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Energy efficiency and thermal behaviour of attached sunspaces, in the residential architecture in Spain. Summer Conditions

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ABSTRACT

This research shows the study and analysis of sunspaces behaviour as passive elements of architecture during the summer, taking into account that they are fundamentally passive solar heating elements for winter. This study is carried out through monitoring and energy simulation of six case studies, applying it to summer 2011–2012 which was extremely hot for the climate zone in which it is located. These results are useful for the study of residential buildings with the forecasts of climate change for Pamplona, especially for an architectural element as sensitive to overheating as is an attached sunspace. The research concludes that attached sunspaces also have a good thermal behavior in summer, even in extreme conditions, as long as they are designed and used properly, and therefore no active cooling system is necessary.

This research also explores the energy efficiency and optimized design of the sunspaces for different climate zones in Spain, selected attending mainly to the severity of summer although with different winter conditions.

1. Introduction

Sunspaces are classic elements of passive architecture, designed as solar heating systems, but that must respond to climatic conditions throughout the year, without causing overheating and discomfort in the housing to which they are attached. European Directive 2010/31/UE, "*on the energy performance of buildings*" (EPBD2010) [1] expressly mentions that the efficiency of buildings must be achieved not only in winter, but throughout the year, and not only with regard to facilities, but also to "*passive heating and cooling elements, shading, indoor air-quality, adequate natural light and design of the building*". The Spanish Technical Building Code (CTE) with its basic requirement in Energy Saving, CTE-DB-HE [2], also requires an envelope that limits the demand in winter and summer, according to the climate and the characteristics of insulation and inertia, air permeability and exposure to solar radiation, limiting the cooling demand between 15 and 20 kWh/m^2 annual, according to the climate zone of summer.

Sunspaces have their design focused on maximum solar collection, which results inappropriate in summer conditions, where avoiding overheating caused by solar radiation is a must. In temperate climates, with cold winters and warm summers as those of the case studies, we look for "*intermediate*" or "*optimized*" solutions, which result in a lower energy demand and adequate comfort throughout the year. In this climate, South orientation of facades is optimal for solar gain in winter, and is an appropriate for solar protection systems in summer. East and west orientation, as well as the roof, must be treated specifically to avoid overheating in most of the Spanish locations.

The definition and typologies of sunspaces found in Spain and their key summer performance characteristics are highlighted here:

- M1. Traditional sunspace s. XIX and s.XX (called "*galerías*" and "*miradores*", in Spanish). They are located in all orientations, have their three sides glazed and could even have a glazed roof. The ones found in Pamplona have the outer sheet (HE) usually glazed in a 100%, and can be opened almost completely for cleaning, although some moving parts lack a fastening ironwork. Usually, HE cannot be protected with solar protection systems (SPS), because they are listed elements and their image cannot be modified, and they have not them originally. The interior sheet of the sunspace (HI) usually incorporates in its glazed part, blinds or shutters on the outside. The separation wall between the sunspace and the interior room has a great inertia.
- M2. Glazed balconies or terraces. They are the result of glazed enclosures in balconies of homes, regardless of the orientation

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or the incidence of such action in the housing. In the majority of cases, they do not have solar protection systems in the HE and they lack sufficient opening elements for adequate ventilation on that new closing. The windows in the HI usually have a roller blind on the outside.

- M3. Bioclimatic sunspaces. Designed as passive elements of solar collection to reduce the demand for heating in winter, but we have found that they lack clear criteria of solar protection in the HE, so the blinds located in the HI are used generally as solar protection. 25% of the HE can be open, although located at a height of 1 m. The separation walls can be designed with or without insulation. Bioclimatic sunspaces have been built profusely in many new urban "*sustainable*" developments, because they are almost mandatory in the regulations, as for example, in the ecocity of Sarriguren, near Pamplona (with more than 5.500 dwellings) or in the neighborhood of Valdespartera, in the nearby city of Zaragoza (with more than 9.650 dwellings, and a harshest summer) (Fig. 1).

