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BOOK OF PROCEEDINGS
Volume

Table of Contents

Foreword	xv
Organization	xvi
Technical Papers	
1. The use of phase change material (PCM) to improve the coefficient of performance of a chiller for meeting domestic cooling in Wales <i>F. Agyenim, M. Rhodes, I. Knight</i>	1
2. Global cooling: effect of urban albedo on global temperature <i>H. Akbari, S. Menon, A. Rosenfeld</i>	6
3. Status of cool roof standards in the United States <i>H. Akbari, R. Levinson</i>	12
4. Passive natural cooling techniques for wooden buildings in warm climate: case study <i>R. Albatici, F. Iannone, A. Savorelli</i>	16
5. The impact of different window configurations, natural ventilation and solar shading strategies on the indoor comfort level in simple rooms, in Mediterranean area <i>G. Alcamo, S. Murgia, M. Sala</i>	22
6. The local microclimate effects on bio-climatically investigative process in Iraq <i>A. Al-musaed, A. Almsad, Z. Khalil</i>	16
7. Saleable passive house. Marketing activities in the context of passive sustainable principles <i>A. Al-musaed, Z. Khalil</i>	30
8. Evaporative cooling process adaptive for Baghdad city climate <i>A. Al-musaed</i>	35
9. Shading effects upon cooling house strategy in Iraq <i>A. Al-musaed, A. Almssad, Sh. Harith, M. Nathir, M Ameer</i>	40
10. Heat island effects upon the human life on the city of Basrah <i>A. Amjad, A. Asaad, Z. Khalil</i>	45
11. The potential application of residential solar thermal cooling in the UK and the role of thermal energy storage technologies <i>E. Ampatzi, I. Knight</i>	48
12. Thermal comfort under transient seasonal conditions of a bioclimatic building in Greece <i>A. Androutsopoulos, G. Kotsiris</i>	54
13. The exergy approach for the evaluation of heating and cooling technologies; first results comparing steady state and dynamic simulations <i>A. Angelotti, P. Caputo</i>	59
14. The evaluation of thermal comfort conditions in simplified urban spaces: the COMFA+ model <i>A. Angelotti, V. Dessi, G. Scudo</i>	65
15. Ventilation strategies as a solution in rural areas houses in hot climates <i>S. Arias</i>	70
16. Parametric study on the dynamic heat storage capacity of building elements <i>N. Artmann, H. Manz, P. Heiselberg</i>	75
17. On the indoor air quality problem in residential areas: the Athens case <i>M.N. Assimakopoulos, A. Sfakianaki, P. Doukas, M. Santamouris, A. Fourtounas</i>	80
18. Numerical investigation of indoor environmental conditions in an office <i>V.D. Assimakopoulos, O.I. Stathopoulou, C.Halios, C.G.Helmis</i>	85
19. Design and control of building-integrated solar energy utilization systems - achieving net-zero building energy consumption in Canada <i>A.K. Athienitis</i>	90
20. Study of energy savings strategies in rural houses of hot climates in Mexico <i>D.C. Avila</i>	97

