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Towards an ideal adaptive glazed façade for office buildings

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Abstract

The development of dynamic building envelope technologies, which are capable of adapting to changing outdoor and indoor environments, is considered a crucial step towards the achievement of the nearly Zero Energy Building target. The main aim of this work is to present a method for defining the ideal/optimal range of adaptive thermo-optical performance of a glazed façades with different reaction time, in order to assess the potential of future adaptive glazed façades. This is achieved by means of a performance-oriented method, making use of single-objective optimisation, based on the minimisation of the total primary energy consumption. The method is applied to the case study of a reference office room with a fixed window-to-wall ratio in three different temperate climates. The results show that, as expected, the energy savings are inversely related to the façade reaction time. The amount of energy savings is a function of the variability of outdoor conditions and their closeness to the comfort range. The results from this study should be particularly useful for guiding future development of adaptive façade technologies.

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Keywords: adaptive building envelope; optimisation; zero energy building; responsive building elements; high performance facades

1. Introduction

New and more stringent CO_2 emissions targets are established in the 20-20-20 European policy, imposing new challenges for the development of new design methods, concepts and technologies aimed at reducing the energy demand of buildings, while maintaining acceptable levels of indoor environmental comfort. The 2010 EPBD Recast [1] (Energy Performance of Buildings Directive 2010/31/EU) requires that by the end of 2020 (2018 for public buildings) all the new constructions should be "nearly Zero

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Energy Building” (n-ZEB). In order to achieve this objective, two main strategies need to be adopted in the design and operation of buildings: (a) reduce the energy demand within the building, and (b) supply the remaining energy demand by means of on-site renewable energy sources [2].

The building envelope and, specifically, the transparent part of the building envelope can play a significant role in reducing buildings energy consumption and achieving higher level of indoor environmental quality [3]. Such an improvement can be achieved by means of two different design strategies: an *"exclusive"* and a *"selective"* approach. In the "*exclusive"* approach the building envelope is conceived as a *"static"* barrier that excludes the outdoor environment from the indoor environment by means of through a very well-insulated and air tight building envelope. There is however, a limit to the energy savings achievable by the *"exclusive"* approach [4]. Much greater energy savings may be achieved by designing the building form and the envelope as a *“selective”* filter between the outdoor and the indoor environment [4]. The ability to manage and modulate the heat and mass flow in *“selective”* building envelopes may be achieved by making use of *adaptive* or *Responsive Building Elements* (RBE) and systems, that show an active and dynamic behaviour, by passively or actively adjusting their thermo-optical properties in a reversible way in order to adapt to changing outdoor environmental conditions with different reaction times (from seconds to seasonal adaptiveness depending on the technology) [5]. Indeed, of the various energy efficient technologies considered by IEA–ECBCS Annex 44 activity [4], adaptive technologies embedded in the building envelope systems are considered to have the largest potential to minimize the energy consumption of buildings. In particular Double Skin Facades or Advanced Integrated Façades [6], smart glazing [7], movable solar shading [8], phase change materials [9] and multifunctional facades [10] are identified among the most promising adaptive façade systems and components in terms of energy reduction potential.

2. The ideal adaptive façade and the route to next generation adaptive façades

Many research efforts are currently underway in the area of adaptive facades, but several important factors have yet to be established. In particular: (a) the building design parameters and time-scale of the adaptive façade mechanism that have the largest influence on the building energy consumption; and (b) the selection of the most appropriate design and control strategy of an adaptive façade according to the building typology and the climatic location. In order to address these factors systematically it is essential to first define a method to devise the thermo-optical time-dependent properties of an ideal adaptive façade. In particular, the definition of an ideal adaptive façade, according to the climatic location and type of building, can help in defining the most effective time-scale of the adaptive mechanisms, the most effective ranges of variability of thermo-optical properties and the maximum amount of energy saving achievable, thereby making it possible to identify the need and the path to the development of new façade materials, technologies and product.

There have been different research efforts to evaluate the energy saving potential of adaptive building envelope technologies. Some of them, such as Zanghirella et al [11], numerically and/or experimentally compare the performance of a specific adaptive system with a state-of-the-art static façade technology. This approach, namely direct or traditional approach [12], appears to be ill-suited to the research issues presented above, because it evaluates a specific case of adaptive mechanisms (in terms of time scale of adaptive mechanisms and adaptive façade properties) and technology. In the direct approach the performance of a new system/technology is characterized first; a model (or comparative experiment) is developed and the performance of such a system applied to specific cases is evaluated; finally properties of the system/technology or its control strategy are optimized to improve its performance. The shortcomings of this approach are highlighted by Zeng et al. [12], who, in contrast, presents the potential of an inverse approach: the ideal value of one of the thermo-optical properties of the building envelope