EUROSUN 2008
1st International Congress on Heating, Cooling, and Buildings
7th to 10th October, Lisbon - Portugal

382 - Thermal performance of a passive solar office building in Portugal

H.Gonçalves, A.Silva, A.Ramalho, C.Rodrigues

INETI, Department of Renewable Energies, Campus do Lumiar do INETI, 1649-038 Lisbon, Portugal

Corresponding Author, helder.goncalves@ineti.pt

Abstract

This paper presents the thermal performance of a Passive Solar Office Building in Portugal in winter and summer 2006 and 2007. This Building, called Solar XXI, pretends to be an example of passive design both for heating and cooling. It contains a direct gain system assisted by a solar thermal system for winter conditions. In summer a ground cooling system (buried pipes) is used to cool the building, together with night cooling strategies. It also integrate in the vertical south envelope a Photovoltaic System (12 kWp) which provide around 12 MWh per year plus a 6kWp in the car parking, which correspond to around 76% of the electric energy consumption of the building. The integration of the PV system, in the building was done in such a way, that it is possible to recovery the heat production from the PV in order to be used for heating purposes

Keywords: Passive heating and cooling (ground, night ventilation), PV heat recovery

1. Introduction

The main goal of this project was the design of an office building, with low energy consumption, integrating renewable technologies (Solar thermal and Photovoltaic System) and passive systems for heating and cooling purposes, full integrated in the architecture design. The building pretend to be an example for new projects and it is an experimental facility of INETI´s Renewable Energy Department. The building has 1500m^2 in three floors, with the main occupied spaces in the south of the building and the less occupied rooms in the north part of the building.

Arch. Project; Pedro Cabrito and Isabel Diniz

Fig. 1. South and North facades of the Solar Building.

2. Heating Systems and Strategies

This building was since the early phases of the project planned to maximize the solar gains into the building through the windows facing south. The envelope of the building is external insulated, with 5 cm thick in a single masonry wall and has 10 cm insulation on the roof. The building has a solar thermal system to assist the auxiliary heating system, for the winter season when necessary. In fact, this auxiliary system has been used very rarely mainly in the north part of the building in periods with a sequence of days with no sun. In the heating season, the heat produced in the PV system in the façade is recovered by natural convection to heat the south facing rooms.

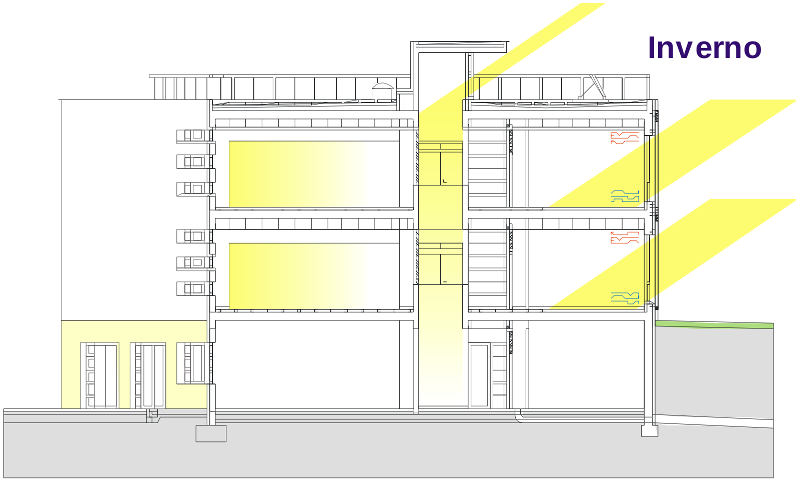

Fig. 2. Heating systems and strategies.

2.1. Winter thermal performance

During these two year monitoring campaign (February 2006 until February 2008) the building showed a very good thermal behaviour in the south part of the building, where the mean temperatures varies between a mean minimum of 17ºC to a mean maximum of 24ºC. In the north part of the building, the temperature are a quite bite lower than in the south part of the building, 1 to 2ºC, which consequently imply the use of some auxiliary heat source. Table 1 presents the mean values for the winter months, and it is very important to see that during daytime (Tdaily) the mean temperatures are always above 20ºC.