21. Computational investigation of the performance of window blinds <i>K. Axarli, C. Vaitzi</i>	102
22. A Green building for the roaring forties <i>A. Barbour, G. Marriage</i>	106
23. Influence of vents type arrangement on greenhouse thermal driven ventilation <i>T. Bartzanas, C. Kittas, N. Tadj, B. Draoui</i>	111
24. TRNDB: a web database and web site for storage and process of building energy analysis data <i>G. Baryannis, G. Stavrakakis, T. Nikolaou, D. Kolokotsa</i>	116
25. Optimal orientation for housing with low energy profile in a semi arid climate <i>S. Bellara, S. Abdou</i>	121
26. Interpreting building simulation modelling data for building designers, with specific reference to the cooling demand <i>C. Bleil de Souza, I. P. Knight</i>	126
27. Dynamic analysis methods and modelling. Application to energy performance assessment <i>J.J. Bloem</i>	132
28. The energy performance of glazed office buildings with double skin facades – BESTFACADE <i>A. Blomsterberg</i>	137
29. Application of new design of wind tower configuration to existing building for passive cooling <i>Y. Bouchahm, A. Djouima</i>	142
30. Integrated design optimization of school pavilions – a case study in Milan <i>G.L. Brunetti</i>	147
31. Very low energy buildings: analyse of two case studies in France <i>V. Bulteau, R. Cantin, G. Guarracino</i>	152
32. Sensitivity analysis of the EPBD, Energy Performance Grading of Buildings <i>K. Burke, P. Kenny, D. Finn</i>	157
33. Feasibility study for renewable and low-energy applications in urban building sector <i>F. Butera, S. Ferrari, R.S. Adhikari, P. Caputo</i>	162
34. Evaluation of design strategies for improving summer comfort conditions in a low-energy residential building <i>F. Butera, R.S. Adhikari, M. Butera</i>	167
35. Building-integrated greenhouse systems for low energy cooling <i>T. Caplow, J. Nelkin</i>	172
36. Evaluation and evolution of the ecourse ecology in architectural design <i>P. Caputo, A. Roscetti, I. Rega</i>	177
37. Study on the cooling ceiling's effect on thermal comfort and energy consumption in an office space for different climates in Europe <i>T. Catalina, J. Virgone</i>	182
38. Insulation as criteria for the energy behaviour of the building stock <i>S. Chadiarakou, M Santamouris</i>	186
39. The impact of moisture on the thermal conductivity value of stone wool based insulating materials <i>S. Chadiarakou, A.M. Papadopoulos, A. Karamanos, D. Aravantinos</i>	190
40. Passive cooling of a wood frame house <i>P. Charvat, M, Jicha, J. Stetina</i>	195
41. CO2 emission and energy saving potential through correct pipe insulation in cold applications <i>J. Chmielarski</i>	199
42. Performance of the raised floor heating system with natural ventilation <i>D. W. Cho, J. Y. Yu, K. H. Yu</i>	203
43. Development and characterization of semitransparent double skin PV facades with heat recovering <i>J. Cipriano, G. Houzeaux, D. Pérez</i>	209
44. Monitoring and modelling the energy efficiency of municipal public buildings-case study in Catalonia <i>X. Cipriano, J. Carbonell</i>	214

45. Energy and carbon performance of housing: upgrade analysis, energy labelling and national policy development	219
<i>J. A. Clarke, C. M. Johnstone, J. M. Kim, P. G. Tuohy</i>	
46. Building low energy cooling and advanced ventilation in cooperative housing	225
<i>J. P. T. Coimbra</i>	
47. A Methodology to study the urban distribution of air temperature in fixed points	227
<i>A. Costa, L. Labaki, V. Araújo</i>	
48. An adaptable urban house designed for the southern Brazilian climate	231
<i>M. Costella</i>	
49. A Study on the energy efficiency of libraries of the west and Tejo Valley region in Portugal	237
<i>F. Craveiro, B. Oliveira, V. Leal, E. O. Fernandes</i>	
50. Building AdVent: aiming to help spread best practice in ventilation	242
<i>A. Cripps</i>	
51. Radiant cooling and ventilation strategies in low energy buildings	244
<i>S. Croce, L.P. Gattoni, R. Arlunno, G. Pansa</i>	
52. Relation between ventilation and the learning skills of pupils in classrooms	253
<i>W. de Gids</i>	
53. A comparison between energy performance of one DSF buildings studied sample and office buildings benchmarks in Europe	258
<i>M. de Matos, R. Duarte</i>	
54. Teaching for integration of building energy simulation in the design process	261
<i>S. Delbin, V. Gomes da Silva, D. Kowaltowski</i>	
55. To restate traditional sustainable solution, Iranian traditional natural ventilation	266
<i>N. Deldar, M. Tahsildoost</i>	
56. Simulation of a large scale ground source heat pump with natural cooling	270
<i>J. Desmedt, H. Hoes</i>	
57. Monitoring results of aquifer thermal energy storage system in a Belgian hospital	270
<i>J. Desmedt, H. Hoes</i>	
58. Building energy management systems in building's retrofit using power lines	274
<i>S. Dolianitis, D. Kolokotsa, N. Kalitsounakis, N. Zografakis</i>	
59. The impact of colored glazing and spectral response of photosensors in the estimation of daylighting energy savings	279
<i>L. Doulos, A. Tsangrassoulis, F. Topalis</i>	
60. Computational analysis of indoor air circulation and heat transfer in a house ventilated by wind-catch	284
<i>P. R. Drach, F. J. Karam</i>	
61. Potential of geothermal heat exchangers for office building climatisation	289
<i>U. Eicker, J. Schumacher, C. Vorschulze, D. Pietruschka</i>	
62. The impact of building envelope design on thermal performance of office buildings in Egypt	293
<i>A. Eisa, A. Pitts</i>	
63. Enhancement of cross-ventilation of a detached house using roof surfaces in densely populated urban areas Part1 Wind pressure distribution by wind tunnel experiment	298
<i>T. Endo, T. Kurabuchi, T. Nonaka, Y. Kadowaki, M. Ohba, T. Goto</i>	
64. The spatial variability of air temperature in the urban canopy layer	304
<i>E. Erell, T. Williamson</i>	
65. A simple calculation method for the energy performance of double skin facades	309
<i>H. Erhorn, H. Erhorn-Kluttig, H. Sinnesbichler, S. Wössner, N. Weiss</i>	
66. Experiences from the first German EPBD implementations:	314
- Field tests for residential and non-residential buildings	
- Certificates for well-known national and international buildings	
<i>H. Erhorn-Kluttig, H. Erhorn, K. Höttges, J. Kaiser</i>	
67. DIN V 18599: The German holistic energy performance calculation method for the implementation of the EPBD	319
<i>H. Erhorn, J. de Boer, S. Wössner, K. Höttges, H. Erhorn-Kluttig</i>	

