Characterization, optimization and efficient implementation of active façades in social housing buildings

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ABSTRACT

The goal of this research project is to provide free heating by using active façades in a social housing building with 32 dwellings that is located in the North of Spain. Thereby, it was necessary to characterize the thermal performance of AFs so as to optimize their implementation in the building. The analysis was carried out by both virtual and experimental characterizations of a façade model and a monitored building.

Keywords: active façades, Paslink Test Cell, Building Simulation, Free Heating, Building Energy Efficiency

1 INTRODUCTION

In order to meet with NZEB requirements for the climate zone of Northern Spain, it is not sufficient to build designs with high insulation That is because ventilation demands due to salubrity reasons create a significant heating demand. Furthermore, it also must take into account the operational cost of facilities and common services. Nevertheless, it is possible to reach the scope with an extra renewable energy contribution obtained through the building envelope system based on solar energy uptake surfaces (AFs).

2 METHODOLOGY

In this study some AFs were tested in sample-scale. The evaluated AFs group was composed from conventional active systems, such as TW, through solutions such as PV façades. These facades were tested in outdoor conditions using a traceable and precise methodology. The testing equipment used is a PASLINK test cell developed by the DYNASTEE (DYNamic Analysis, Simulation and Testing applied to the Energy and Environmental performance of building) network at the Basque Government LQCB.

Accordingly, these tests not only showed the efficiency of different AF, but they also provided detailed information to define a mathematical model of an active performance (such as ventilated cavity's convective behavior) [2-4] to introduce them in building scale simulation. In this way, a considerable amount of dynamic simulations were conducted by TRNSYS to evaluate the studied cases.

In this preliminary stage of characterization, the design principles were corrected in order to improve the thermal performance of these AFs. Both the tests and simulation results demonstrated that the AF optimization should be carried out focusing on the use of the evacuated heat by convection in the ventilated cavity through an AEFS.

Finally, these design principles were applied in the construction of the aforementioned social housing building. Three different types of façades were installed along the Southern orientation of the building with different use of energy generated in the implemented AFs. Furthermore, a relevant criteria has been defined to adjust the operation of these active elements and, in consecuence, to find the optimal renewable system that provides free heating to tenants.

3 PASLINK TEST CELL

To get a proper characterization of AFs by testing, 3 requirements are needed: reliable equipment, a fully representative sample and finally an accurate and confident process of calculation and analysis of the obtained data. All these points are reached working with PASLINK cells and its test methodology.

The test was created by The European Project PASSYS (Passive Solar Systems and Component Testing) which was developed from the mid-1980s to the mid-1990s. In 1994 a European Economic Interest Group was created: the PASLINK EEIG [1]. Nowadays all the experience of the PASLINK group has been integrated in the DYNASTEE (DYNamic Analysis, Simulation and Testing applied to the Energy and Environmental performance of buildings).

There are two PASLINK test cells in the LQCB facilities; they are called EGUZKI and ILARGI. They were upgraded following the indications provided by Dr. J.J. Bloem of the European Institute DG Joint Research Centre, Institute for Environment and Sustainability in Ispra-Italy.

The PASLINK test cell consisted of a well-insulated structure of 8 x 2.7 x 2.7 m with two spaces [5]. One called "test room" facing the south, and an adjoining space to the north called "service room" containing acquisition and air conditioning equipment. The south façade (and cover if applies) of the test room is interchangeable so it is possible to test different building components (walls or roofs). The sample holder system consists of a structural metal frame, filled with insulating material (expanded polystyrene with a thickness of 0.4 m) [10].

Figure 1: PASLINK test cells in LQCB

It is possible to measure the heat flux through the test room envelopes by a number of heat flux sensors in the form of tiles (HFS tiles) [6]. Besides, the test cell is equipped with a suitable instrumentation in order to monitor the interior and exterior conditions.

The test strategy is based on a routine of heating power input in the test room known as ROLBS [7] which allows it to reach enough differences among environments ($\Delta T \geq 20$ºC) to measure accurately. The heating input intervals of this routine last days, hours or thirty minutes. This variability allows us to obtain the necessary information in order to disconnect the thermal inertial behavior of the test cell envelope from the test sample.

The analysis of the data and the determination of the main parameters and thermal properties of the samples is carried out using the following tools: LORD (LOgical R-Determination) [9], and CTSM (Continuous Time Stochastic Modeling) [8].

The construction of the sample is carried out inside the industrial hall, placing all the needed instrumentation on it. After that, the sample holder is installed in the test cell, where final works on the specimen and sealing of all perimeter joints are performed to reduce infiltrations. The suitable sealing of the joints is verified by the pressurization test, achieving the requirement of less than 0,5 ACH (Air Change per Hour) with 50Pa of pressure difference.

