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Evaluating rehabilitation of the social housing envelope: Experimental assessment of thermal indoor improvements during actual operating conditions in dry hot climate, a case study

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ABSTRACT

The energy efficiency improvements in social housing have become a priority goal for the European Union, also to promote a culture of energy efficiency among the local population. Characterizing the social housing stock is the first step to be taken, followed by the thermal behaviour analysis of these existing buildings.

In hot and dry climate regions such as Madrid, buildings normally use air-conditioning in order to provide an acceptable level of thermal comfort during the summer period. Many times these buildings are overcooled or the use of the HVAC is redundant and kept running for a much longer time than needed. This convectional energy consumption could easily be reduced including bioclimatic techniques.

This paper presents the results of a case study example designed to monitor, analyze and evaluate the improvement indoor conditions by upgrading the thermal–physical characteristics of the building envelope in a social housing. With this aim two measurement campaigns were carried out during the summer period (2002 and 2006). The quality of thermal indoor conditions has been assessed accurately during the buildings' occupancy period. The refurbishment of the building envelope, as demonstrated, is always convenient, by considering all possible point of views, better indoor microclimate and thus energy savings [1].

1. Introduction

The housing sector consumes about 30% of the total energy in Spain and it is responsible for 25% of CO_2 emissions, rising steeply in the last years due to the increasing use of air conditioning. Thus, energy consumption has increased by 5% since year 2000, approaching the level of energy consumption to the Northern European countries, in spite of its warmer climate [2].

The National Statistics Institute (year 2001) data shows that about 67% of the Spanish apartment stock was built before 1980, just when the first Spanish thermal regulation (NBE-CT 79) became effective. There is a similar situation in the case of the Madrid where more than 75% of the apartment stock was constructed before 1980 [3].

Building stock of Madrid is characterized by the construction period in this study. Several factors act upon construction features, like social and financial situations and/or building regulations. As far as thermal requirements are concerned, after the Oil Crisis in the 70s, in Spain, like in many European countries, the requirements for insulation of buildings were considerably reinforced. With this aim in mind, the first thermal regulation was developed and came into force in 1979. Unlike in other European countries, there was no new Spanish thermal regulation till 2006, when the Spanish Technical Building Code (CTE) [4] came into force.

In the housing sector it is essential to study all the construction process, in such a way that it is possible to rationalize energetic consumption, following the entire productive die: from the waste for the material production, to their carriage and fitting. So, selected and intelligent choices would suggest directing our efforts towards new materials and technologies, developing buildings that allow us to significantly reduce energy consumption.

One of the main goals for the energy design of buildings is the proper use of its envelope features, which should be adapted to the climatic conditions of the location. The efficient design of these construction elements reduces heat losses and attenuates thermal excursions between outdoors and indoors, mainly due to solar radiation and the impulsive endogenous gains.

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In continental weathers there are two marked seasons during the year: winter and summer, so two climatic profiles have been obtained. During the winter time low temperatures and medium solar radiation values leads to maximize solar gains and reduce heat losses. However, during the summer months very low humidity and high ambient temperatures and solar radiation values leads to minimize solar gains and maximize heat losses. The building performance is characterized by the global annual energy balance, so it is necessary to combine winter and summer bioclimatic strategies.

In the countries of the southern Europe, long summer seasons with high temperatures and solar radiation values produces more discomfort days due to heat than cold, so it is very important to avoid excessive gains during the overheating season.

Therefore, elements designed are adjusted to the high yield that the irradiance conditions of the zone enable.

Considering the climatic conditions, the retrofit of the building envelope could induce higher indoor microclimatic stability, lower energy demands, lower polluting emissions.

The implications and benefits of energy renovations have consequences also in social aspects. One of them is the so called fuel poverty, which is mainly a consequence of a combination of three causes: poor energy efficiency of housing, high energy prices and low household incomes [5]. Poor energy efficiency can be responsible of high summer indoor temperatures and this problem is increasing in the last years in Spain, as shown in Tirado Herrero et al. [6]. Thus, both, energy savings and improvement on the indoor comfort, have to be taken into account during energy renovations projects.

Finally, this approach, even if quite expensive when applied to existing buildings, is more effective and produces higher long-term benefits.

