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Effect of nano vacuum insulation panel and nanogel glazing on the energy performance of office building

Muhammad Abdul Mujeebu *, Noman Ashraf, Abdulkarim H. Alsuwayigh

Department of Building Engineering, College of Architecture and Planning, University of Dammam, 31451 Al-Dammam, Saudi Arabia

HIGHLIGHTS

- Polystyrene thermal insulation wall and roof is replaced by nano VIP.
- Double-glazed (DG) window is replaced by nano silica aerogel (nanogel).
- Nanogel glazing alone could save 16% energy consumption compared to DG window.
- Nano VIP in wall and roof has only nominal impact on energy performance.
- The energy-saving potential of nanogel glazing is sensitive to setpoint temperature.

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ABSTRACT

Nanotechnology has proved to be a promising candidate for thermal insulation of buildings. Nano aerogel and nano vacuum insulation panel (VIP) have been widely explored in the recent past, and their viability in buildings remains an ongoing research challenge. Even though a lot of works have been reported from around the globe, the Gulf Cooperative Council (GCC) region, particularly the Kingdom of Saudi Arabia (KSA) – a leading building construction market in the world, has a wide scope of research in this area. This article presents a simulation study on the energy performance of a prototype office building in KSA, by replacing the conventional polystyrene insulation and double-glazing with nano VIP and nano aerogel (nanogel) glazing. The building model was built in Autodesk Revit (version 2015), and the energy simulation was performed by ECOTECT software (version 2011) by using the weather data of Dhahran. Considering polystyrene insulation in walls and roof and double-glazed windows as the base case, nanogel and nano VIP were employed individually, and in combinations of window, wall and roof. The results show that, compared to the base case, the nano VIP in walls and roof and nanogel glazing in windows could jointly save about 18% of annual energy consumption of the building, wherein the contribution of nanogel glazing alone is 16% for the setpoint temperature (ST) band of 19–27 °C. The sensitivity analysis has revealed that the energy saving potential of the nanogel glazing is sensitive to the ST band.

1. Introduction

The energy-efficiency requirements for buildings lead to the increase of the insulation thickness for traditional insulations materials [1], and vacuum insulation panels (VIPs) have been introduced as one of the viable options to address the demand for thinner and high performance insulation materials [2–5]. The introduction of VIPs to building industry dates back to 1990s, and their relatively low thickness (5–50 mm) that could replace conventional insulations of up to 250 mm is the most attractive feature [6]. The thermal resistance of VIPs is up to ten times higher than the conventional insulation materials such as polystyrene of comparable thickness [1,7–10]. The long-term properties and the durability of VIPs were observed to be acceptable for a wide variety of operating conditions, and detailed characterization and testing with real applications is an ongoing research challenge [11]. Many researchers have been active in the characterization of VIPs with different envelope and core materials under various operating environments [8,11–28]. Tenpierik and Cauberg [29] performed numerical simulations to study the effects of integrating a VIP into an insulation board and found that there existed a certain maximum thickness of VIP for optimal thermal performance. Also the researches carried out within IEA/ECBCS Annex 39 'HiPTI – High Performance Thermal Insulation' have contributed substantially

* Corresponding author.
E-mail addresses: mmalmujeebu@uod.edu.sa, mamujeebu@gmail.com (M. Abdul Mujeebu).

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Table 1
Specifications of the study building.

Item	Specification
Type	Office building
Location	Dhahran, Saudi Arabia
Floor area	200 m^2 (10 m × 20 m)
No. of floors	1
Floor height	3.8 m
No of occupants	19
Office hours	7 a.m–6 p.m.
Window to wall ratio	1:4
Orientation	North–South
Base case insulation	Polystyrene foam for wall and roof
Windows	DG with aluminum frame

to the topic [30]. A comprehensive account of the conventional and emerging building insulation materials and their relative merits and demerits was provided by Jelle [31], while Baetens et al. [32] and Alam et al. [33] provided exclusive reviews of VIPs, with special focus on application to building envelopes. Detailed insights into the heat and mass transfer phenomena across VIPs filled with nano-porous silica and their modeling aspects were given by Bouquerel et al. [2,34]. Recently, Kalnæs and Jelle [35] presented a state-of-the-art review of commercially available VIP products and the research challenges ahead.

