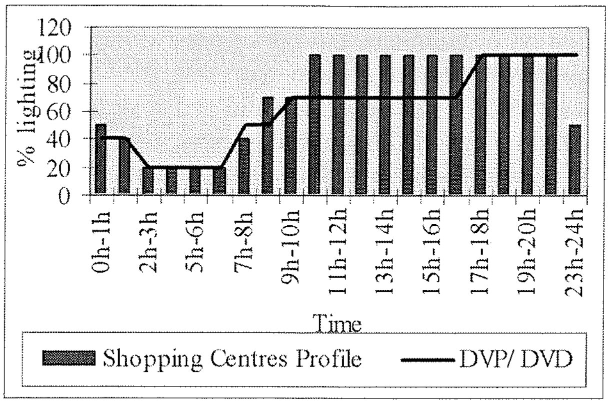

Figure 4: The lighting use per hour (in percentage)

- *Prevention measures and solar protection*: to comply with this requirement, in addition to low U-value and low solar factor for the windows (as previously mentioned), other measures were carried out such as the use of appropriate insulation (mainly in the covering where the high solar exposure is observed during the summer) and the use of clear colours in the building (with adequate reflection factors). A better insulation was also achieved in the shops, taking advantage of the existent technical corridors, placed between the stores and the external walls that are working as air chambers, thus helping to raise the thermal insulation level.
- *Use of night ventilation in summer* - this is advantageous in vacating periods and when the external temperature is lower than indoors. This fact is promoted through the existing difference between indoor and outdoor pressures that help the evacuation of the day heat load. This situation can be achieved either through a chimney effect, through the direct action of the wind or through the difference between temperatures (indoor and outdoor).
- *Evaporative cooling* - through the existence of a notable fountain in the atrium of the Shopping centre, it is possible to decrease the indoor temperature taking advantage of the evaporative process. This procedure allows a decrease of at least 1°C, inside the space, proven through local temperature measurements.

Due to its typology, the DVP was able to only use a few passive solar measures but in compensation used efficient strategies to reduce energy consumption such as:
- Use of centralized technical management systems and procedures, with which higher HVAC performances are achieved, namely through scheduled operations, definition of adequate set-points of temperature, and setting of other equipment.
- Use of electronic ballasts and occupancy sensors to better control and economize on artificial lighting.
- Air treatment unit with insufflation and extraction fans with variable speeds, depending on the interior thermal needs.
- Escalators with variable frequency to adjust the rotation speed.
- Use of thermal energy storage, known as ice banks. The ice banks do not actually provide a saving on electric power but the displacement of the search. While the chillers, generate cold for immediate and momentary needs, the ice bank stores cold to be (during off-peak time hours) used during peak periods (more expensive).

4. THE IMPORTANCE OF PASSIVE AND EFFECTIVE MEASURES FOR EPBD

Ever since the new EU directive (EPBD) was established, member countries have assumed a commitment to define new legislation related to construction quality, with the objective of increasing energy efficiency, indoor air quality and reducing $C0_2$ emissions.

In Portugal two existing regulations were adapted and redefined so that implementation would allow for strict inspections by official institutions to assure their fulfilment. On June 2006 three new Decrees-Laws (78, 79 and 80/2006) were published determining strong changes in the construction sector. Nonetheless only law 78/2006 (SCE- Building Certification system) and 79/2006 (RSECE – The regulation for buildings with installed HVAC systems) will directly affect new and existing shopping centres.

As can be observed, the design of this building (DVP) was carried out prior to the new legislation (79/2006). Consequently, the implementation of passive strategies in the DVP represent a set of voluntary measures to reduce energy demand and to decrease the HVAC (Heating, Ventilation and Air Conditioning) dependency in the operational phase. These measures are now fundamental to accomplish the mandatory character of this new legislation. As such, this study presents a set of successfully applied measures in a shopping centre which contributes to the achievement of the very new and much more demanding objectives of this recent legislation. According to EPBD objectives, a table is now being presented summarising the passive measures that were implemented in DVP to comply with the new legislation and also some other measures that, although not implemented in this case, could serve as an important reference for future shopping centres.

