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Facade typologies as a tool for selecting refurbishment measures for the Spanish residential building stock

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ABSTRACT

Today, the building sector alone accounts for 40% of the total energy consumption in the European Union (EU). In most EU member states, about 70–90% of the buildings were constructed at least 20 years ago. Due to this, these buildings have a worse energy efficiency behavior than the new ones that comply with current regulations. As a consequence, acting on the existing building stock is needed, developing special methods on assessment and advice in order to reduce the total energy consumption. This article addresses a procedure allowing the classification and characterization of existing buildings facades. It can help researchers to achieve in-depth knowledge of the facades construction and therefore knowing their thermal behavior. Once knowing that, the most appropriate upgrading strategies can be established with the purpose of reducing the energy demand. Furthermore, the classified facade typologies have been verified, complying with current and future Spanish regulations and according to the results obtained, a series of upgrading strategies based on the opaque part and those in the translucent part, have been proposed. As a conclusion, this procedure helps us to select the most appropriate improvement measures for each type of facade in order to comply with current and future Spanish regulations. This proposed method has been tested in a specific neighborhood of Madrid, in a selected period of time, between 1950 and 1980, but it could be applicable to any other city.

1. Introduction

In recent years in Europe, the importance of improving the energy efficiency in existing buildings has been constantly addressed because the building sector represents 40% of the European Union's (EU) total energy consumption [1]. In the average Spanish home (Fig. 1), the energy consumption due to heating and cooling units, represents 48% of the total energy use, including: lighting, domestic hot water (DHW), appliances, and climate control systems [2]. Therefore, there is a great potential for energy savings in the existing building stock, that were built according to old regulations, reducing the energy demand in order to achieve more energy-efficient buildings.

The Spanish Ministry of Economy and Competitiveness is funding the SHERIFF Research Project, which falls under the INNPACTO program. This project aims to increase the rate of the existing buildings refurbishment from the energy efficiency point of view by designing a facade system that must be an economical, flexible and integrated solution. For this purpose, prior to design the new system, it is necessary to define a procedure that allow the classification and organization of the existing facades and, according to this classification, proposing the most appropriate energy-efficient solution for each type of facade, checking their compliance with regulations. SHERIFF Research Project contains six different work packages and this paper is focused on the first one called "Constructive characterization and energy evaluation of buildings". As well as the work elaborated in this paper, other different tasks are currently under development. The evaluation of the facades energy performance before and after refurbishment will address by monitoring onsite and simulating, in order to discuss the effect of combined interventions and to evaluate the cost/benefit of these interventions.

This paper pursues the goal of selecting the most appropriate upgrading measure for different type of facades. To this end, it is essential to know how the existing facades were constructed in order to evaluate the energy performance of the existing buildings and subsequently, propose the most appropriate upgrading strategies. For this reason, this paper is divided in the following two parts:

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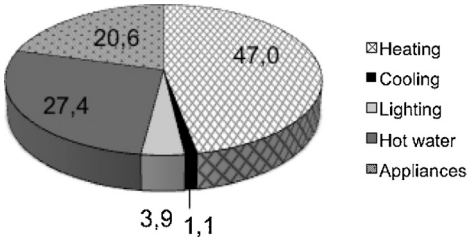

Fig. 1. Energy consumption distribution of households in the residential sector, 2010. Institute for Energy Diversification and Savings (IDAE).

1. Developing a procedure to classify the different types of existing facades.
2. Proposing upgrading strategies, for the classified facades, to comply with current and future regulations.

In the first part of this paper, the classification procedure is framed in a particular time period with the purpose of collecting the maximum available building information. In this article, building information means the architectural project information (drawings and documents) that can help to understand how the building was built. Subsequently, a selection of the neighborhoods of study was done and, within these neighborhoods, the most representative building typologies were chosen. Afterwards, data concerning these representative building typologies was gathered from different sources. A classification of the most representative facades, in terms of their thermal characterization, was concluded based on the data. In other studies, some classifications have been proposed considering general information about the building stock, without a deep insight in the construction of the facade [3,4]. For example in Denmark, there is a classification that divides the building stock according the specific year of construction [5], but it does not look deeply in the facade construction. Other authors have developed a classification procedure based on in-situ evaluations of the building' energy behavior [4]. This part of the paper is organized as follow: study period selection, procedure of neighborhoods and building types selection, consulting building information in Public Administrations, classification of facade typologies, and classification of facade typologies, and simplification of cataloguing system.