The thermal performance of VIPs depends basically on the envelope (gas barrier/foil facer) and the core material [36,37]. The future research should focus on developing VIP envelopes capable of preventing air and water vapor penetration into the

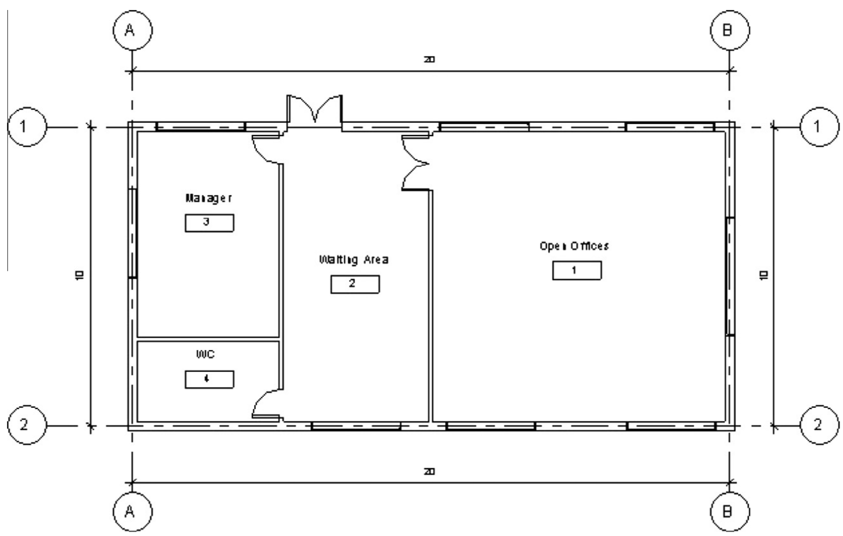

Fig. 1. Plan of the study building.

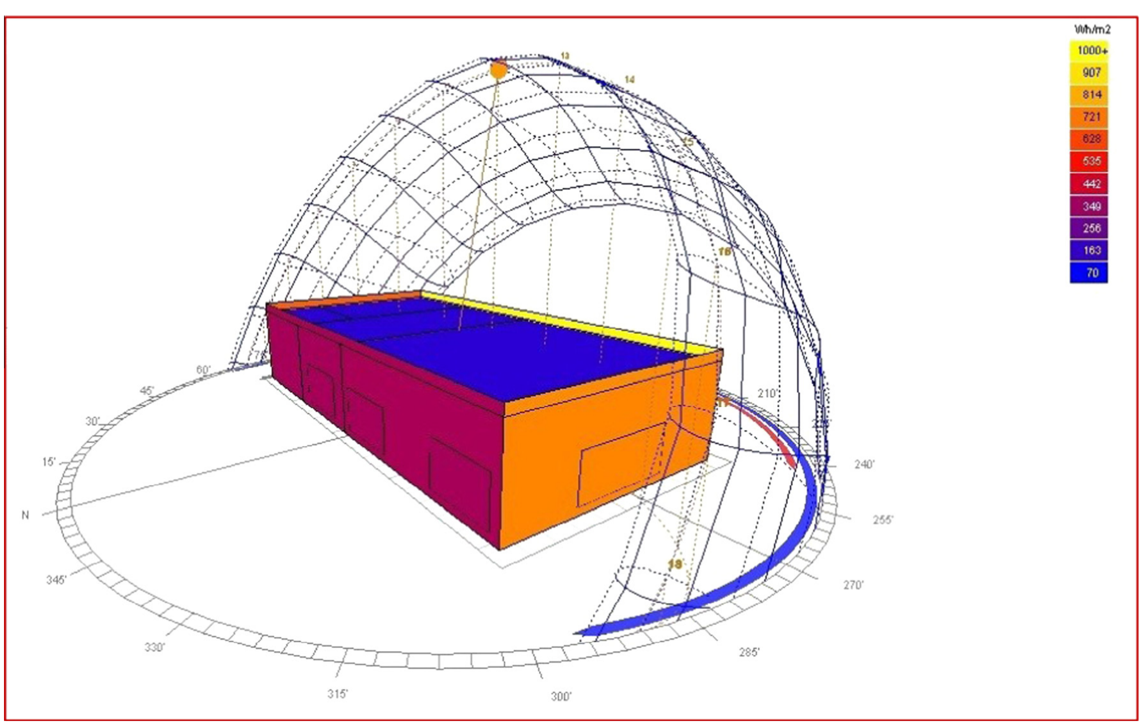

Fig. 2. The 3D simulation model with solar incidence profile.