Some passive and efficient measures advised for Existing Shopping Centre in the I2-V2 climate area

Daylighting	
Passive	Applied into DVP
- Maximization of southern exposure and glazing properties	X
- Establishment of lighting levels considering the occupant needs.	X
- Use of toplighting strategies.	X

- Verification of the shape of the building considering the daylighting and thermal control.	X
- For indoor space, selection of light coloured surface materials and ideal ceiling heights (minimum 6 meters), to increase reflection index and thermal comfort.	X
- Consider exterior shading techniques for solar control (mainly movable shading), based on glazing height and latitude.	
Daylighting	
Efficient measures	
- Use of Sun Tunnels and solar hybrid systems.	
- Choice of efficient low consuming lamps.	
- Use of Leds, which consume 12% less energy than a normal lamp, with a life expectation of 80 years.	
- The reduction of energy demand through the control of the electric lighting system in response to daylighting.	
- Lighting management establishing timetables for each zone.	X
- Adjust efficient lighting (Lumens/W) and lamps to optimize the optical control (maintaining desire illumination levels on the required space)	X
- Use of electronic ballasts and occupancy sensors to better control and save effective lighting costs.	X
Passive cooling measures	
- Prevention measures and solar protection through appropriated insulation and building shape.	X
- Use of night ventilation in summer.	X
- Evaporative cooling	X
- Ground cooling (direct and indirect contact).	
- Associate similar activities to obtain larger advantages in building orientation and storage of similar cooling needs.	
- Use of technical areas as air chambers	X
- Reduce the paved areas to decrease the heat storage around the building;	
- Consider the use of green roofs to increase thermal insulation;	
Active/ efficient measures	
- Use of renewable energies, such as the solar thermal systems (thermal energy) and photovoltaic modules (electrical energy). The solar photovoltaic energy can be more cost effectiveness through BIPV (Building Integrated Photovoltaic).	
-Use of centralized technical management;	X
-Use of thermal energy storage, known as ice bank;	X
-Use of Cogeneration / Tri generation -Cogeneration saves 15 to 30% through combined heat (thermal) and power (elect.) production, reducing costs in 40%. Tri generation means combined production of power, heat and cold.	
-Selection of high efficiency equipments, operating on a bi-modal function (for total or partial loads).	X

5. CONCLUSION

This study shows the advantages of daylighting and passive solar measures, which are very important and necessary to the present reality related with the objectives of EU Directive for energy efficiency and reductions of $C0_2$ emissions in buildings.

The passive solar measures carry a set of essential procedures to promote sustainable buildings, as they will determine the level of difficulty that a building may have to achieve the new European directive targets. Thus, to reduce the dependence on HVAC and the energy consumption in buildings, the use of passive measures in projects will be needed more than ever.

These passive strategies are valid and may be implemented on any building typologies or in any country. The most important aspect is to consolidate a set of actions that will define a new concept of Shopping Centres in the twenty-first century where environmental responsibility and triple bottom line management are crucial for their success.

ACKNOWLEDGEMENT

The authors would like to thank to FCT- Fundação para a Ciência e a Tecnologia, for grant given to the first author of this paper.

REFERENCES

Enermodal Engineering Lda (2002). Daylinghting guide for Canadian Commercial Building. Ottawa.

Environmental Building News (1998) "Daylingting: Energy and Productivity Benefits", Volume 8, Nº 9. USA

EPBD-Energy Performance Building Directive (2003). Directive 2002/91/CE of the European Parliament and Council from 16 of December 2002. Official Journal of the European Communities.

Gonçalves, Hélder and Graça, João (2004). Conceitos bioclimáticos para os edifícios em Portugal. Lisboa: DGE.

International Council of Shopping Centre (ICSC) (1999). ICSC Shopping Centre Definitions. New York: ICSC.

A. Ramalhão (2006) Auditoria energética do DVD. Porto.

Osso, Annette et. Al. (Public Technology) (1996). Sustainable Building Technical Manual, USA.

RCCTE – Decree-Law nº 80/2006 (2006) The Thermal Regulations for Building. Portugal

RSECE – Decree-Law nº 79/2006 (2006). The regulation for buildings with installed HVAC systems. Portugal

SCE – Decree-Law nº 78/2006 (2006). Building Certification system. Portugal.

Rusak, B. et. al. (1997).Lighting and Human Health: A review of the literature. Ottawa.