Table 1. Mean Temperatures
(external, internal mean, internal mean maximum, internal mean minimum and internal mean daily).

	Feb06	Nov06	Dec06	Jan07	Feb07	Nov07	Dec07	Jan08	Feb08
T_{ext}	10.3	16.0	10.8	10.9	12.9	12.8	9.8	11.5	12.2
T_{int}	21.4	21.5	19.4	19.6	19.7	20.3	18.7	19.9	19.7
T_{max}	23.7	24.0	23.0	23.3	22.6	22.9	21.6	22.8	22.6
T_{min}	16.0	20.1	17.4	17.6	18.0	18.7	17.1	18.3	18.0
T_{daily}	20.7	22.5	22.5	21.1	20.9	21.6	19.9	21.2	20.9

Figure 3 presents the hourly temperatures, in the 3 levels of the building, for the coldest month in winter (January 2007), where it is possible to see that during day time the temperatures are always above 20ºCC, except days 9, 10, 11, 17 of January where some extra heating was needed.

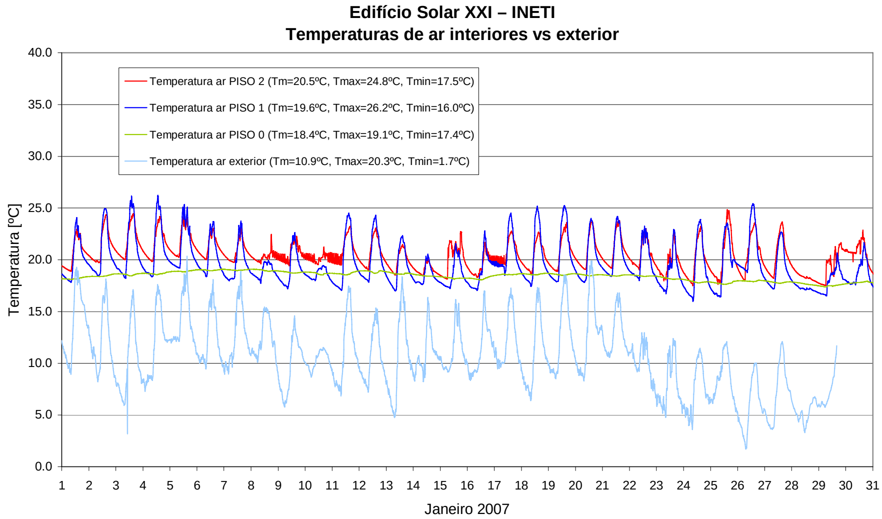

Fig. 3. Hourly temperatures in Solar Building XXI in January 2007

2.2. The heat recovery from PV systems.

The photovoltaic system plays an essential role in this building, not only for the production of electricity (see 3) but one of the strategies of this building in winter is to recover and use the heat produced in the PV system and used in winter time, according Figure 4. There are several possible situations which can be used in this system.

In winter the user during daytime, open the vents which connect the interior of the building with the space between the PV and the wall. By natural convection, the air enter through this vent, is heated and return to the building, during nigh time to user has to close this circulation closing the vents.

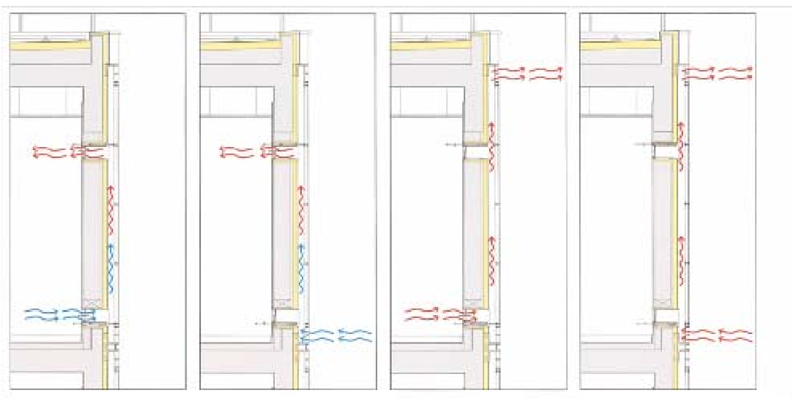

Fig. 4.Convection strategies through the PV system.