During the test, the most important parameters are recorded, such as the air temperatures and air velocities at different points and heights of the sample. The heat gained within the ventilated gap can also be calculated using a thermo pile which measures the difference between the inlet and outlet temperatures. Besides, to characterize the thermal properties of each layer, the temperatures of their surfaces are measured [11].

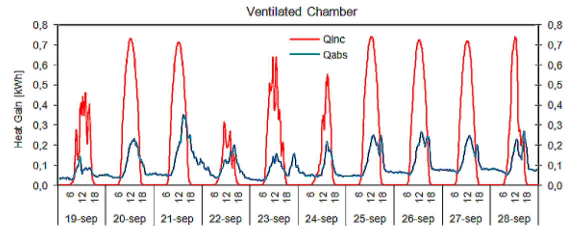

Figure 2: Measured parameters in PASLINK test cell

Then the solar radiation uptake efficiency (ɳ) and the heat gain in the ventilated gap (ϕ) of the four tested AF typologies are shown:

	ɳ[%]	ϕ [kWh/m^2]
SVF	22	0.90
TW	61	2.60
PVP	30	1.00
PVP with AEFS	99	3.86

Table 1: Efficiency of AFs

The building's design was open to place two types of AFs and a completely passive construction system in the southern facing wall. It has been decided to use a TW and SVF, both with AEFS, given that AEFS improves considerably the uptake efficiency.

In SVF's test results it has been seen that its low uptake efficiency was due to the low emissivity of the material. Thus, this variable has been corrected in the building replacing the original sheet with another one that has higher emissivity.

4 USE OF RENEWABLE ENERGY

It has been seen that to get a proper solution in areas where heating demand prevails, it is necessary to use the evacuated heat by convection [12]. Along these lines, another criteria that needs to be evaluated is the tipology of exploitation of the heat generated in AF's gaps (SVF and TW) by forced convection.

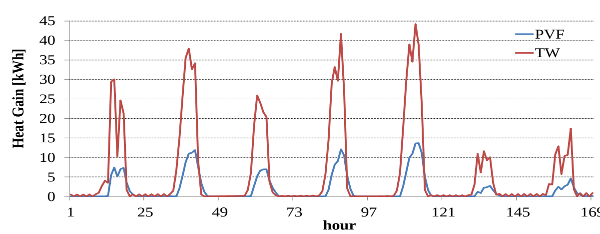

Figure 3: Solar Heat Gain in gaps (TW and SVF) in a week.

Thereby, at first, it has been proven by simulations in TRNSYS [13] which façade absorbs more solar radiation among them. The results have shown that it is the TW (figure 3). Therefore, assuming the thesis that the total AF surface in the building is TW, simulations for two types of utilization of the energy generated in the gap have been carried out: introduction of the preheated air in MVS through a MVHR and the heat input in the HP to supply heating for tenants through the radiating floor [15].

The heating PEC of the whole building has been calculated with both types of exploitation, assuming that a CB is used to cover the rest of the heating demands in the dwellings. Then these results have been compared with the PEC of a system with a single CB, without any renewable input, in order to rate the EP savings with AFs. Thus, it has been observed that the renewable energy input translated into the EPRs in case of the utilization in the HP are higher than if exploited by MVHR. This is because a great quantity of the energy generated in TW is not usable in MVHR due to too high temperatures reached in the gap.

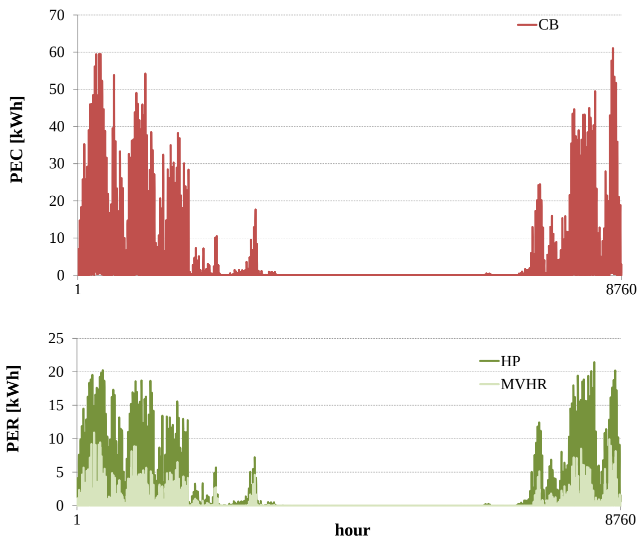

Figure 4: Comparison of the PEC

Almost all heating demands, are covered using the renewable energy by HP, without support from the CB. This means that if the electric power required for the HP's operation is derived from a renewable source, the PEC virtually would desappear. In consequence, a new case has been simulated: utilization of the heat generated in AF by HP, which operates with electric power generated by 28 PVPs.

	CB	MVHR	HP	HP+ PVP
EPC [MWh/year]	24,04	22,00	12,86	3,82

Table 2: EPC in analyzed cases

Accordingly, the most efficient system is a TW in conbination with HP and PVPs. In this housing unit two systems (TW with MVHR and SVF with HP+PVP) have been implemented in order to compare their potential and check the results of the simulation analysis for the development of new improvements for upcoming SH projects.

