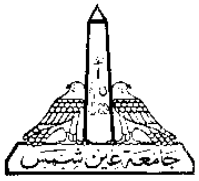

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Architecture Engineering

Energy-Efficient Retrofitting of Residential Buildings in Egypt
An Analytical study of Buildings' Envelopes' Treatments

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Architectural Engineering

by

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Bachelor of Science in Architectural Engineering

(Architecture Engineering)

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Architectural Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Signature

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Energy-Efficient Retrofitting of Residential Buildings in Egypt - An Analytical study of Buildings' Envelopes' Treatments

ABSTRACT

The increasing energy consumption of residential buildings in Egypt, which reached about 42% of total energy consumption in the latest energy statistics, affirms the need for energy-conscious design of buildings. Research fields concentrate on the energy efficiency of new designs and constructions. The real challenge is to retrofit the existing building to limit the exhaustion of energy. This research outlined different energy retrofitting techniques led to a reduction in cooling loads via the building envelope for the existing building. This research aims to evaluate the energy retrofitting measures for buildings' envelope in order to reduce energy consumption in a hot arid climate and propose a strategy for retrofitting an existing residential building envelope according to its economic feasibility. The energy analysis carried out by employing advanced simulation via Design Builder software for a residential building located in Cairo, This case study analyzed the performance of 3 retrofitting scenarios in a residential building façade in the different cardinal orientations each time of simulation, first scenario is changing glass type and color, the second scenario is using different types of cavity walls, the third scenario is the integration between using cavity wall and changing glass type. The model was validated by taking a field measurement to measure and quantify the temperature of a selected room taken within three consecutive days in May and June 2019 and compared to the simulation tool results; the average error percentage was 2.15%. The research also focused on the financial feasibility of the retrofitting investment compared to the return based on the quantitative results of the energy simulation. For this reason, the payback period has been calculated.

Keywords: Energy efficiency, existing residential buildings, energy retrofit, building envelope, retrofitting measure, energy analysis, feasibility study, payback period.

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OVERVIEW

The provision of comfortable and safe thermal conditions for humans inside and outside the building is one of the main objectives of the architectural and urban design. There are numerous architectural trends and attempts to achieve internal thermal comfort to reduce reliance on modern industrial means of heating and cooling such as air conditioners, but The importance of retrofitting the existing buildings' envelope stock must be underlined because it represents the most significant potential for energy savings To reduce the increase in energy consumption in these modern mechanical means.

The process of retrofitting an existing building to increase its energy efficiency should be emphasized on the building envelope, and its efficiency should be more than 50%, and to seek more efficiency, the retrofit must be applied to both the building envelope and heating and cooling machine [1]. Study results showed that a single retrofit such as the use of aerogel in walls and floors could reduce energy consumption by 11.3% while construction costs are 63% higher than average. On the other hand, the use of R-15 XPS foam insulation can reduce energy consumption by 10.8%, and the cost of construction is only 2.3% higher [2]. Another study showed that replacing the glass only in hot-dry climates can save up to 16.5% of total energy while increasing hours of rest in air-conditioned and non-air-conditioned areas. The proposed strategies suggest a range of solutions that reduce energy consumption and open the potential for passive energy retrofit as a base towards zero energy objectives in Egypt and arid countries [3]. In another side, the local study showed that it is possible to reduce the energy consumption of a residential building in Egypt by 23% using shading louvers only, while it can be reduced by only 2% when controlling the airflow through, either when using wall insulation, the effect was not noticeable [4].

Research Problem

The research problem lies in the process of finding the appropriate retrofitting techniques for existing residential buildings' envelope which represent the largest sector of energy consumers in Egypt in the presence of several determinants in the building and surrounding environment that make it difficult to adapt to the task of reducing energy consumption. Moreover, Egypt is a developing country that does not have advanced technology for retrofitting, so the prices of retrofitting the building envelope are

exceptionally high, and that makes it difficult to persuade the homeowners to take the retrofitting decision.

Research Goals

The main objective of the research is to evaluate the energy retrofitting measures for buildings' envelope in order to reduce energy consumption in a hot-arid climate and propose a strategy for retrofitting an existing residential building envelope according to its economic feasibility.

In order to achieve the main objective, some secondary objectives were identified:

1- Studying and analyzing the selected components of the buildings envelop and their impact on building energy consumption rates.

2- Determine which retrofitting measures can be applied to reduce building energy consumption by selecting the most appropriate methods for environmental and economic determinants.

Research Hypothesis

The main hypothesis of the study is that energy consumption in existing residential buildings can be reduced by some simple, cost-effective retrofits applied to the building envelope, thereby reducing the national energy consumption of residential buildings.

Research Methodology

This research is based on a set of research approaches:

Theoretical Approach:

Which is a gradual analysis of the most comprehensive of all the research points under the title of the thesis. These include "energy efficiency, energy saving strategies, retrofitting envelope, building performance simulation tools, and optimization methodologies.

Analytical Approach:

Analytical study of global and local retrofitted residential buildings case studies and the conclusion of some retrofits used to reduce energy consumption and achieve the required energy reduction in a cost-effective manner in the study area.

Applied Methodology:

The practical approach was made through the use of a computer program specialized in the simulation of energy consumption “design Builder”, the simulation applied to the model of a residential apartment in New Cairo city and the assessment of the current building situation was held through a comprehensive survey of elements, components, and systems of the building used. After the addition of each retrofit and write the results of each element separately and make comparison of them in terms of the energy efficiency and price in Egypt the researcher selected the optimal set of retrofits "according to previous results" that can reduce energy consumption by up to 40 in a reasonable price in the Egyptian market.

Research content

The research components are presented in four sections:

Chapter One: " Energy-Efficient Building Envelope "

This section includes the study and analysis of the basic concepts: building energy use, energy efficiency, energy saving strategies, energy retrofitting, and building energy codes.

Chapter Two: " Energy Efficient Retrofitting of Residential Buildings’ Envelope"

It is a part of the study and analysis of the various factors affecting the retrofitting envelope of the buildings, including elements and components to study them in detail study the suitability of each of them for residential buildings in Egypt, Each component of the outer shell of the building was studied in detail, and the treatment methods has been studied separately for each component, considering previous studies conducted on this subject. Then local and global case studies related to this research scope were studied and analyzed.

Chapter Three: " Case Study- Residential Building in New Cairo City"

This case study analyzed the performance of 3 retrofit scenarios in a residential building façade. The case study is not intended to be representative of all the potential retrofit options in a residential building. Models are created for the base case (pre-retrofit model) in four orientations and three façade retrofit scenarios for each orientation to analyze the data for

retrofitting a residential façade in terms of energy use. The case study considered the retrofitting initial cost as an investment and studied its financial return to the homeowner in order to make it easier for the owner to make the decision, whether to retrofit the façade or not.

Chapter four: "Conclusions and Recommendations."

This section deals with the findings of the thesis and recommendations for retrofitting of buildings envelop to achieve energy efficiency and recommendations for the homeowner and further researches.