In the second part of this paper, the minimum requirements demanded by the Spanish Technical Building Code (CTE) for facades were determined. Then, different improvement actions depending on the climate and location of the existing buildings were proposed for meeting the current regulations. A large demanding requirement was also addressed under the consideration these specifications will be increased, in the coming years, according to the Nearly Zero Energy Buildings demands. This part is organized in the following steps: upgrading measures applied in the facade and, upgrading measures in the translucent part of the facade.

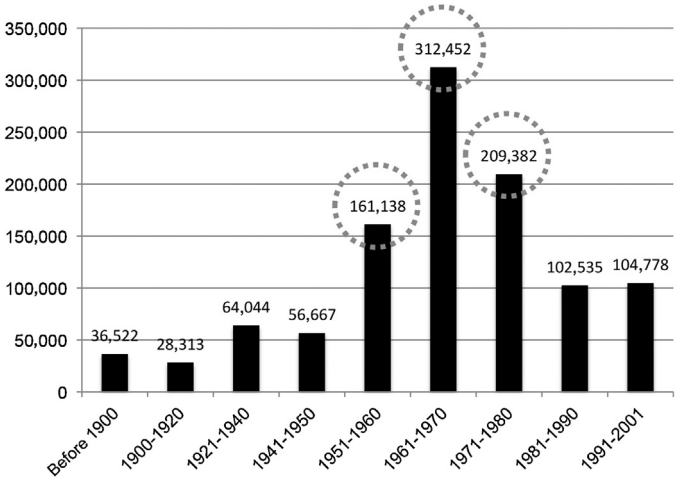

Fig. 2. Number of buildings per year of construction in Madrid [7].

2. Procedure to classify different types of facades

In order to facilitate the comprehension of the procedure, a case study has been introduced through the methodology. This case study is framed on a selected period of time, between 1950 and 1980, in a neighborhood in the city of Madrid called Los Ángeles, where SHERIFF project is being developing and thus more information is available.

2.1. Study period selection

Building information is usually provided by Public Administrations and to obtain this data can become an arduous process. Moreover, the existing residential building stock is so large and varied in Spain that defining a study period is essential. A chosen period provides the researcher with the building construction types and facilitates his concentration on the changes of thermal behavior due to different layers of the facades [6]. By knowing the thermal behavior, it is possible to provide a better solution on how to upgrade the energy efficiency for each type of facade. Once developed, the methodology for classification can be applied to any study period.

In order to define the study period, most representative historical periods have been selected considering the following aspects: milestones in Spanish technical standards, data collected by the National Statistics Institute, and relevant historical data. The classification of buildings was initially based on the year of construction [6]. The number of buildings was obtained from data taken from the National Statistics Institute (see Table 1).

The case study period chosen was between 1950 and 1980 because in that period there was a large increase in housing construction (Fig. 2). In Spain, these homes account for more than 8.5 million households, representing more than 35% of the national total [9]. Additionally, in 1979 the Basic Thermal Conditions in

Table 1
Total dwellings per type of building from different periods and percentage of each category of the total building stock [8].

	Single unit houses		Multi unit houses		Total	
Before 1900	767.656	11%	554.412	4%	554.412	4%
1900–1920	354.954	5%	369.027	3%	369.027	3%
1921–1940	405.196	6%	498.539	4%	498.539	4%
1941–1950	435.942	7%	548.948	4%	548.948	4%
1951–1960	679.882	10%	1.305.565	9%	1.305.565	9%
1961–1970	761.201	11%	2.910.774	21%	2.910.774	21%
1971–1980	1.084.141	16%	3.888.633	27%	3.888.633	27%
1981–1990	1.096.051	16%	1.781.978	13%	1.781.978	13%
1991–2001	1.097.568	16%	2.282.988	16%	2.282.988	16%