Figure 5, presents the measured temperatures in the vents (upper and lower vent) as also in the room, and in synthesis it is possible to see that in an winter day the incoming temperatures from the PV system are around 30ºC in a sunny day and could achieve the 37ºC.

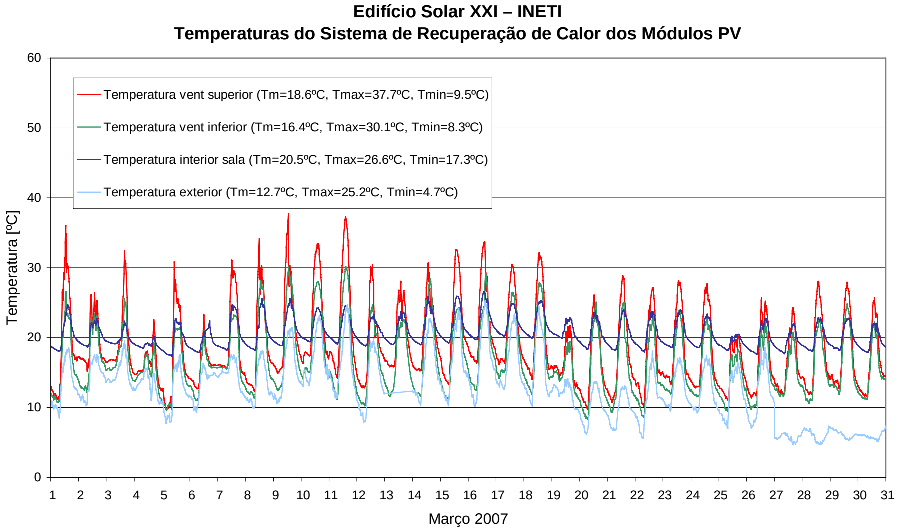

Fig. 5.Temperatures in the vents from the PV system.

3. Cooling Systems and Strategies

One of the main decisions in this project was to design a building without air conditioning; it was one of the main challenges in this building design and in this climatic conditions. The main cooling strategies used in summer in this building are; (a) prevention of solar heat gain, (b) night ventilation and (c) ground cooling system.

(a) The building is very well insulated by outside, the windows have external shading devices which permit the user to have a total control of the incoming solar radiation;

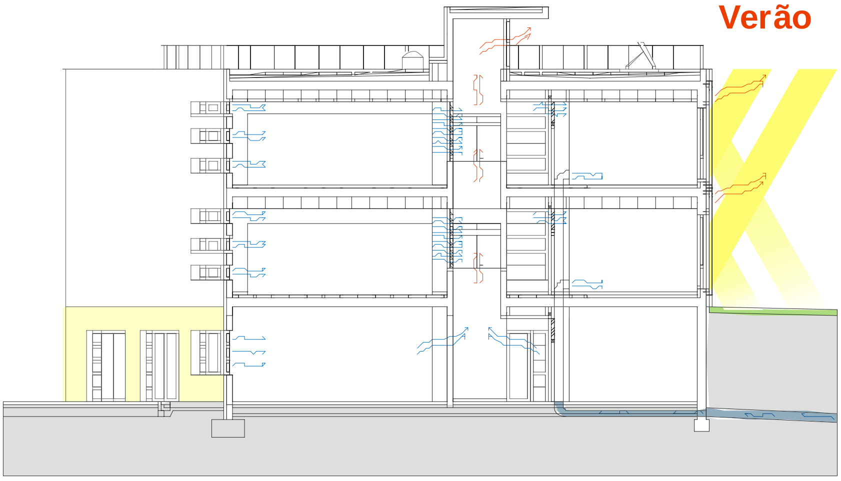

Fig. 6.Summer cooling strategies.