In this article a residential building located in Madrid (Spain) has been analyzed before and after the refurbishment works. This building is composed by social houses, which are designed to incorporate heating system but no cooling systems. So it is very important to minimize the overheating periods during the summer months. This paper evaluates the thermal improvements achieved as a consequence of the refurbishment of the building envelope like passive strategies applied in the building [7].

There are several of similar field studies available in the literature to assess thermal comfort in low energy buildings [8], office buildings [9] or vernacular or historical buildings [10–12]. Another study is interesting in support this work, Ma et al. [13] provide a systematic approach to proper selection and identification of the best retrofit options for existing buildings. Nevertheless, it is not so prevalent to come across with this kind of studies applied to the social housing sector. One exception could be found in [14], but they do not have experimental comparison data after and before the refurbishment works and do not take into account the action of envelope refurbishment.

Moreover, as affirmed in Kavgic et al. [15], the assumptions for the operating conditions are usually based on profiles considered as standard, rather than those from field measurements. Thus, having field measurements on the indoor conditions in social apartments is necessary to obtain a more accurate analysis of the energy renovation potential in the social housing sector.

In order to define optimal strategies in building renovations, its thermal behaviour must be known. Thus, architectural and thermal behaviour of social housing stock in Madrid is assessed in a field study. Along this line, the main aims of this paper are:

(a) Provide an insight of the thermal improvements achieved as a consequence of the refurbishment of the building envelope of social housing stock in Madrid, a city with dry hot weather conditions in summer period; (b) identify the potential improvement of the social housing stock; (c) provide indoor environment field measurements of these 2 apartments, which can be used in future researches and models to set up operating conditions not based on standards, but on field measurements; and (d) provide a comparative and qualitative analysis of thermal building indoor improvements of 2 apartments, representatives of the social housing stock.

2. Features of studied building

2.1. Building characteristics

This building is the result of the working line developed by EMVS (Empresa Municipal de la Vivienda y Suelo de Madrid) to progress towards higher energy efficiency in their social housing promotions, and it is a part of the “Regen Link” Project. This project was approved by 5th Framework Program for Technological Research and Development (R+D) and it is sponsored by the T.R.E.N. General Department of the European Commission. This European program identifies clear guidelines for energetic adaptation and its principal aim is the reduction of CO_2 emission and the improvement of energetic efficiency in “urban regeneration” operations.

This rehabilitated building is located on an existing plot of land in the surroundings of a southern district of Madrid (San Cristobal de los Angeles), like one of new construction (Fig. 1) [16]. This development was carried out following the construction principles used in the sixties new expansions. As far as construction features are concerned, these apartments can be considered representative not only of the social housing in Madrid, but also of the social housing stock of the main urban areas in Spain.

The shape, dimensions and orientation of the plot seem to predetermine a rectangular-type of building with longitudinal axis in a north–south orientation, as shown in Fig. 1. The building is characterized by a minimal intervention that affects only the exterior layer and metal structure, without changing the existing openings on the facades and maintaining the location of common areas. Only bad orientation of windows of the east façade has improved; by a sawtooth element with southeast orientation, as shown in Fig. 2.

2.2. Envelope characteristics: before and after rehabilitation

Direct surveys done on 2002 allowed knowledge of composition of the building envelope, kind of adopted ceiling and floor structures, and thus thermal–physical properties, with reference to both steady state [17] and dynamic [18] parameters.

The main features of ancient envelope are described as follow:

- External wall: starting by the inner side, there is a first layer of hollow bricks. The wall has a gypsum plaster on the inner side, while, on the external one, the hollow bricks are visible (Fig. 2 left), without any type of thermal insulation and, thus, are critical thermal bridges (that could penalize significantly energy performances of buildings [19–21]). The measured/calculated overall thermal transmittance is equal to 1.80 W/(m^2 K) (Fig. 3C).
- Windows: simple-glazing without any type of solar shading. It has been evaluated an average thermal transmittance around 5.4 W/(m^2 K).

During the design of overall renovation, architects wondered if an energy-oriented retrofit of the envelope could be useful.

The envelope improvement would induce surely better indoor conditions, because the highest external insulation increases the thermal capacity of the shell. Analogously, in summer time, the solar shading of windows reduces the “short-time fluctuations” of indoor temperatures due to variable intensity of solar radiations. Really, as shown by [22–25], solar radiation affects also the heat transfer through the opaque envelope and thus, when possible,