A passive solar Office Building in Portugal

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ABSTRACT: This paper presents a Passive Solar Building, recently built at INETI Campus in Lisbon, during 2004/2005 which opened in January 2006. 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, which correspond to around 60% 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.

The use of a solar passive, and active systems in this building, will consequently reduced the energy consumption for comfort which partially will be provided by the PV system. This project is the result, of a strong and effective cooperation between the Architecture and the Engineering teams, in order to find integrated solutions for the different energetic systems and in this way avoiding negative visual architectonic impacts. This paper describes the main characteristics of the building, as also the passive systems and strategies which are know under study in this Research facility.

Keywords: Integration of PV system in building façade, passive cooling and solar heating

1. BUILDING CONCEPT

This Building called, ***Solar XXI***, pretend to be an "*ex-libris*" of the use of solar systems (active and passive) and also the integration of a PV system in the building façade for electric and heat purposes.

The project of this building, since the early beginning, is focused in "passive and low energy architecture", with a full integration of passive solutions, as the driving force to accomplish through out the year, good thermal comfort in the building.

The main goal is to accomplish those comfort conditions, reducing the heating and cooling energy demands of the building, and reducing the use of conventional AVAC systems. In such a way, that the building have an auxiliary heating system, (boiler assisted by solar thermal) and do not have any air conditioning system for summer.

On the other end, and from the point of view of the architects, the goal was that the "solar systems" did not seems, to be "*aliens*" added to the architecture, but that, them self could generate a formal concept of the building and not cause of disturbance. One of main difficulties of the integration of the so called passive solar systems, are usually assigned to the idea that they do not fit properly in the design, and moreover they, prejudice and they inhibits the creative character of the architectonical solution.

This building intends to demonstrate that an adequate use of the solar energy is compatible with a contemporaneous building architecture and reach a coherent project.

Figure 1: South Façade of Solar Building, with the PV integrated in the envelope.

2. PROJECT STRATEGY

The first concern was to implement energy efficient measures, the second one the use of passive solar systems (heating and cooling) and lastly the integration of active solar systems, thermal and photovoltaic. It includes the following strategies:

- Envelope optimization, reducing the building thermal loads;
- South solar façade with a gain direct system;
- Photovoltaic façade (96m^2 equivalent to 12 kWp);
- Thermal recovery of the photovoltaic façade by natural convection;
- Passive cooling by buried tubes;
- Ventilation and natural daylighting systems;
- Active solar system for space heating supported by a natural gas boiler.

3. BUILDING DESCRIPTION

The Solar XXI is an office and laboratory building, in INETI Campus in Lisbon (Portugal) with a total area of 1500 m^2 with 3 floors; one is buried in the south façade (Figure 1, 2 ,3).

The building plant shows a south façade, perfectly oriented south, a central corridor, which has a 3 floors common skylight which is a central element for daylighting and natural ventilation in the building.

Figure 2: Building South Facade.

Regarding spatial distribution, the rooms with daily and permanent occupation are located in the areas facing south, in order to use the direct gain for heating as also the heating gains from the PV system. In the north façade are located the laboratories and the meeting rooms, spaces that do not have a permanent occupation.

The south spaces and the north spaces intercommunicate by the central zone (corridor) by translucide adjustable openings placed over the doors. These openings allow controlling the heat transfer, by natural convection from the south zones to the north ones and also the reverse is possible.

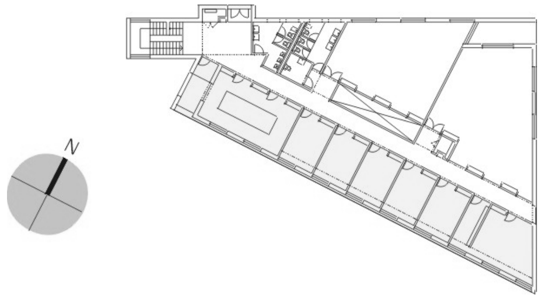

Figure 3: Building plant.

3.1 Building Constructive Elements

The brick walls are insulated by the outside with 6 cm of EPS, has an U-value of 0.5 W/m^2 K. The covering slab is massive, insulated also by the outside with 10 cm (5 cm of EPS + 5 cm of XPS). The floor slab is in concrete also insulated by 10 cm of EPS. The application of the insulation by the exterior eliminate the thermal bridges is a good solution in winter and summer. In the summer decreases the heat conduction from the exterior to the building allowing in this way a lower contribution in the building cooling load.

