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Analysing Heat Flows Through Building Zones in Aspect of their Orientation and Glazing Proportion, under Varying Conditions

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Abstract

One of the most important objectives in building design is to achieve acceptable indoor comfort levels with minimum energy requirements. To accomplish this, firstly a serious consideration must be given to various construction and design parameters, such as the building's envelope structure and shape, its orientation, as well as the climatic data of the region. Secondly, as the envelope heat transmission contributes to the heating and cooling loads, the incorporation of an adequate heating, ventilating and air-conditioning system (*HVAC*) must be considered. In this study, the effect of the thermophysical properties of a brickwork layer and the thickness of a thermal insulation layer, on the heat flows of a building zone with a varying orientation, is determined. This building zone, having a specific outline geometry, is exposed to winter conditions that correspond to the northern region of Greece (Thessaloniki). The heating loads are assessed for different indoor temperature settings within the building enclosure, while the operation of the system is assumed to be continuous. Although some other aspects could be considered, this study also stresses to the importance of incoming solar radiation by glazing surfaces on the internal surfaces of the studied building zone; the above solar heat gain analysis relies on the sunlit-pattern approach. The foregoing presentation is concerned with varying proportions of glazing surfaces to the total wall surface. As it is shown, the consideration of the above issues is influential to maintain an acceptable indoor environment, while decreasing the heat flow exchanges through building envelopes. For the purposes of this study, a lumped thermal-network model incorporating several heat flow paths has been employed (transient thermal analysis).

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Keywords: thermal analysis/modelling; building zone; orientation; glazing proportion; indoor temperature settings; heat gains/losses.

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Nomenclature

A	surface area [m^2]
d	layer thickness [m]
λ	thermal conductivity, heat transfer coefficient due to conduction [W/(m·K)]
ρ	bulk density [kg/m^3]
C_p	specific heat capacity at constant pressure [MJ/(kg·K)]
$\rho \cdot C_p$	volumetric heat capacity [J/(m^3·K)]
h_e	exterior surface heat transfer coefficient due to combined convection and radiation [W/m^2·K]
h_i	interior surface heat transfer coefficient due to combined convection and radiation [W/m^2·K]
R	thermal resistance [K/W]
C	thermal capacitance [J/K]
q_{sol}	solar radiation [W/m^2]
α_{sol}	solar absorptivity of building material (external coating exposed to the ambient environment) [-]
τ_{sol}	solar transmissivity of glazing [-]
U-value	overall heat transfer coefficient of opening [W/m^2·K]
E_{SHG}	solar heat gain through glazing [kWh]
T	temperature (ambient-air T_o, indoor T_{in} and sol-air T_{sa}) [ºC]
Q	heat flow [W]
Δt	time step [s]
$E_{G/L}$	heat gain or heat loss due to glazing [kWh]
ω	angular frequency, rotational velocity [rad/s]
v	ordinary frequency [cycles/s]
P	day period, where P = 86400 [s]

1. Introduction

Fossil fuel consumption in buildings to provide comfort conditions in the cold weather can disturb ecological balance, while environmental pollution endangers life. In recent years, one of the most important and essential objectives in building design is to attain acceptable indoor conditions and reduce energy consumption and its adverse consequences on the environment. Therefore, the determination of the energy requirements of building envelopes is increasingly receiving special attention. The literature from this area is very comprehensive; a number of studies aiming to investigate and improve the thermal performance of building envelopes have been reported over the years.

Up to now, several studies have dealt with the effect of varying environmental and operating conditions on the energy demands of buildings. Building thermal performance is mainly due to the aggregate behavior of building materials and their structure; the geometrical characteristics and the thermophysical properties of building materials, as well as glazing surfaces have a very profound effect on the energy efficiency of buildings. Ozel[1] analysed numerically the effect of insulation location and thickness on the heat transfer characteristics of building walls by using an implicit finite difference method under steady periodic conditions. In another study, Sami Al-Sanea et al.[2] have determined the optimum *R*-values for building walls under the climatic conditions in the Kingdom of Saudi Arabia (KSA). On both papers and the references quoted therein the influence of building configurations on the thermal response of building envelopes is revealed. Another related study by Kontoleon and Bikas[3] focuses on the influence of the zone's indoor temperature settings on the cooling/heating loads for fixed and controlled ventilation; in this work a thermal – network model was employed. More recently, Ozel[4] investigated numerically the effect of indoor design temperature on cooling and heating transmission loads through walls with a varying orientation (over the whole year for climatic conditions corresponding to Elazığ, Turkey); this work was carried out by adopting an implicit finite difference method under steady periodic conditions. However, these papers neglect the impact of solar radiation on the thermal behaviour of buildings. The assessment of solar heat exchanges through glazing surfaces is