Passive Solar Buildings in Portugal
Experiences in the Last 20 years

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Abstract

Passive solar buildings are quite new in Portugal. Only a small number of these buildings have been built in the last two decades, by a few numbers of professionals. In order to get a detailed information regarding these buildings, in terms of construction, thermal parameters, type of passive systems used and thermal evaluation a two years project, denominated "*Thermal Characterisation of Passive Solar Construction in Portugal*" was set up. The aim of this project is to identify the existent buildings, the integration of passive systems in the building, the passive strategies used for each building, the degree of satisfaction of the occupants and to obtain its thermal performance. This paper presents the overall results of this project, for 20 buildings.

CLIMATE

Portugal is known as having a mild climate, with a 3 to 4 month period of winter, strongly influenced by the 700 Km Atlantic coast. This influence lead to a moderate winter, with mean temperatures for the coldest month (January) ranging from 4ºC to 12ºC, which in terms of *heating degree days*, for a base temperature of 18ºC, range from 1000 in the south of the country to 2500 in the north. The solar radiation is quite good, averaging 1.8 to 2.6 kWh/m^2, (mean daily horizontal irradiation) in January. Nevertheless, the most part of the buildings are cold and they do not achieve the minimal thermal comfort conditions.

The summer period is also moderate, but fairly warm. The air temperatures, may reach daily peak values around 35ºC in most part of the country, although with considerable daily swings around 10 to 15ºC. The *cooling degree days* for a base temperature of 24ºC range from 50 to 300. This type of climate, with nice temperatures in winter and good sunshine conditions is quite favourable for the use of passive solar systems. In summer, the considerable high daily amplitude is favourable to night ventilation strategies.

This type of climate lead to the non-existence of central heating or cooling systems in most part of the buildings, exceptions made for the service buildings.

Passive buildings

The current work presents the passive solar buildings identified during this project, standing at twenty. The selection of buildings for this study was made on the basis of personal acquaintance with the buildings or with the designers, a country-wide survey and answers given to an advertisement published in the newspaper of the Architectural Association.

Twenty buildings are presented in this work, those, which the architects classified as "solar". This definition usually refers to a good orientation, good insulation level, south facing glazing, the use of some passive solar system (direct gain, massive walls, Trombe walls, sunspaces) and cooling strategies. The most part of the buildings are single or multi-family residences; schools, offices and labs complete the whole range of buildings. The floor areas of the dwellings vary between 150 and 300 m^2, while the non-residential buildings have areas reaching up to 3200 m^2.

Building envelope

Building envelopes in Portugal are usually quite massive but not well insulated. The envelopes presented here are well insulated, comparing favourably both with prevailing building practice and with the thermal standards. The good envelope conditions, that characterise most of the examples in terms of wall insulation, the use of double glazing and moderation in of glazed areas, lead to overall U-values (infiltration losses not included) between 2 and 7 W/m^{2}K. The construction is quite massive, as they have concrete structures, brick walls and massive slabs. Consequently, the thermal capacity of these buildings is quite high: the thermal capacity per unit of floor area varies between 0.5 and 2.4 MJ/m^{2}K (see fig 1).

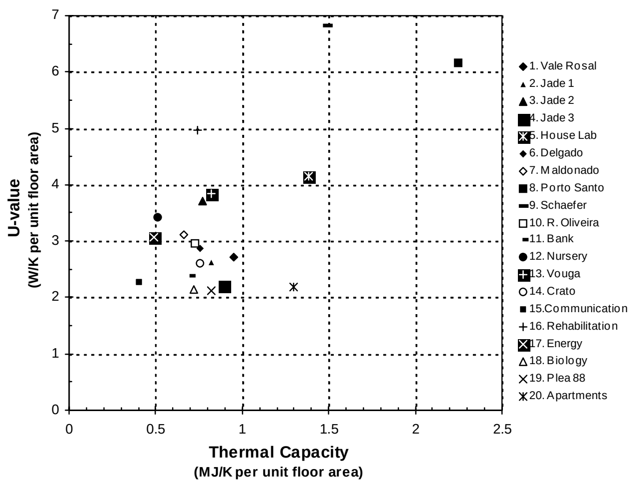


Figure 1. Thermal Capacity and U-Values

Glazing and shading

Double-glazing exist in most of the residential buildings, for all the orientations. In some cases single glazing was used only for south and double for north. In schools, usually single glazing was used. The glazing area compared with the floor area is not quite big, with relations up to 35 %. But the glazed area is prominent in south orientations, 50 to 80 % of the total glazing is located in south.

In all buildings there are solar protections. Most of the glazing is shaded by external roller-shades or internal blinds, which allow partial or full control of the incoming radiation. In one office building, an internal shading device was used within the air gap of double glazing. These protections also bring, a useful increase in the overall U-value of the aperture when deployed, e.g. at night.

