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Adaptive Façade: concept, applications, research questions

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Abstract

Adaptive building envelopes can provide improvements in the building energy efficiency and economics, through their capability to change their behaviour in real time according to indoor-outdoor parameters, by means of materials, components and systems. Therefore, adaptive façades can make a significant and viable contribution to meeting the EU´s 2020 targets. Several different types of adaptive façade concepts have already been developed, and an increase in emerging, innovative solutions is expected for the near future. The objective of this paper is to contribute to these developments by presenting the findings of an analysis of the existing concepts and case studies and by proposing a new approach for characterization of these elements.

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1. Introduction

Recent studies show that in developed countries people spend on average 90% of their time indoor [1]. This trend reflects the large number of requirements of the indoor environment, where buildings assume a key role in ensuring the welfare of people. Statistics are also showing that, in terms of primary energy consumption, buildings represent around 40% in most IEA countries [2]. In this context, it is of fundamental importance to devise strategies for the building stock to achieve the objectives in terms of energy efficiency and climate change set by different countries [3].

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In Europe, one of the most important legislative instruments aiming at improving the energy efficiency of European buildings is the directive 2010/31/EU [4]. A key element of this Directive is its requirements regarding Nearly Zero Energy Buildings (nZEBs). Similar policies were also promoted in other developed countries outside Europe (e.g. USA, and Canada) [5,6]. Taking into account that the façade is the main parameter that influences the energy performance of buildings, façade elements need to be designed to provide the buildings the necessary flexibility needed in terms of energy flow and thermal comfort.

Current standards require building envelopes to behave as energy efficient mechanical systems, able to react to non-continuous, changing external conditions. In practice this means that, to reach the prescribed levels of efficiency and functionality, the façade needs to change or adapt. Therefore, the adoption of adaptive façades provides opportunities for significant reductions in building energy use and CO_2 emissions, while preserving the thermal and visual comfort of occupants. Several different types of adaptive façade concepts (materials, components and systems) have already been developed, and an increase in emerging, innovative solutions is expected in the near future. The goal of this paper is to contribute to these developments aiming at providing a classification of the adaptive façade materials, components and systems according to indoor and outdoor parameters. This analysis is supported by a case studies database [7] and is developed within EU COST Action TU1403 – Adaptive Façade Network [8].

2. Adaptive façades

According to recent research [9], the term adaptive in the context of building façades is often associated in the literature with a long list of similar terms, as shown in Fig. 1. While the meaning of some of these terms in the context of building façades is not entirely clear, the definition of adaptive façade in this study uses as common basis the description according to which adaptive façades consists of multifunctional highly adaptive systems, where the physical separator between the interior and exterior environment (i.e. the building envelope) is able to change its functions, features or behaviour over time in response to transient performance requirements and boundary conditions, with the aim of improving the overall building performance [10].

Fig. 1. Adaptive concept in the literature [9].

According with the above semantic frame, adaptive facades should provide adequate response to changes in internal and external environment to ensure or improve the functional requirements of the envelopes in terms of heat, air and water vapour flow, rain penetration, solar radiation, noise, fire, strength and stability and aesthetics. Therefore, multi-functional adaptive façades should be able to respond repeatedly and reversibly over time to changes in performance requirements and changing boundary conditions. In other words, adaptive façades would be able to provide controllable insulation and thermal mass, radiant heat exchange, ventilation, energy harvesting, daylighting, solar shading or humidity control. Moreover, in the context of nZEB, where the buildings must be