Figure 4: East and North Facade

The windows are a double clear glass, shaded by external roller shutters adjustable by the user with solar factors equal to 0.04 (with the shutters close) in order to avoid the solar gains during summer period. This type of adjustable shutters, permit the user to control the amount of daylighting in its particular space.

3.2 Passive Solar Systems

In the main façade, (oriented to south) large windows maximize the solar gains in winter period. However, these glass areas are protected by external roller shutters, individually adjustable, that allow the solar gain control and avoiding unwanted solar radiation in summer period.

Figure 5: Building Construction (Brick)

Figure 6: External Insulation

The solar gain through out the windows and the heat from the PV system, associated to thermal mass and an insulated envelope is the main strategy to in winter to get indoors thermal comfort conditions. Nevertheless in small periods of time, it will be necessary the use of auxiliary heating system. The building is equipped with natural gas boiler and hot water convectors assisted by solar collectors placed on the ceiling (and solar storage).

Figure 7: Solar Collectors in the roof

3.3 Solar Photovoltaic

The building has a photovoltaic system to produce electricity to be used directly in the building, and its integration was done, in order to be possible to recovery the heat produced by the PV system.

Figure 8: PV System in the south facade

These last purposes conduce to the integration of photovoltaic panels vertically in the south façade. Even if the solar gain are penalized by its vertical position (see figure 9), it will be easy to recovery the heat by natural convection to the interior of the space.

In the south façade, 96 m^2 of photovoltaic panels (polycrystalline) were installed with 12 kWp, which will produce around 12 MWh per year that is directly injected into the building, according with the prevision (Figure 9, Carlos Rodrigues, António Joyce, INETI).

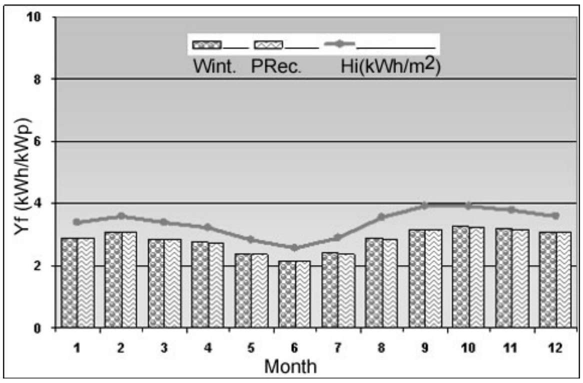

Figure 9: PV Annual Predictions (C.Rodrigues, A.Joyce)

This annual energy prediction corresponds to 50% to 60% of the electrical building consumption (light and equipment). From June 2005 to March 2006 was produced 9800 KWh, that confirms the initial expectations.

To recover of the heat produced by the photovoltaic panels, two vents were placed in the wall behind the PV panels. The user manually manages the opening of the vents according several strategies, represented in Figure 10. This strategy is one of the innovations of this project.

In winter period, the user, during daytime, open the lower and upper vents, which will allows the natural convection between the indoor space and the space between the PV and the wall.

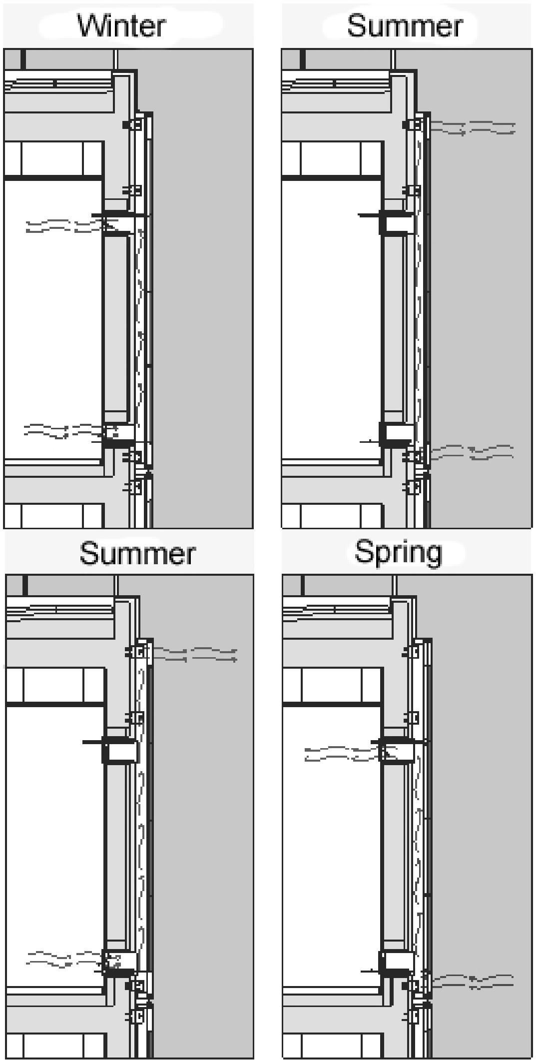

Figure 10 : PV heat recovery scheme

In summer period may occur two functional situations, the heat produced by the PV panels will be extracted to the exterior by two openings directly interconnect with the exterior. Another situation corresponds to use the chimney effect in order to extract the room internal heat to the exterior.

