ARTICLE IN PRESS

Alexandria Engineering Journal (2017) xxx, xxx–xxx

HOSTED BY ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Retrofitting strategy for building envelopes to achieve energy efficiency

Ingy El-Darwish *, **Mohamed Gomaa**

Department of Architecture, Faculty of Engineering, Tanta University, Egypt

Received 20 March 2017; revised 22 April 2017; accepted 7 May 2017

KEYWORDS

Retrofit;
Energy-efficiency;
Thermal comfort;
Building envelope;
Higher educational spaces;
Simulation tools;
Hot aid zones

Abstract With the excessive energy consumption worldwide, the demand for saving strategies increases. Energy consumption in public buildings increased drastically over the last decade. Significant policy actions towards the promotion of energy-efficiency in the building sector have been developed with different intensity and structure. This study aims at proposing a retrofit strategy in an attempt to improve energy efficiency in a sample of higher educational buildings located in a hot arid climate (Egypt). Retrofitting some of the building's envelope features can provide comfort without compromising functional needs. Comfort needs, which include thermal, visual and acoustical, can reduce energy consumption. Emphasis is placed on thermal comfort in terms of energy efficiency. Some of the important measures used in the retrofitting process of the building envelope include: external walls' insulation, windows' glazing type, air tightness (infiltration) and solar shading. The study results show that simple retrofit strategies such as solar shading, window glazing, air tightness then insulation can reduce energy consumption of an average of 33%. From the feasible envelope features' used in this study, the research provides a suggestion for design codes that maintains thermal comfort, propose a feasible strategy for retrofitting and a baseline reference specifically devised for local energy efficiency.

1. Introduction

Unfortunately, retrofitting of existing buildings in the third world countries focuses on structural or aesthetic measures and mainly on historical buildings for conservation. Reducing energy consumption levels is of equal importance due to its financial impact. It should not be underestimated that a building with better indoor air conditions and low fuel consumption reduces carbon dioxide emissions and pollutes less the environment [7]. Governments around the world have taken strong measures towards the retrofit of existing buildings in terms of improving energy performance. The ODYSSEE database provides a comprehensive monitoring of energy efficiency trends in all the sectors and priority areas to address EU policies [3]. In UK, part of the government strategy is to meet a target of an 80% reduction in the UK's carbon emissions by the year 2050 [18]. The European Energy Performance of Buildings Directive demands a 20% energy savings target by 2020 [2]. In the USA, the Department of Energy (DOE) which participates in both the ASHRAE (American Society of

* Corresponding author.
E-mail addresses: eldarwishi@yahoo.com (I. El-Darwish), msrgomaa@googlemail.com (M. Gomaa).

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2017.05.011
1110-0168

Heating, Refrigerating and Air-Conditioning Engineers) and ICC (Internal Codes Council) development processes, developed and submitted code change proposals that strive to make cost-effective, energy efficient upgrades to current model codes [28]. The recent publication of Standard 90.1-2016 marks the latest edition of the Standard, setting the stage for future building energy efficiency requirements in commercial buildings. The new technical envelope requirements include [1]:

- Mandatory requirements for envelope verification, supporting reduced air infiltration, and increased requirements for air leakage to overhead coiling doors.
- More stringent prescriptive requirements for metal building roofs and walls, fenestration, and opaque doors.
- Improved clarity of exterior walls definitions, building orientation, and clarity around the effective R-value of air spaces.
- New requirements based on the addition of climate zone 0.

Suggestion has been estimated that 75% of U.S. buildings will be new or renovated by 2035. Building energy codes ensure they use energy efficiently over the life of the building. A general overview can be shown in Table 1 which gives a brief summary of building envelope policy assessment of major regions. Some of the high rating regions have building envelope material test, rating and labeling assessment [19].

Currently, Housing and Building National Research Center [17] has published codes for energy efficiency in residential and commercial buildings. Air conditioning system in buildings consumed 56% of total energy consumed in buildings [24]. Energy consumption in Egyptian public buildings, including administrative, educational and health buildings (9%) is the second largest type after residential (40%) [4]. According to the International Energy Agency (IEA) in the USA which defines energy efficiency as a way of managing and restraining the growth in energy consumption a report published by IEA's EBCP states that educational buildings consume high energy and therefore their retrofit is a necessity within this sector [11]. Although it is important to state that energy consumption in educational buildings depends, mainly on the building's activities, time of use and number of students, employees and academic staff.

In most of the retrofit projects, energy efficient retrofit strategies are not applied due to a lack of knowledge about the amount of investment required and the efficiency of the potential energy saving strategies [7]. For many, it is the complexity of retrofit and financing that present a barrier to intervention and uptake [14]. Based on the correct retrofitting strategy improvement of the building envelope energy performance is provided. To understand thermal performance of retrofit the properties of the existing buildings must first be understood [13].

Most of the public buildings specifically educational in hot arid climates consume large amounts of energy. The energy usage is focused on thermal comfort. Simple feasible retrofit variables can provide thermal comfort and hence reduce this energy.

The objective of the study is to investigate experimentally a retrofitting strategy for higher educational building envelopes. This first objective is to evaluate the thermal comfort efficiency and in turn energy performance after adding some feasible retrofit features that reduces energy usage. The second objective is to provide a process for retrofit strategy in higher educational buildings that provides thermal comfort that match with functional standards. These retrofit objectives can be set as a legislative measure for energy efficient educational spaces. Nevertheless, it is essential to set energy efficient and code enforced retrofit measures to start on national levels.

This research adopts an inductive methodology, whereby it starts with a limited definition of the problem and relevant practices and as the work proceeds a clearer perspective is identified. As the research progresses into the application part the multiplicity of challenges unfolds. Specific parameters and factors are cross-examined and checked to reveal a definite course of action and required interventions. These are then taken into consideration and incorporated into a full standpoint and orientation to develop the necessary approach with viable guidelines and solutions.

This paper consists of two parts. The first part presents a theoretical discourse that reviews variables and criteria of retrofitting existing buildings' envelopes and the approaches found worldwide designated to address energy efficiency & achieving thermal comfort in higher educational spaces. This study is an attempt to test & appraise specific notions in the domain of envelope retrofit, as suggested by experiences elsewhere. The main aim is to increase general insight, and to focus more on a conceptual framework of the process.

The later part of study reviews several cases within the specific context of Egypt (defined as hot arid) in order to test the theoretical views on a pragmatic level. Such a multi-step methodology is envisaged to help in better addressing the general research problem in a local climatic context with its precise

Table 1 Building envelope policy assessment of major regions. Source: [19].

Region/Policy	Asian	Brazil	China	EU	India	Japan/Korea	Mexico	Middle East	Australia	Russia	South Africa	USA
Governance	L	M	H	H	M	M	M	L	M	L	M	M
Energy Prices	L	M	M	H	M	H	L	L	M	L	M	M
Infrastructure and human capacity	M	L	M	H	M	H	M	L	M	M	M	H
Commodity of efficient materials	L	M	H	H	M	H	M	L	M	M	L	H
Voluntary programs	L	L	L	M	L	L	L	L	L	L	L	L
Mandatory building codes	L	L	M	H	L	M	M	L	M	M	M	H

Note: H: High, M: Medium, L: Low.

Please cite this article in press as: I. El-Darwish, M. Gomaa, Retrofitting strategy for building envelopes to achieve energy efficiency, Alexandria Eng. J. (2017), http://dx.doi.org/10.1016/j.aej.2017.05.011