(b) The building has a system of openings, which allows very easily the cross ventilation and upper openings which facilitate the use of nigh ventilation strategies, very efficient in this type of climatic conditions.

(c) A ground cooling system was built (Figures 7 and 8) and it consist in a set of 32 concrete pipes with 30 cm of diameter, buried at 4,5 m depth, beneath the lower basement (Figure 7). Will allows the air to flow from the inlet, placed at 15 m in front of the building, to inside the building. The air is cooled in these pipes, to a temperature near the ground temperature, and goes directly to the rooms in first and second floor, two pipes per room. The user in each room can control individually the incoming fresh air by opening the apertures or turning on a small fan. This system only affects directly the south part of the building, which is the more problematic in terms of heat. The north part of the building is naturally ventilated and less problematic.

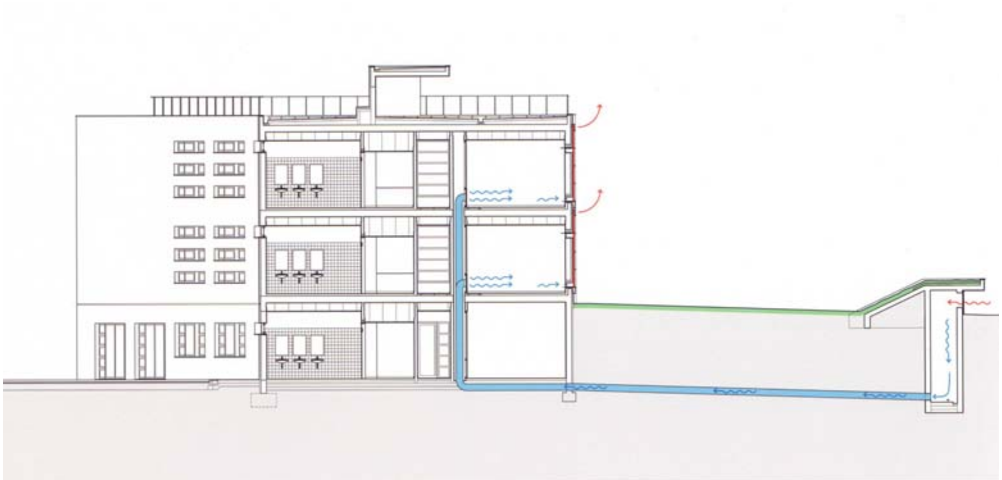

Fig. 7.Ground Cooling System.

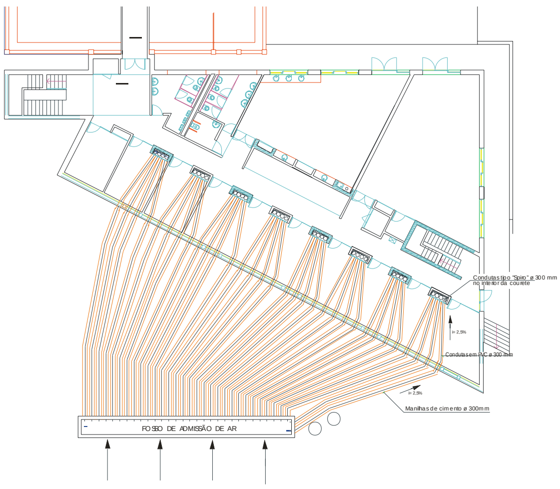

Fig. 8.Buried pipes for ground cooling.

3.1. Summer thermal performance.

The two summers of 2006 and 2007 reach external temperatures quite high for Lisbon, above 35ºC achieving even 40 ºC during day time. In these two summers the mean temperatures inside the building varies between 24ºC and 25.4ºC, for mean maximum temperatures from 26.4ºC up to 28.1ºC (see table 2). These temperatures correspond to the rooms in the south part of the building which are the hottest one, in the north part of the building, like in winter a difference in these location can achieve 2ºC.