The system can also be used in the middle season as a pre-heating system of the fresh air. Through the aperture between the cells and the exterior the outside air is directly injected into the room by natural convection by the top aperture or opening of the cells and the room.

The building was occupied since mid January of 2006 and it is already possible to test that this system, in a sunny day, causes in the space adjacent to the PV panels temperatures between 40 to 50 ºC being the injection temperature into the room close to 30 - 35 ºC.

One last remark related to the heat recover from the photovoltaic panels, which is expected to contribute to a better efficiency of the PV systems as a consequence of the temperature decrease of the cells.

Figure 11 : Vents inside the building

3.4 Passive Cooling System

During summer, cooling can be provided by a set of strategies that will allow the natural ventilation, mainly at night and also during periods when the outside temperature are lower than inside the building.

The obstruction of the solar gains through the windows with the adjustable external blind shutters and the attenuation of the solar gains through the opaque envelope reducing the heat conduction due to the external thermal insulation, has a major impact in the reduction of cooling needs in the building.

Finally the use of the cold earth as a cooling source, through the buried pipes will allow the cooled air enter in the building.

Thirty two (32) pipes in concrete with 30 cm of diameter were buried at 4,6 m depth, beneath the lower basement (Figure 13) will allows the air to flow from the inlet, placed at 15 m of the building, to inside the building. The air pipes enter into the building in the basement and go directly to the rooms in first and second floor, two pipes per room. In each room will receive two pipes that the user can control individually by opening the apertures or with a small fan.

Figure 12: Buried Air Pipes for Cooling.

Figure 13: Buried Air Pipes for Cooling.

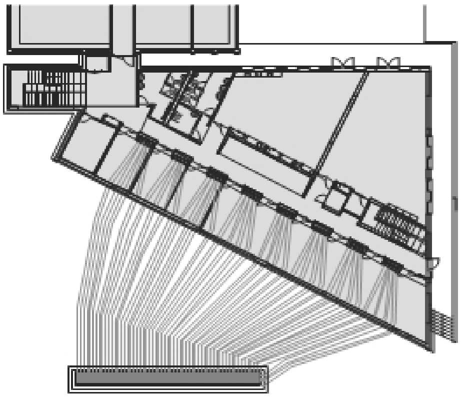

Figure 14 : Air distribution through the building.

Figure 15 : Installation of Pipes .

In each room, these two pipes can be controlled individually by the user, opening the apertures (Figure 16), a small door or a small fan can help this flow.

This system is applicable mainly for summer conditions, when the external air temperature can reach 30 to 35 ºC while the ground temperature 14 ºc to 18 ºC. In this way, when the soil temperature is cool enough, it is possible to utilize it for cooling the air and inject it into the rooms. The system management will depend on the global building thermal behaviour however, is expected that, the system will have a better performance promoting the air entry in the middle afternoon when it is necessary cool the air in order to compensate the increasing of the internal air temperature.

The natural ventilation has an important role in this building in both seasons. The ventilation of the interior of the building during winter will allow the heat transfer from the south spaces to the north ones.

Figure 16 : Air distribution inside.

Figure 17 : Internal corridor with opening in the top of the doors.

In summer this cooling strategy will be applicable essentially during night period in order to release, during night period, the thermal loads accumulated during daytime and cooling the building thermal mass.

Different opening types were applied, in order to have transversal and vertical air circulation placed on the ceiling, skylight and on the east and western top of the stairs. This load management strategy is essential for the building thermal performance and each user will have an important role on it.

Daylighting play an important role in this building, the central skylight has a distributor of light in the 3 floors is fundamental, as also the translucide glazing in the doors which communicate from south spaces to corridor, and from corridor to north spaces. Due to these systems the electrical light needs are reduced.

4. CONCLUSION

The Solar XXI Building is a research facility, which is now under study in order to quantify the thermal performance of the buildings and its systems.

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