

Article

Estimating Optimal Cost, Insulation Layer Thickness, and Structural Layer Thickness of Different Composite Insulation External Walls Using Computational Methods

Mohammed R. A. Alrasheed 

Department of Mechanical Engineering, College of Engineering, King Saud University, Riyadh 11421, Saudi Arabia; mohalrasheed@ksu.edu.sa

Abstract: All the modern gadgets and space conditioning in buildings consume lots of energy. Energy consumption can be optimized using Composite Insulation External Walls (CIEW) built from mortar plaster and structural and insulation layers. This study aimed to improve the overall performance of CIEW by optimizing the structural and insulation layer thickness. The objective was to minimize the Life Cycle Cost (LCC) and maximize the Life Cycle Savings (LCS) of CIEW. The nonlinear Least Squares Estimation (LSE) optimization technique for optimizing LCC and LCS of CIEW was used in the study. The study considered three insulation materials—Extruded Polystyrene (XPS), Rock Wool (RW), and Glass Wool (GW)—across three heat sources, including Circulating Fluidized Bed (CFB), Grate-Fired Boiler (GFB), and Air-Source Heat Pump (ASHP). The Life Cycle Cost Analysis (LCCA) methodology suggested by Huang using a traditional optimization technique was used as a basis for mathematical formulations and result comparison. The payback period of CIEW with optimal structural and insulation layer thickness was computed. The findings revealed that applying the LSE method enabled greater economic efficiency than the LCCA method, with an up to 9.12% increase in LCS value and an up to 7.41% decrease in LCC value. The research also revealed significant correlations between insulation and structural layer thicknesses and economic parameters.

Keywords: nonlinear least squares estimation; insulation materials; economic efficiency; architectural design; composite insulation external walls; life cycle cost analysis; life cycle savings; life cycle cost



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1. Introduction

Modern buildings consume one-third of the energy generated worldwide [1]. Space conditioning, i.e., Heating, Ventilation, and Air Conditioning (HVAC) in these buildings, utilizes up to 50% of the consumed energy [2]. Use of thermal insulation in exterior walls is one of the energy conservation strategies [3]. However, determining the optimal thickness for insulating materials has emerged as a challenge. Available research has shown that other than cost-effective insulation thickness for exterior walls, the wall material, geographic location, and even the orientation of the building significantly influence energy savings [4–7]. Enhancing building energy efficiency could yield estimated savings of 20–40% [8].

Existing research in the field of insulation applications emphasizes the importance of a tailored approach that considers multiple factors in a given environment. Ramin et al. [9] highlighted the complexities in determining the optimum insulation thickness for conventional walls, specifically focusing on materials like aerated brick and concrete. Their research findings demonstrate that selecting insulation materials and their positioning can lead to significant variation in yearly transmission. Rossi et al. [10] undertook an extensive analysis across different climate zones in Iran, employing a Life Cycle Cost Analysis approach. They pointed out the variation in optimal thickness depending on wall type, orientation, and environmental factors. Hou et al. [11] investigated the optimal insulation thickness in the northeastern Sichuan hills of China and corroborated the notion

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