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Simulation-based method to determine climatic energy strategies of an adaptable building retrofit façade system

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ABSTRACT

Vast amounts of the European residential stock were built with limited consideration for energy efficiency, yet its refurbishment can help reach national energy reduction goals, decreasing environmental impact. Short-term retrofits with reduced interference to inhabitants can be achieved by upgrading facades with elements that enhance energy efficiency and user comfort. The European Union-funded Meefs Retrofitting (Multifunctional Energy Efficient Façade System) project aims to develop an adaptable mass-produced facade system for energy improvement in existing residential buildings throughout the continent. This article presents a simplified methodology to identify preferred strategies and combinations for the early design stages of such system. This was derived from studying weather characteristics of European regions and outlining climatic energy-saving strategies based on human thermal comfort. Strategies were matched with conceptual technologies like glazing, shading and insulation. The typical building stock was characterized from statistics of previous European projects. Six improvements and combinations were modelled using a simulation model, identifying and ranking preferred configurations. The methodology is summarized in a synoptic scheme identifying the energy rankings of each improvement and combination for the studied climates and façade orientations.

1. Introduction

1.1. Background and significance

Although new and highly demanding regulations concerning energy use have been developed in the European Union (EU), Switzerland and Norway, a large part of their existing residential building stock was constructed when building regulations had a limited energy scope. The European residential stock grows at only 1% per year [1], thus minimizing the impact of new legal requirements. Therefore, retrofitting the existing residential stock in order to achieve sustainable development and zero-energy buildings provides particular opportunities and challenges towards research for new systems that correctly apply energy strategies to achieve high savings [2,3], expanding options that need to be incorporated into national construction policies [3,4]. Not only consumption and emissions will be significantly reduced, but occupants can improve their thermal comfort conditions, as at present older buildings usually do not have energy-efficient options for thermal conditioning. Energy renovations also increase the perceived economic value and appreciation of the property [5].

Given the extremely large number of affected buildings, a different approach from traditional renovation is needed in order to obtain energy savings and emission reduction results in a significant time frame. Traditional renovation methods have extended execution time and prolonged disruption of inhabitants' lifestyle. Punctual actions can therefore be more appropriate. One option is to start from the façade, as residential envelopes account for 20–30% of total energy consumption [6].

Use of prefabricated elements to achieve energy savings to improve existing residential buildings has been suggested as EU policy, since it is a viable solution to accelerate the process [7]. However, commonly found prefabricated systems have setbacks such as limited design options or adaptation to unexpected geometries and a generic appearance regardless of location. Due to the lack of a coherent methodology to determine energy strategies, most systems lack adaptation to different climatic zone requirements. Another challenge is that the end-result has to perform as close to a new building, even if characteristics of the original building go against energy efficiency. Additionally, due to the large influence of the built environment on energy consumption and

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emissions, older buildings need to be adapted for flexibility to respond to possible climate change and new energy use patterns generated by it [8].

1.2. Brief description of the system

The EU-funded project Meefs Retrofitting (Multifunctional Energy Efficient Façade System) [9] has as objective to develop a prefabricated façade system for energy saving in European apartment buildings needing renovation, addressing EU energy reduction policy objectives. The system is intended to be modular and adaptive, in order to support many technological and structural options in a single system to be used in multiple climates. It will also address the shortcomings of traditional prefabricated systems. The concept is illustrated in Fig. 1, where “technological units” represents the areas where technical systems will be installed within the system as needed. The project involves a total of 16 partners from industry and academia.

1.3. Objective and brief description of research steps

This article focuses on the methodology to determine the most appropriate energy strategies and their combination that a modular system has to meet according to each climatic region in the continent, using as example the Meefs system.