Table 2. Mean Temperatures
(external, internal mean, internal mean maximum, internal mean minimum and internal mean daily).

	Julb06	Aug06	Set06	Jul07	Aug07	Set07
T_{ext}	23.7	24.5	22.3	21.8	21.5	21.2
T_{int}	25.1	25.4	24.2	24.1	24.7	24.2
T_{max}	27.3	28.1	27.1	26.4	26.7	26.7
T_{min}	23.3	23.3	21.5	22.3	23.2	21.5
T_{daily}	26.3	26.8	25.5	25.3	25.6	25.4

In figure 9, for the hottest month of summer 2006, the hourly temperatures are presented for outside air temperature (light blue) and for the three building levels. In the hottest days, with outside air temperatures above 35ºC the air inside the building in the upper level reaches around 30 ºC (mean maximum of 31.6ºC). In particular in 6 of August for an outside air temperature of 40ºC, the 3 level reached 30ºC in the upper floor, 28 in the middle floor and 24 in the basement.

The basement is of course the one where the temperatures are the best (in green in figure 9). For the whole month a very smooth line between 23.2ºC and 24.1ºC has been measured.

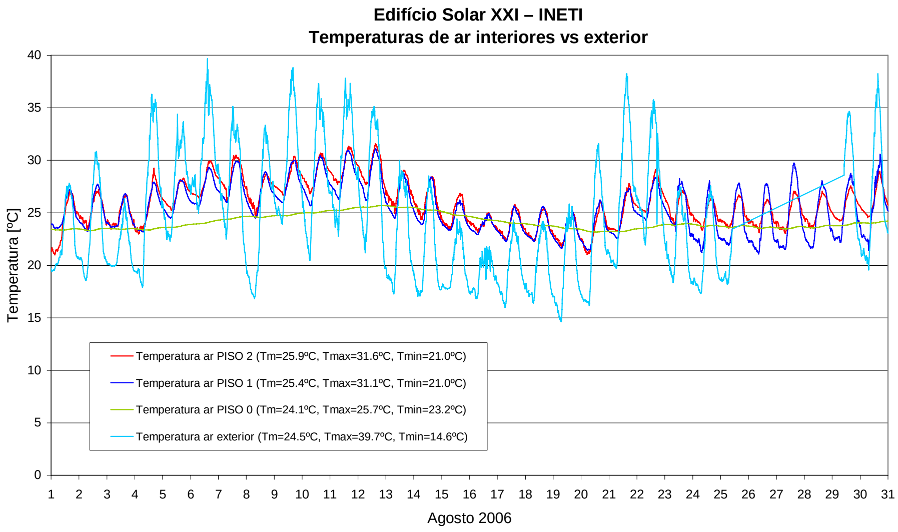

Fig. 9. Hourly temperatures in Solar Building XXI in January 2007.

3.2. Ground cooling system

The ground temperature during summer period varies between 17.5ºC to 19.5ºC which is a very interesting temperature for cooling purposes. Figure 10 presents the hourly temperatures for the hottest month in summer 2006 (August) in the system and boundary. External air temperatures reaching in August 6, 39.7ºC (light blue), the ground temperature almost constant with a mean temperature of 19.1ºC (dark red), and the temperatures in the pipes: red near the inlet tube (mean temperature of 21.1ºC); green in the middle of the tube (mean temperature of 20.6ºC) and blue near the enter of the building (mean temperature of 20.7ºC).

