Journal of Building Engineering 3 (2015) 135–143

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Façade refurbishment of existing office buildings: Do conventional energy-saving interventions always work?

Francesco Pomponi [a], Eric R.P. Farr [b], Poorang Piroozfar [a,c,*], Jonathan R. Gates [a]

[a] School of Environment and Technology, University of Brighton, Cockcroft Building, Brighton, East Sussex BN2 4GJ, UK
[b] NewSchool of Architecture and Design, 1249 F Street, San Diego, CA 92101, USA
[c] @BEACON (Advanced Technologies in Built Environment, Architecture and CONstruction), Division of Built Environment and Civil Engineering, School of Environment and Technology (SET), University of Brighton, Cockcroft Building, Brighton, East Sussex BN2 4GJ, UK

ARTICLE INFO

Article history:
Received 9 March 2015
Received in revised form
13 July 2015
Accepted 13 July 2015
Available online 17 July 2015

Keywords:
Façade refurbishment
Sustainable retrofit
Office refurbishment
Office buildings
Building energy simulation
Building performance

ABSTRACT

Offices account for 40% of energy use in construction sector. Office building stock is already underperforming and dilapidating at a fast pace. With the current rate of replacing old building stock in the UK, it is expected that at least 60% of what was built before 1985 still exists in 2050. Therefore, refurbishment, with an aim to improve performance of buildings, seems to remain as the most feasible and arguably most cost efficient way forward. Precedent studies in this area are not few and far between. However, some recommendations and interventions seems to have been taken for granted and thought to be globally applicable almost everywhere. This study chooses a recently refurbished office building to challenge this common belief. It was shown that, from the carbon point of view, benefits as a result of interventions were marginal. It was found that a full pre-refurbishment survey, measures aimed at reducing the performance gap between intended and actual figures, and study of occupancy patterns would probably help in this respect. The study results also showed that study of contextual conditions i.e. careful considerations with regards to building orientation, topography, site constraints, and exposure to solar gains will help achieve better results. Finally it was envisaged that better user engagement, communication and using few other measures to enhance user satisfaction will help guarantee some other aspects pertaining to performance than its mere energy consumption or carbon footprint.

1. Introduction

The construction sector represents one of the major contributors to the depletion of finite natural resources across the planet [1–3]. In the UK, buildings account for about 40–50% of all energy consumption and greenhouse gases (GHG) emissions [4–6]. In cities like London, this figure can rise up to 61%, which is substantially higher than the average in the EU (41%) and the US (36%) [7]. More specifically, non-domestic buildings tend to have greater energy consumption per m² of floor area compared to dwellings. Among non-domestic building typologies, offices are one of the major energy consumers [8], accounting for around 40% of the total consumption in the sector [4]. More than 75% of the UK non-domestic building stock was built before 1985, and about 60% of it will still exist in 2050 [9]. In fact, whilst 1–2% of the building stock is newly built each year, the rest is already out there and needs improvement [10]. More specifically in terms of the age of the office building stock, about 80% of the office floor spaces, in all regions of the UK, were built before 1990 [11], with U-values double, if not triple the current levels. Such poor thermal performances, along with the high-density occupancy profile, and the significant internal heat gains due to lighting, appliances and IT equipment, make existing offices one of the most energy intensive building types. In actual fact, they nearly double the sector average for heating, cooling, and ventilation [12]. In terms of CO_2 emissions, offices account for more than 20% of the national figure but there is the technical potential to cut their emissions by up to 80%, implementing solutions which are already available today [9].

In this context, existing office building stock offers a great opportunity for cutting back on greenhouse gas (GHG) emissions and energy consumption [13] and for reducing the negative impact of the construction sector on the environment [14]. Furthermore, those buildings are at the centre of everyday life in the urban fabric hence, if suffering from scarce thermal performance, they could have significant negative impact on economic, social and cultural aspects of their users' lives [8], making the sustained and continuous operation of the existing building stock a "much bigger

* Corresponding author. Tel.: +44 1273 642421; fax: +44 1273 642285.
E-mail address: A.E.Piroozfar@brighton.ac.uk (P. Piroozfar).

http://dx.doi.org/10.1016/j.jobe.2015.07.003
2352-7102/

but less focused question" than new construction [8].

Given façade's role as a physical barrier between the indoor and outdoor environments, interventions aimed at improving its performance are considered as one of the most effective ways to reduce energy consumption of buildings [15] and to enhance their indoor environmental quality [16]. In the continental climate of the UK, additional thermal insulation, replacement of existing windows with high performance glazing systems combined with thermal break frames, and installation of shading devices to reduce cooling loads, are all considered effective refurbishment interventions – just to name a few [17,18]. This research aims at investigating whether and to what extent such a common belief about façade improvements holds true regardless of the context. In doing so, a case study has been selected, simulated and assessed.