68. Ecobuildings: Towards an energy-efficient European building stock beyond national requirements	322
<i>H. Erhorn-Kluttig, H. Erhorn</i>	
69. Best practice for double skin facades - The BEST FACADE project	327
<i>I. Farrou, M. Santamouris, S. Zerefos, R. Heimrath, H.Engsberger, T. Mach, W. Streicher, R. Waldner, G. Flamant, X. Loncour, S. Prius, G. Guarracino, H. Erhorn, H. Erhorn-Kluttig, R. Duarte, M. M. Matos, Å. Blomsterberg, L. Sjöberg</i>	
70. 'Designer village', low energy dwellings - The DEMOHOUSE project	332
<i>I. Farrou, M. Santamouris, K. Pavlou, K. Sfakianaki, H. Petroulopoulou, G. Lykouriotis</i>	
71. Retrofitting of the General Secretariat Information Systems	336
<i>I. Farrou, M. Santamouris, Y.Zervas, K. Zachakis, C. Toumbexis, P. Tzamalís</i>	
72. Passive cooling in Évora's traditional architecture	341
<i>J. Fernandes, J. Correia da Silva</i>	
73. Building envelope and heat capacity: re-discovering the thermal mass for winter energy saving	346
<i>S. Ferrari</i>	
74. "The environmental and ecological semeiology in architecture"	352
<i>N. Fintikakis</i>	
75. Out of the box – reinventing the industrial warehouse	353
<i>C. Fong</i>	
76. In situ measurement of window air tightness: stakes, feasibility, and first results	358
<i>M. Fournier, S. Berthault, R. Carrié</i>	
77. Comparative study of various CESI optimization criteria and proposition of a global evaluation approach	363
<i>G. Fraisse, Y. Bai, N. Le-Pierres, T. Letz</i>	
78. Methodology and results of construction company R&D department in energy efficiency in building	368
<i>I. Friedrich, A. Alonso Cepeda, D. Martinez, A. Gal</i>	
79. Solar shading and ventilation patterns: to what extent are they accurate to comfort expectations?	372
<i>C. Ganem Karlen, H. Coch Roura</i>	
80. Two energy efficient projects in Athens	376
<i>A. Gavalas</i>	
81. Energetic evaluation in real condition of use of housing	381
<i>E. Giancola, S. Soutullo, R. Olmeda, M^a. R. Heras</i>	
82. Energy efficient ventilation systems and components in sport facilities	384
<i>G. Giorgiantoni, D. Finizio</i>	
83. Natural Heater Project	389
<i>E. Grala da Cunha, N. Machado, L. Turella, L. de Negri</i>	
84. Lowehotels – low energy hotels in Southern Europe An EU – funded demonstration project	391
<i>L. Gramkow</i>	
85. Integrated energy design in public buildings EU intend	397
<i>L. Gramkow</i>	
86. Horizontal air-to-earth heat exchangers in Northern Italy: testing and application	401
<i>M. Grosso, L. Raimondo</i>	
87. Thermal effect of orientation differentiations in a university building in Izmir, Turkey	406
<i>B. Güçyeter, B. Terim, Z. Durmuş Arsan</i>	
88. Thermal insulation of buildings and cooling demand	411
<i>C. Hamans</i>	
89. Modelling of indirect evaporative air coolers	416
<i>Gh. Heidarinejad, M. Bozorgmehr</i>	
90. Experimental and computational evaluation of the thermal performance of double skin Façades	421
<i>M. Hernández T, L. Shao</i>	
91. Compact fluorescent lightbulbs: an acceptability study	426
<i>C. Hobart, M. Wilson</i>	
92. Internal airflow sensitivity in a naturally ventilated atrium subject to variation in external wind conditions	431
<i>J. Horan, D. Finn</i>	