For effectiveness, cost and time saving, a simplified method is needed at the very early stages of the project, in order to identify correctly adequate technologies that may be applied in multiple situations in order to maximize energy savings. This method helps to overcome uncertainties typically found at the beginning of large residential retrofit projects, in order to decide the feasibility of going ahead with refurbishment actions. The model was calibrated by taking into account weather characteristics, constructive features categorized in European-wide databases with physical and energy performance of similarly documented buildings [10–13], as well as by using a reliable energy calculation engine that has been verified against existing buildings. Simplified methods optimize the correct application of energy strategies by summarizing the results of previous analysis [14,15]. These steps also correspond to the first research stage of the Meefs project. Energy strategies will be translated into specific technologies to be assigned into modular units having specific structural capabilities for fixation on different types of external walls. They also allow technology combinations according to each climate zone.

In order to pass from the conceptual to the production stage, assumptions on the housing stock were made. A large number of computer simulations through a well-validated model were used as a tool to obtain data to evaluate performance of each of the theoretical design strategies, as well as their combinations as described in the following sections. Strategies were ranked using this data, using a system that allows designers to rapidly prototype and decide on specific solutions based on a range of project conditions such as location and non-energy constrains such as budget or local normative.

The second stage of the project, to be carried out in the near future, foresees implementation and monitoring of the system in an inhabited apartment building located in Spain. The results of the monitoring will allow the verification of the accuracy of the simulations to predict real performance of the technological units under real conditions, and perform adjustments if necessary. The selection methodology will be translated into a computer selection system for designers and end-users that will also incorporate economic aspects of each technology. The interaction of economic aspects with energy savings is still under research.

2. Depiction of the existing situation

2.1. Classification of weather types

The European continent presents a large variety of local and regional climate characteristics; each weather type is designated differently by every country. A uniform system based on the Köppen-Geiger classification was used to understand better which strategies are appropriate for each climate at the continental level. Observed data for the period 1976–2000 was used [16,17] for similarities and differences between climates which were compared with HDD (heating degree days) and CDD (cooling degree days) for representative cities. This led to identify three main climate distributions:

The North climate zone corresponds to Dfb, Dfc and Cfa climate types, with HDD values higher than 3000. It includes Scandinavian and Baltic countries together with those in Central and Eastern Europe.

The Centre climate zone corresponds to the Cfb climate zone, with HDD day values between 2500 and 3000. It includes the Benelux region, France and the United Kingdom.

The South climate zone corresponds to Csa and Csb climate types. HDD day values are lower than 2500. It can be found in the Southern part of the Iberian Peninsula and most of the Mediterranean Basin.

A total of 13 urban centres were chosen to represent the different climates, used as basis to study local construction

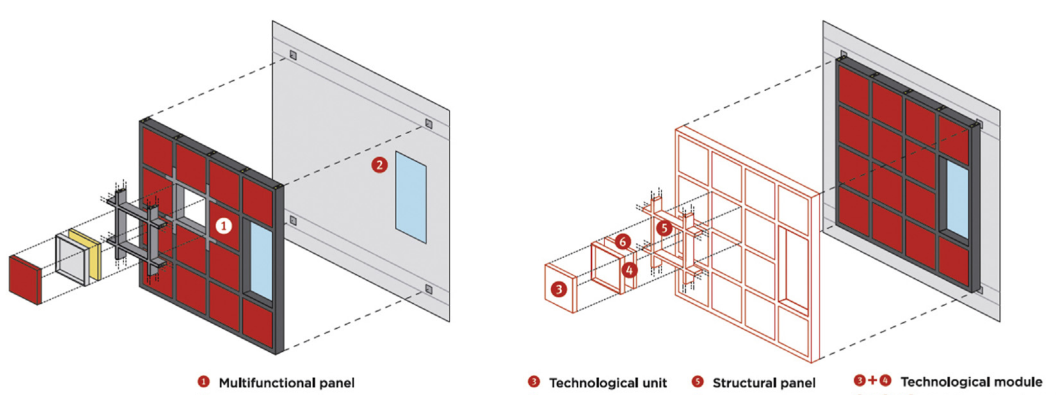

Fig. 1. Conceptual scheme illustrating principles of the Meefs modular system. (Source: Meefs project website http://www.meefs-retrofitting.eu/).