The specific objectives of this research are: to check the thermal behavior of sunspaces in temperate summers like Pamplona and other locations in Spain, to see if its incorporation into housing improves the comfort of the room which it is attached to and has minor energy consumption, versus a window, and to establish the design parameters and use conditions that optimize the behavior of the sunspace in summer.

The methodology that has been followed is based on the study of existing research and in six case studies that have been monitored, tested, and simulated with the data obtained from monitoring. Then a comparative study between all the houses and sunspaces has been made. Finally, a comparative study between different Spanish climate zones is done, looking for the optimization of the design and use of sunspaces according to the severity of the summer.

2. Study of the thermal behavior of sunspaces in summer

The study of the behavior of the sunspaces in summer is described in the revised papers, only in those climates with cold winter but warm or hot summer, since in areas with a cool summer it is not necessary because there are already exterior conditions of comfort. In climates where sunspaces work as a solar heating system in winter, the approach is that they should not contribute to overheating in the housing in summer, and if they do, measures to prevent this are proposed. In summary, optimized solutions are looked for throughout the year.

Mihalakakou and Oliveti studies compared the use of sunspaces in different climatic conditions. The first verified that these elements contribute significantly to the reduction of heating loads in winter in the European cities of Milan (45° N), Dublin (53° N), Athens (38° N) and Florence (43° N), but create serious overheating in Mediterranean areas such as Athens, through energy simulation. To avoid overheating, adding to night ventilation and solar protection, the passive technique of buried pipes was proposed, which introduces air at lower temperature in the sunspace, concluding that all the measures reduce overheating, although the best results are obtained with a combination of the three passive techniques [3]. Oliveti studied and compared through simulation, behavior between three cities of Italy, Cosenza (39° N), Rome (41° N) and Milan (45° N), and checked that sunspaces do not cause overheating in these latitudes, if they are shaded and ventilated properly, reaching the sunspace a temperature close to the exterior one, so that in the cities of the study, the sunspaces can be used practically throughout the year [4].

Other studies analyzed the behavior of sunspaces in buildings and specific locations. Zhu compared through simulation, the thermal behavior, heating consumption and CO_2 emissions throughout the year, between a traditional Chinese house with inertia, the "*Yaodong*", with and without adjacent sunspace (called *New Yaodong* and *Old Yaodong*), and a "*modern*" brick house [5]. He checked that in addition to a better performance in winter, traditional dwellings also offer better performance in summer and do not require cooling, mainly due to the thickness of envelopes and natural ventilation.

Okutucu studied by monitoring three houses with sunspaces in Turkey, with the aim of knowing why they do not work well in winter and in summer, and applying what they learned to the design of a new house [6]. The lack of solar protection is the most important problem detected in summer conditions. Bataineh studied the efficiency of sunspaces in Amman (Jordan) throughout the year with simulation [7], finding that in summer they suffer serious overheating, unless using passive techniques of night ventilation and solar protection (in this case, interior curtains), concluding that with a sunspace, global heating and cooling loads are reduced in 42%.

The authors of this paper also tested the summer behavior of a sunspace prototype, which incorporated water storage to optimize its behavior in winter, and which remained empty in the summer to avoid overheating. This prototype was compared to another sunspace without water accumulation and to a single window, through monitoring (summer 2011 and winter 2012) and simulation. In summer conditions, the best results were obtained in the prototype, and the worst in the single window, since the first has exterior solar protection, and provides better ventilation because of the better design of the outer sheet [8,9]. This research concluded that the use of the sunspace is closely linked to a design that allows adequate ventilation and solar protection in summer, and the importance of an active and adaptive use versus a static use, throughout the day.

3. Climate study and comfort criteria

The climatic conditions in which sunspaces have been monitored in summer, have responded to typical summer conditions in Pamplona in terms of averages, although there has been a series of completely unusual heat waves. The thermal behavior of sunspaces and dwellings has been tested thus, and therefore the incidence of the design of the sunspace and the use made by the occupants,

Fig. 1. Images of sunspaces typologies M1, M2 and M3, with a general absence of solar protection in the sunspace HE.