5 IMPLEMENTATION IN BUILDING AND RESULTS

5.1 Building description

The building is situated in Portugalete (Northern Spain) and it consists of 32 dwellings distributed among 5 floors and 3 adjacent blocks.

The façade shown in the following figure is the southern face, where the AFs are integrated. From left to right, the first façade is a standard passive system (U=0,22 W/m2K). For the second block a ventilated façade with a micro-perforated sheet (SVF) (U=0,26 W/m^{2}K) has been designed that has a AEFS linked with a HP (Power 45 kW; electrical consumption 12,5 kW) which supplies the heating demand of the whole building. And finally, a TW (U=0,33 W/m2K) with AEFS, has also been installed, where the preheated air is directed into the building dwellings of the 3rd block within the MVHR.

Figure 5: Southern façade of the social housing object

In addition, the building has the following facilities:

- MVHR for the 1st and 2nd block without any connection with AFs.
- CHP (Electricity Power 5,5 kW; Thermal Power 14,8 kW) for DWH demand.
- 88 PVP with 255Wp of nominal power that supply power for the lighting of public areas and the MVS of dwellings. The rest of produced power is redirected to the HP.
- CB with a Rated Heat Output of 102 kW.

An optimal configuration of these systems has made it possible to supply free heating for all tenants, without any energy cost. During the daylight the solar heat gain reduces the HP consumption, which is covered with the electricity power generated by PVPs and CHP. Thereby, the heating system is entirely renewable for a few hours a day.

5.2 Results

The building presents a very low heating demand of 17,7 kWh/m^2 y plus 7,07 kWh/m^2 related to DHW demand. According to the simulation results, the project is a Net Zero Energy Building [14], with all the PEC compensated with renewable energy sources (PV, CHP and renewable HP). The results are summarized in Figure 6.

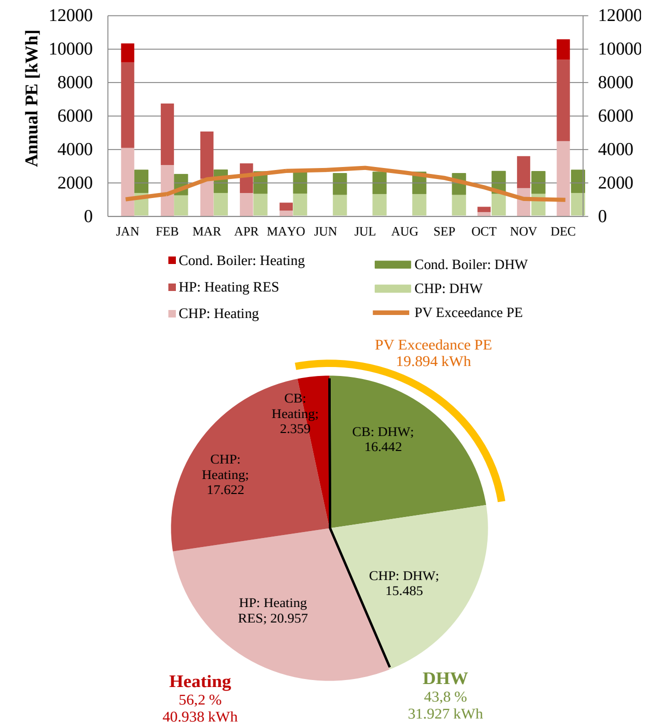

Figure 6: Performance results of the public housing nZEB.

The building and all the systems are monitored by a control and management software that is open to main stakeholders (tenants, owner, utility managers) and facilitates useful information (instant and cumulated parameters). This software can adjust and improve every system operation to the real energy use, and show the performance and usage of each service.

The first tenants will move in before the summer of 2016, so that it has not been possible to publish monitorization data. This information will be made known in future communications.

6 CONCLUSION

The implementation of the "Free Heating" concept has been a major achievement, which has been possible due to a proper characterization and optimization procedure.

"Free heating" will be implemented in the upcoming SH projects. The information obtained from the monitored building and expected upcoming simulation analysis will be determining how to optimize the efficiency of façades systems. The TW with the MWHR, for example, has high potential to maximize its performance, setting a variable flow ventilation in dwellings depending on the amount of solar radiation.

Notation

SVF	Sheet Ventilated Façade
LQCB	Laboratory for the Quality Control in Buildings
AEFS	Air extracton forced system
MVHR	Mechanic ventilation with heat recovery
HP	Heat Pump
CHP	Conbined heat and power
DHW	Dwelling hot water
PVP	Photovolaic Panels
CB	Condensing Boiler
PEC	Primary Energy Consumption
PER	Primary Energy Reduction
SH	Social Housing
AF	Active Facade

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