93. Daylight availability in an office interior due to various fenestration options 436
N. Ibrahim, A. Zain-Ahmed
94. Exergetic evaluation of high-temperature radiative cooling combined with natural ventilation 441
T. Iwamatsu, Y. Hoshino, E. Kataoka, M. Shukuya
95. The effect of natural ventilation on the indoor air quality in classroom of the elementary school 446
without heating equipments during winter season
G. Iwashita, H. Yoshino
96. Passive solar energy management strategies in shopping centres 450
L. Jesus, M. Almeida, A. Almeida
97. Estimation of the main thermal parameters of a real size solar chimney from outdoor dynamic tests 455
M. J. Jiménez, M. R. Heras, J. Arce
98. Air quality measured in a classroom served by roof mounted natural ventilation windcatchers 460
B.M. Jones, R. Kirby, M. Kolokotroni, T. Payne
99. Performance study of air washer chilled water coil system for a yarn industry 465
S. Jothyramalingam, D. Mohanlal
100. GIS-Based urban elements study and its rooftop greenery potential in NUS campus 473
S. K. Jusuf, N. H. Wong
101. Enhancement of cross-ventilation of a detached house using roof surfaces in densely populated ur- 478
ban areas Part 2 Numerical investigations about the effects of the roof surface use by CFD
Y. Kadowaki, T. Kurabuchi, T. Nonaka, T. Endo
102. Use of genetic algorithms for the optimum selection of the fenestration openings in buildings 483
S. A. Kalogirou
103. Operation and measurement results of the solar cooling installation in Rethymnon village hotel 487
M. Karagiorgas, P. Kouretzi, L. Kodokalou, P. Lamaris
104. Solar assisted heat pump in dual mode: direct and indirect space heating by the air collectors 491
simulation results and evaluation with measurement results
M. Karagiorgas, M. Tsagouris, K. Galatis, A. Botzios-Valaskakis
105. The theory and practice of use quickly build of buildings in usual conditions and extreme situation: 496
experience of Russia by 2007
J. N. Kazakov
106. Little floors town-planning complexes with energy protect building systems and new types concrete 502
in Russia at 2007
J. N. Kazakov
107. Architecture of St.-Petersburg: yesterday, today and tomorrow. How Europe to do favourable invest- 506
ments into construction into city, areas and Russia?
J. N. Kazakov, T.M. Nikolaeva
108. Offers Ahe Russian Academy of architecture and building sciences on wooden housing construction 511
as to one of perspective directions of realization of the project «Accessible and comfortable habita-
tion – to citizens of Russia »
J. N. Kazakov, T.M.Nikolaeva
109. Cooling by underground earth tubes 517
Z. Khalil, A. Al-musaed, A. Almsad
110. Ventilation systems to minimize food odor spreading in high rise residential buildings 521
T. Kim, B. Park, S. M. Lee, J. H. Lee, Y. Lee
111. Distribution of a tracer gas in a naturally ventilated greenhouse. measurements and simulations for 526
Pesticides Dispersion Determination
C. Kittas, N. Katsoulas, A. Sapounas, T. Bartzanas
112. Assessing the operational energy profiles of UK educational buildings: findings from detailed sur- 531
veys and modelling compared to measured consumption
I. Knight, S. Stravoravdis, S. Lasvaux
113. Environmentally responsive architecture; passive design for school in Southern India 537
V. Kohli, S. Yannas

114. Office building facades and energy performance in urban environment in Greece 541
C. J. Koinakis, J. K. Sakellaris
115. Modelling of double ventilated façades according to the CEN Standard 13790 method and detailed simulation 547
G. Kokogiannakis, P. Strachan
116. Bioclimatic intervention in a central region of Heraklion in Crete 552
C. Kokolaki, M. Papoutsaki
117. Air quality in indoor swimming pools: associations with air distribution, water treatment, aerosols and airway symptoms 556
H. Kokotti, T. Jauhiainen, P. Yli-Pirilä, A. Hirvonen, R. Halonen, A. Korpi, T. Keskikuru, L. Kujanpää, M. Reiman
118. e-EPBD: A distance training tool for the energy performance buildings directive 561
D. Kolokotsa, G. Saridakis, O. Fenekos, A. Karagounakis, D. Tsoukakis
119. Modelling building envelopes in order to assess and improve their thermal performance 565
K. J. Kontoleon, M.C.A. Torres
120. Fuzzy control system for regulation of integrated shading and ventilation 570
M. Košir, Ž. Kristl, A. Krainer
121. Mediterranean Strategy for Sustainable Development 575
S. Kouvelis
122. The creative design process supported by the restrictions imposed by bioclimatic and school architecture: a teaching experience 577
D. Kowaltowski; L. C. Labaki; V. T. de Paiva; G. Bianchi, M. E. Mösch
123. Methodologies to bring innovative environmental technology R&D results into the market 582
K. Krell
124. The Determination of conditions for microbial growth in the crawlspaces 585
T. Kröger, K. Vepsäläinen, M. Reiman, T. Keskikuru, R. Halonen, H. Kokotti
125. Window opening behaviour and resultant thermal and air quality environment in elementary school classrooms 587
T. Kurabuchi, T. Endo, K. Kumagai, H. Yoshino
126. Measures to improve the cooling energy performance of student halls in Greece 593
Th. Kyparissi, A. Dimoudi