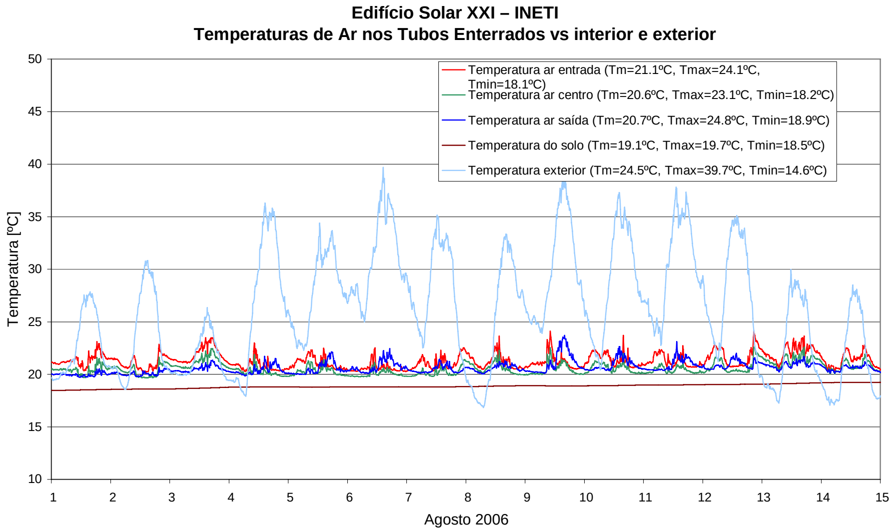

Fig. 10. Hourly temperatures in the buried pipe system in August 2006.

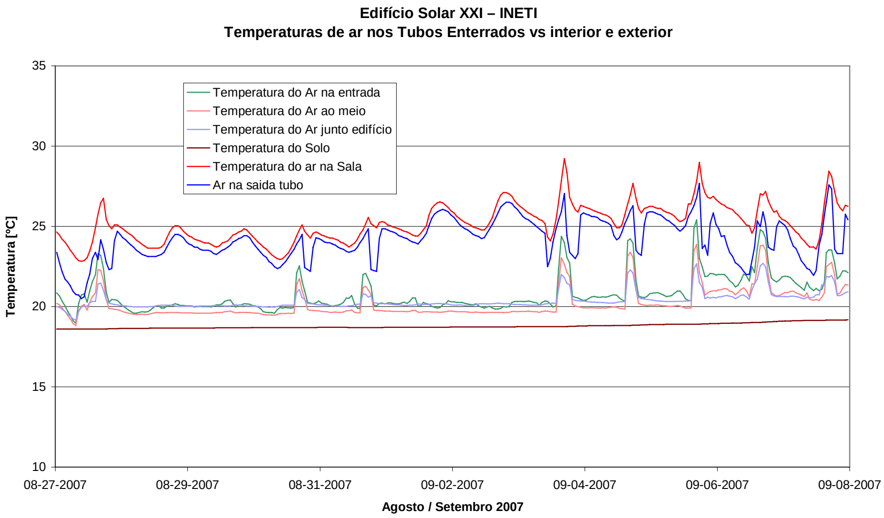

Fig. 11.Influence of the cooling system in air temperatures (August-September 2007).

Figure 11 presents the behaviour of the system when operated by the user in some particular days (from August 27 to September 8, 2007). There are two different modes of operation with circulation ON (4-9 Sept) and OFF. During the ON period, the temperatures incoming in the building (blue colour in the graph) can decrease up to 5ºC when the circulation in the pipes are operating. In terms of air temperature in the room this can correspond to a decrease up to 3ºC (red colour) see September 4.

4. PV Systems

The Solar Building XXI has in the south façade 96m^2 of PV (Polycrystalline), which correspond to 12kWp, plus a 6kWp (Amorphous silicon) in the car parking in front of the building (see figure 12). These two systems are responsible for an overall PV annual production of 12 MWh (in the façade) plus a 8MWh (in the car parking), which correspond to around 76% of the electricity consumption of the building.

Fig. 12.The Solar XXI Building and the PV system in the car parking.

5. Acknowledgement

To INETI and Program PRIME by the financial support to this Project. To Arch. Pedro Cabrito and Isabel Diniz authors of the Architecture Project and all colleagues which participate in the Project Alves Pereira; Manuel Nogueira, Antonio Joyce and also to all the workers which make it possible.

References

[1] Helder Gonçalves, Pedro Cabrito, Passive and Low Architecture Conference Proceedings, Vol.1 (2006) 821-825.