Passive Solar Systems

In the buildings under study, it was possible to find several passive systems, that integrate only heating or cooling strategies, or both. In most part of the cases, heating strategies are more common. In addition to direct gain systems, one may find massive walls (concrete and water), Trombe walls, sunspaces and air panels in the facades. Although these systems appear in a variety of combinations, the association of south-facing windows and massive walls is the most predominant system. This solution is found in ten buildings with distinct configurations of glazed area, material and thickness of the mass element, type of glazing, shading and night protection.

The cooling strategies used are those related with solar protection, movable or fixed shading devices. The cross and night ventilation are usually referred by occupants as an usual procedure. There are also a few cases, that make use of ground and evaporative cooling (Porto Santo, Schäfer Residence and Crato School).

Fig. 2 presents the energy needs versus solar fraction for the analysed buildings, using the Solar SLR method.

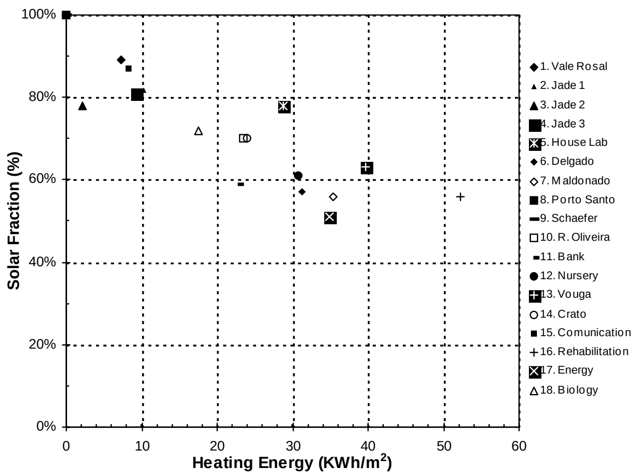


Figure 2. Solar Fraction and Heating Energy (15°C)

The massive walls and Trombe walls have areas of 2 to 6% of floor area (from 3.5m^2 up to 33m^2), which in some cases amounts to very significant areas in relation to the size of the adjacent space, that usually corresponds to bedrooms but may also be a living room. Wall thickness of 15 to 40 cm was found. The majority of the walls do not have any vents. The glazing used in most of them is single. In terms of summer protection, some use movable or fixed shades, others do not have any solar protection at all.

Sunspaces are present in several residential buildings, mostly as greenhouses but occasionally also as living spaces (see paper of this conference [15]). According to their function, the sunspaces encountered in these buildings are of the attached or semi -enclosed type. The use of sunspaces as living spaces is very problematic. When proper solar protection is not used, overheating problems can occur in this type of climate, mainly in summertime. Particular problems in the ventilation of some sunspaces were also found.

Air collectors in the facades were identified in two cases, namely a school and an office (Crato School and Porto Santo), as devices for pre-heating the incoming air in wintertime and promoting exhaustion in the summer.

Building thermal standards

The buildings analysed in this study enjoy a good standing in terms of the present standards. The energy requirements for winter and summer are below the limits imposed by the actual regulation, (their Thermal Performance Index is lower than unity), as can be seen in fig. 3 and 4. Nevertheless, in winter results are better than in the summer, which may denote some difficulty in achieving good comfort conditions for these buildings in warmer periods.

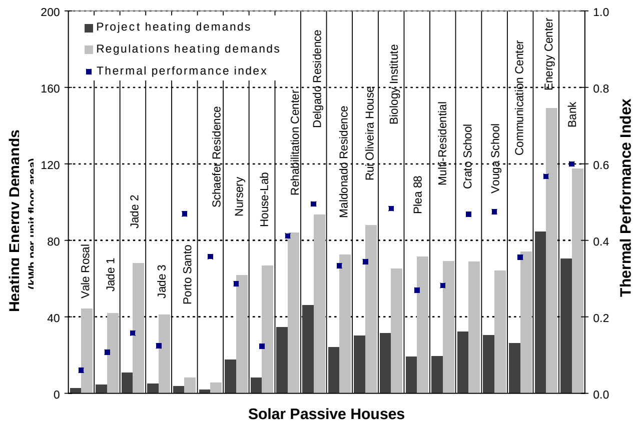


Figure 3. Heating Demands and Thermal Performance Index

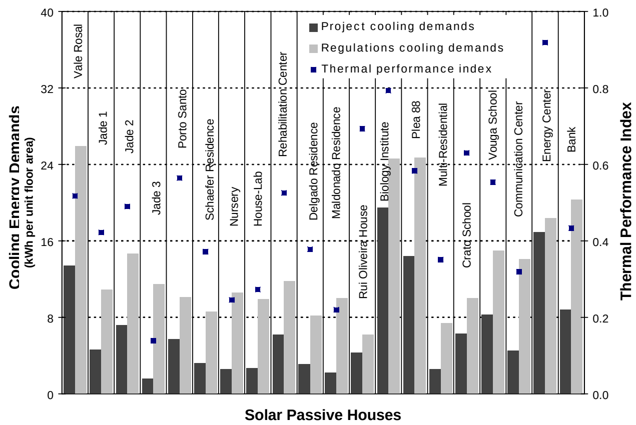


Figure 4. Cooling Demands and Thermal Performance Index

BUILDINGS

RESIDENTIAL BUILDINGS [1]