Passive solar energy management strategies in shopping centres

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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 CO₂ 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 - APPLICATION

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 n° 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/m ² °C)
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).

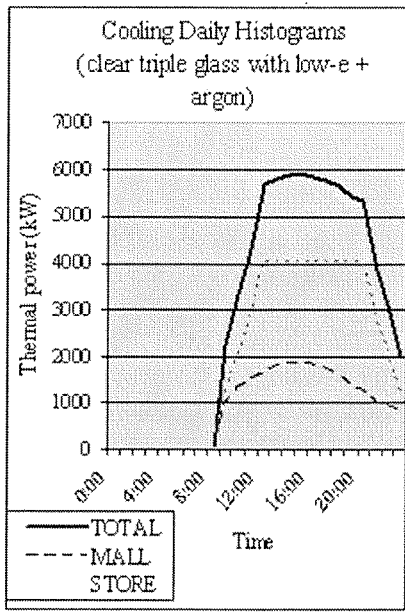


Figure 1: Comparison among histograms (triple glass)

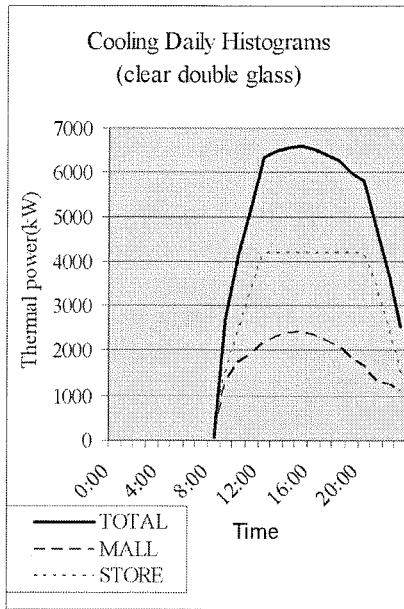


Figure 2: Comparison among histograms (double glass).

The glazing selection can contribute to the reduction of thermal load and consequent decrease of cooling needs, by 30%.

- *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 CO₂ emissions.

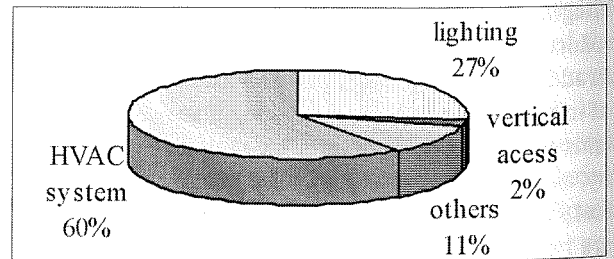


Figure 3: The total energy demand in the DVD.

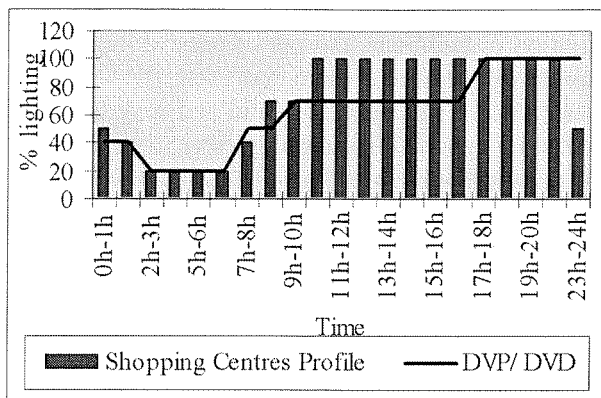


Figure 4: The lighting use per hour (in percentage)

- *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 EFFEC-TIVE 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 CO₂ 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 12-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	
<i>Efficient measures</i>	
- 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 CO₂ 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.

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