



Field assessment of thermal behaviour of social housing apartments in Bilbao, Northern Spain



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ABSTRACT

A field study of 10 social housing dwellings in the north of Spain is presented in this paper. Knowing the building stock is the first step to set up priorities in a global strategy to improve the energy efficiency of the existing building stock. Moreover, improving the energy efficiency of buildings is one of the most effective ways to tackle fuel poverty, which is increasing in Spain in the last years, being social housing one of the most vulnerable sectors of being at risk of fuel poverty.

The aim of this research is to describe a methodology for analysing the thermal performance of buildings under a holistic approach. An overview of the thermal performance of the social housing stock in a city with mild climate in Spain is presented. Social housing stock in Bilbao is classified by means of selecting 10 representative dwellings. A field study was performed during 10 months. Results of heating consumption as well as indoor conditions are presented. Results show that energy consumption in winter is not as high as expected, due to the low indoor temperatures. Amongst other factors, the influence of the occupants plays an important role in the final thermal performance of dwellings.

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1. Introduction

Currently the energy consumption of the construction sector is estimated to be over 40% of the total energy consumption in the European Union. Thus, the energy and environmental situation requires improving the energy performance of buildings. The National Statistics Institute (year 2001) data shows that about 67% of the Spanish dwelling 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 Basque Country (a region located in Northern Spain) where more than 75% of the dwelling stock was constructed before 1980 [1]. Therefore, to reduce the energy consumption, the main effort must be focused on the challenges of the existing stock.

The implications and benefits of energy renovations have consequences not only in the reduction of CO₂ emissions and energy savings, but also in financial and 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 [2]. Poor energy efficiency can be responsible of low winter indoor temperatures and in some countries it is an important factor contributing to cold related morbidity and mortality as well [3]. Some other studies about energy

efficiency, fuel poverty and the suitability of energy renovations have been carried out, such as in [4–6]. This problem is increasing in the last years in Spain, as shown in Tirado Herrero et al. [7]. Thus, improving the energy efficiency of the existing stock is one of the main strategies, not only for reducing CO₂ emissions, but also for delivering affordable warmth to the fuel poor households. Both, energy savings and improvement on the indoor comfort, have to be taken into account during energy renovations projects.

Regarding occupants influence on the energy consumption in buildings, Annex 53 states that human behaviour could have a great impact, even greater than building characteristics or other factors. Several studies have pointed out large differences in energy consumption for similar buildings [8,9] thereby suggesting to the occupant's behaviour a strong influence. In Olivia [10] relationships between behavioural patterns, user profiles and energy use are thoroughly analysed. Related to this approach, rebound effect [11] is another factor to be considered when effectiveness of energy renovations is evaluated, as shown in several studies such as in [12–17].

Because of all the above reasons, energy efficiency improvements in buildings, and especially in social housing sector, have become a priority goal for the European Union. Due to its characteristics (such as households with low incomes and construction features of the buildings), this sector is one of the most vulnerable to fuel poverty. This way, quantifying the potential energy savings in the social housing stock must become a priority. Characterizing the social building stock is the first step to be taken, followed by the

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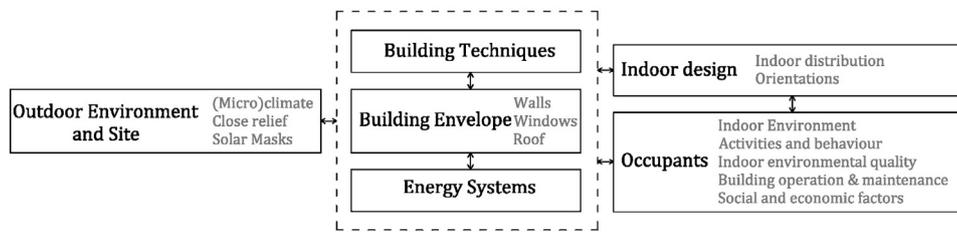


Fig. 1. Subsystems for investigation.

thermal behaviour analysis of this building stock. Moreover, many energy models have been developed in the last years to predict changes on energy consumption as a result of energy renovations. As affirmed in Kavgić et al. [18], 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 dwellings is necessary to obtain a more accurate analysis of the energy renovation potential in the social building sector.

A global approach is necessary to study the thermal performance of buildings, considering the building as a complex system composed by different subsystems. With this aim in mind, in this work 10 occupied apartments have been studied under a holistic approach to have an overview of their thermal performance. There is no shortage of similar field studies available in the literature to assess thermal comfort and energy consumption in low energy buildings [8], office buildings [19] or vernacular or historical buildings [20–22]. 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 the large-scale surveys carried out by Warm Front Project [23].

2. Objectives

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 Bilbao is assessed in a field study. Along this line, the main aims of this paper are:

(a) Provide an insight of the thermal performance of social housing stock in Bilbao, Northern Spain, and identify the real energy consumption in social dwellings in a city with mild weather conditions both in winter and summer; (b) identify the potential improvement of the social housing stock; (c) provide energy consumption and indoor environment field measurements of these 10 dwellings, 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 performance of 10 selected dwellings, representatives of the social building stock.

This study is not only focusing on energy consumption itself, but also on assessing thermal comfort in the dwellings. Previously mentioned aspects related to health issues, however, are out of scope of the present study, although they must be taken into account when energy retrofitting benefits are considered.

To accomplish with these goals the building stock of social housing in Bilbao has been classified according to the criteria described in Section 4. Based on this classification, 10 social housing apartments, representatives of the different construction periods of the 20th Century have been studied using a holistic approach. Results obtained from this survey provide an important database to quantify the potential benefit of retrofitting the existing social building stock in the Basque Country.

3. Approach

A holistic approach is applied in this study. In this systemic approach, buildings are treated as open systems considering interactions between them and their environment. Similar approaches are explained and used in Cantin et al. [20] with historical buildings, in Annex 53 [24] or in Yu et al. [25]. The approach used in this paper is based on these references. The different considered subsystems are shown in Fig. 1.

Building techniques, building envelope and energy systems could be considered as a boundary subsystem, which makes a separation between outdoor environment and occupants or indoor environment [26]. The combination of all these factors will give as a result the energy performance of the dwelling.

Building renovations are usually focused on the improvement of three subsystems: building techniques (such as thermal bridges), building envelope and energy systems. However, although the objective of any improvement in the building energy performance is usually within these subsystems, it is important to take into account the interaction amongst building techniques, building envelope and energy systems, and the other subsystems, and the consequences of these interactions on the overall energy consumption. The study presented in this paper has been carried out bearing in mind this approach.

4. Choice of buildings

This field study has been carried out in Bilbao from November 2011 to September 2012. All apartments have been occupied during the monitoring period. Different heating systems are used in the selected dwellings: out of the 10 dwellings, 4 are heated by natural gas heating systems, 3 by electric heaters, 1 by kerosene heater, 1 by butane heater and 1 has not a heating system whatsoever. All the studied dwellings have no mechanical ventilation system. The climate for the studied area (Bilbao), located in latitude 43°N, is oceanic. The proximity to the ocean makes summer and winter temperatures relatively temperate, with low intensity thermal oscillations. Average maximum temperature is between 25 °C and 26 °C during summer period, while the average minimum in winter can vary between 6 °C and 7 °C.

4.1. Building stock classification criteria

Building stock of Bilbao is characterised 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 70's, 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) [27] came into force. Detailed data about the Building stock in Bilbao, based on Population and Housing Censuses

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