The paper starts with a critical review of literature to gauge how façade refurbishment can help improve energy performance in office buildings and how effective such interventions can potentially be. The design research and methodology will follow next to explain how it was tailored to suit the specific target of this research. This leads into the data collection strategies followed by the data analysis. The findings of the selected case study, an office building in south-east England which has recently gone through a major façade refurbishment with an aim to improve its energy performance, will then be discussed and triangulated with the previous work. This will be concluded to show how what seems to have been common expectation in such projects might not prove to be so if some preliminaries are not fully taken account for or if some aspects of the process involved are overlooked. Finally we will provide some suggestions for further research.

2. Literature review

The Carbon Trust [17] states that "the existing [UK] building stock remains largely untouched and many refurbishment projects miss the opportunities to reduce emissions and deliver low carbon buildings". Recently, it is becoming clearer that reducing energy demand through retrofitting buildings deserves to become a priority [19]. Also European regulations see renovations of buildings as a must-take opportunity to enhance energy performance and reduce operational energy consumption [20]. In countries where fossils fuels still dominate, including the UK, operational energy – through its related GHG emissions–is deemed as a major contributor to Global Warming Potential (GWP) [21]. In this respect, innovations in non-domestic buildings in the UK have been estimated to be able to save up to 86MtCO2 by 2050 [22], which is more than 10% of the reduction needed to achieve the 2050 Climate Change Act target [23].

Significant opportunities to deliver such energy-efficient and low-carbon refurbishment undoubtedly lay within improvements to the building envelope [17]. Additional thermal insulation, installation of high-performance glazing systems, and passive measures such as natural ventilation, shading systems, and the use of daylighting are all beneficial interventions in that respect [18]. Some authors suggest that an improved insulation is more important than an increased solar control in existing, poorly insulated office building [12]. There are, however, counter-arguments which suggest traditional means of improving façade thermal performances are likely to increase cooling loads during warm/hot seasons [24].

The upgrade from standard single or double glazing to high efficiency double glazing to reduce heating loads has been considered as the most effective way to reduce the negative environmental impacts as a result of poor performance of old façade components [14]. Reduction in space heating in some investigated cases have been recorded to be as high as 35.5% [14]. Similarly, optimisation in envelope retrofit strategies involving the improvement of both transparent and opaque areas of the façade have been analysed and showed reduction of annual energy consumption by 15% and a decrease in annual CO_2 emissions by 20% [25].

Different retrofitting strategies have also been investigated for different types of office buildings in different climatic regions [24,26]. Amongst those strategies, many relate to elements of the building façade such as the improvement of wall insulation, the replacement of windows and window frames, the use of shading devices, and the maximum deployment of natural ventilation. Such interventions resulted in significant energy reductions for all the office types in all the climatic regions, with values ranging from 20% up to more than 50% [24,26]. Beneficial effects due to façade improvements, related to heating/cooling loads reduction, natural ventilation, and appropriate shading are also echoed by Wong et al. [27] and Jin and Overend [28].

Improved retrofitted fabrics have been also investigated in future scenarios from a climate change perspective [29]. The improved retrofitted fabric can achieve an impressive 61% reduction in terms of CO_2 emissions related to heating, cooling, and ventilation [29].

Finally, when analysed from a life cycle perspective, interventions related to the building envelope have shown capable, in some cases, of reducing life cycle primary energy consumption of up to 53% [30]. To summarise, three main conclusions related to façade refurbishments can be drawn from the studies reviewed:

- Great energy reduction is achievable.
- Significant carbon emissions can be saved.
- Interventions beneficial in one season may have counter effects in other seasons.

This paper will aim to verify whether those generally accepted hypotheses hold true in the selected case study whose full details are introduced in the next section.

3. Research design and methodology

This research utilises a single-case study research methodology with multiple-unit of analysis to investigate a recent sustainable refurbishment project. A case study is an intensive investigation of a phenomenon in its natural setting, and often makes use of a variety of data sources [31]. It is based on a constructivist paradigm [32]. Yin [33] strengthens the methodological legitimacy of case studies by arguing that a "fatal flaw in doing case studies is to conceive of statistical generalisation as the method of generalising the results of the case study" because cases are not sampling units and should be treated as experiments [34]. The primary strength of case study research is its reliance on data enquiry from different sources and multiple data collection techniques. This increases the validity of findings [35] hence the approach of this research; where a multitude of other methods–building energy and fabric surveys, energy simulation using an industry standard simulation software package, energy and carbon assessment and comparison against available benchmarks–have been employed to enrich and deepen the findings, increase its construct validity, internal validity, external validity and reliability [36].

The tool chosen for the Building Energy Simulation (BES) is IES VE (Virtual Environment), a powerful dynamic simulation software tool widely used by academics and practitioners alike. Among the main benefits of IES are its flexibility, a fairly user-friendly interface, and the possibility to address different aspects related to buildings without loss of accuracy and precision. In fact, the software tool is built around different sections that can