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Energetic analysis of a passive solar design, incorporated in a courtyard after refurbishment, using an innovative cover component based in a sawtooth roof concept

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Abstract

This paper presents the experimental results and specific thermal and energetic saving analysis from the systematic monitoring carried out to analyse the energetic performance of a building with an innovative component, which is based on an optimisation of the sawtooth roof concept.

This component has been installed at a building of the University of Almería. The constructive goal has been to refurbish an existing 350 m^2 courtyard, without practical utilisation before that moment, so as to incorporate energy saving techniques in the climatic conditioning of the available resulting zone. The innovative elements of the modified sawtooth roof are South orientated openings, thermal insulation, overhangs and integrated devices to improve natural ventilation as solar chimneys into interior space.

Equipment, thermal and meteorological sensors have been installed, and the most representative parameters to analyse the thermal performance of the space have been recorded for a year. These data have made possible to analyse the feasibility, regarding functionality and thermal response of the constructive solution adopted. The analysis has been carried out through the climatic description and comparison with the climate measurements for the recorded monitoring period, and afterwards the most important efforts have been done for the thermal analysis that included the thermal comfort and the energetic characterisation of the building using the monitored data measurements.

Keywords: Energy calculations; Energetic evaluation; Passive solar building design; Educational buildings; Innovative courtyard component; Thermal comfort; Natural ventilation; Shading; Internal gains

1. Introduction

This paper describes the energetic evaluation carried out in the building of University of Almería into MED-UCA (Model Educational Buildings for Integrated Energy Efficient Design) Project. The work has been

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carried out by CIEMAT's Solar Energy in Building Project researchers in collaboration with Almería University's Physics Applied Department researchers within the framework of the MEDUCA Project. This project aims to create representative examples of the application of natural air conditioning techniques and Renewable Energies in educational buildings. The main objective of the project is to contribute to the dissemination and the teaching on building energy savings techniques by ordinary use and exploitation of actual systems installed at educational environments. In this sense, apart from the technical activities, other expected deliverables of the MEDUCA project are educational tools and guides for students and professors, as well as specific experiences in this field. Being among these experiences the refurbishment of an existing building at the University of Almería (UAL) in Spain, carried out aiming to save energy and increase indoor thermal comfort, and the analysis of the degree of achievement of these objectives.

2. The building and the implemented saving strategies

The goal has been to refurbish a 350 m^2 courtyard, without previous practical utilisation, so as to incorporate energy saving techniques in the climatic conditioning of the available resulting zone. The initial aim of this work was to demonstrate how it is also possible to optimise the energetic performance of a simple and traditional constructive solution with an acceptable daylight performance, reducing the loads for heating and cooling including easily feasible structural concepts.

The starting point for the new roof design was the sawtooth concept which is a well known architectural solution that serve as daylight mechanism to large sized building areas having a proven performance despite its simplicity and being so far extensively employed in many edification typologies. This conventional solution has served as base case for the covering of a 20×17.5 m^2 courtyard at the University of Almería (Spain) with the goal of transforming the original open space into a multi-purpose room for exhibitions, meetings, etc., assuming also the preservation of the function of the original space for those periods when the new room is not used, that is, the daylighting of the adjacent corridors and offices and the building air renovation.

The modified roof structure, as it is shown in the Fig. 1, consists of two main zones: a passive zone, with five teeth including 1.7 m high vertical openings and an active zone placed in the north side, consisting of a 5 m high solar chimney. In the conventional constructive solution, the vertical openings face away to the north side, constituting a zenithal pass-through daylighting component, providing diffuse light and high light levels without contrast to the space below. Although this roof function is well established, the orientation of the vertical apertures in this normal mode restricts the possibilities of using the available solar radiation impinging the glazing as an extra thermal load during the winter period.

In this project, an alternative strategy has been settled to allow a seasonal control of solar gains, permitting the solar direct radiation to enter to the conditioned space during winter period by facing away to the South side the roof vertical openings. To prevent overheating and to refine the control in the months with maximum solar radiation availability, each vertical opening into the roof has been equipped with a 1.5 m overhang that, in order to preserve the simplicity of the original structure, is in line with the general 35 ºslope of the opaque part of each tooth. In addition to this, to reduce internal glare, the indoor framework of the roof has been designed to act as lightshelf, redirecting light to the internal ceiling and walls during the period in which beam solar radiation enters into the room through the roof vertical openings.

On the other hand, the strategy for room ventilation tries to take the advantage of two natural indoor-outdoor air interchange mechanisms to achieve indoor air quality and thermal comfort. The first one is to ease warm air exhaust by stack effect and the second mechanism consists of the renovation of indoor air by outdoor fresh air coming from the coast (100 m distance from the building) transferred by the sea-land breeze process. Both mechanisms occur without mechanical support thanks to the installation of the north chimney. The design of this component has been carried out considering it not only as a warm air pass trough element, but also producing wind and thermal driven pressure drops.

As a complement of the overall solar design of the new roof, part of the sun exposed area of the north chimney was occupied by a photovoltaic system integrated into the building aimed to produce enough electricity to balance the new enclosure electrical devices consumptions as well as to produce a surplus to be added to the overall building savings when the room is not in operation.

3. Monitoring

The main objective was to obtain measurements to perform an experimental study of the energetic and comfort behaviour of the patio after its refurbishment, which incorporates passive conditioning techniques in its covering.

The measured quantities and also sensors locations have been defined following the guidelines previously