1. Vale Rosal

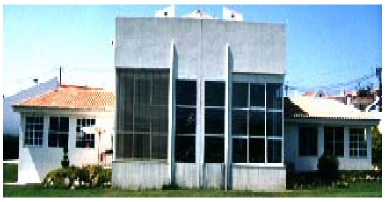
Direct Gain
G_a/F_a=32%
F_a=169 m²
Trombe Wall
A=3,5 m²
Sunspace
G_a/F_{as}=100%

Figure 5. Vale Rosal Building (Charneca da Caparica-Lisbon)

2. Jade 1

Direct Gain
G_a/F_a =30%
Trombe Wall
A=11,8 m²
F_a=257 m²

Figure 6. Jade 1 Solar House (Nafarros-Sintra)



3. Jade 2

Direct Gain
G_a/F_a =24%
F_a=484 m²
Trombe Wall
A=16 m²

Figure 7. Jade 2 Solar House (Nafarros-Sintra)

4. Jade 3

Direct Gain
G_a/F_a =25%
Trombe Wall
A=11,5 m²
F_a=533 m²

Figure 8. Jade 3 Solar House (Nafarros-Sintra)

5. House Lab

Direct Gain
G_a/F_a =31%
Trombe Wall
A=8,5 m²
F_a=140 m²

Figure 9. House-Laboratory (Porto)

6. Delgado Residence

Direct Gain
G_a/F_a =23%
F_a=310 m²
Trombe Wall
A=11 m²
Sunspace
G_a/F_{as} =244%

Figure 10. M. João Delgado Residence (Porto)

7.Maldonado Residence

Direct Gain
G_a/F_a =17%
Trombe Wall
A=3,6 m²
F_a=229 m²

Figure 11. E. Maldonado Residence (Vila Nova de Gaia)

8.Porto Santo

Direct Gain
G_a/F_a =44%
Ground Cooling
F_a=94 m²

Figure 12. Solar House (Porto Santo-Madeira)

9.Schäfer Residence

Direct Gain
G_a/F_a =25%
F_a=131 m²
Trombe Wall
A=12 m²
Ground Cooling

Figure 13.Schäfer Residence (Porto Santo-Madeira)

10.R. Oliveira House

Direct Gain
G_a/F_a =17%
Vegetation Shading
F_a=154 m²

Figure 14. Rui Oliveira House

11.Bank

Direct Gain
G_a/F_a =14%
F_a=473 m²
Trombe Wall
A=11,3 m²
Sunspace
G_a/F_{as} =187%

Figure 15. Bank (Pedrogão Grande)

12. Plea 88

Direct Gain
G_a/F_a =15%
F_a=1273 m²
Trombe Wall
A=19,2 m²
Sunspace
G_a/F_{as} =129%

Figure 16. Plea 88 Building

[1] G_a means glazing area, F_a living room floor area and F_{as} sunspace floor area.

13. Multi-Residential

Direct Gain
G_a/F_a =15%

Shading Devices

F_a=1240 m^2

Figure 17. Apartment Building (Vila Nova de Famalicão)

SCHOOL BUILDINGS

14. Nursery

Direct Gain
G_a/F_a =23%
F_a=669 m^2

Trombe Wall
A=33,5 m^2

Sunspace
G_a/F_{as} =282%

Figure 18. Nursery (Mertola)

15. Vouga School

Direct Gain
G_a/F_a =20%

Daylighting

F_a= 2917 m^2

Figure 19. High School (Valongo do Vouga)

16. Crato School

Direct Gain
G_a/F_a =27%
F_a=2954 m^2

Sunspace
G_a/F_{as} =81%

Evaporative Cooling

Figure 20. High School (Crato)

SERVICE BUILDINGS

17. Commun.Center

Direct Gain
G_a/F_a =26%

Blinds between glazing

F_a=1481 m^2

Figure 21. Communication Center

18. Rehabilitation Center

Direct Gain
G_a/F_a =17%

Sunspace
G_a/F_{as} =59%

F_a=2075 m^2

Figure 22. Rehabilitation Center (Ferreira do Zêzere)

19. Energy Center

Direct Gain
G_a/F_a =18%

Sunspace
G_a/F_{as} =900%

F_a=3018 m^2

Figure 23. Energy and Biomass Center (Miranda do Corvo)

20. Biology Institute

Direct Gain
G_a/F_a =15%

Shading Devices

F_a=3216 m^2

Figure 24. Molecular and Cellular Biology Institute (Porto)

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