Investigation of Thermal Behavior of Different Common Roofing Systems in Buildinings Using Computational Fluid Dynamic Method

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Extended Abstract

Introduction: In the past decades, significant energy consumption of fossil fuels had damaging impacts on the atmosphere. Buildings currently consume 40% of total energy use. Also, heating, cooling, and ventilation of buildings are responsible for 35% of total energy consumption of buildings and for approximately 40% of total direct and indirect CO2 emissions. Therefore, the reduction of energy loss through walls, roofs, and windows as well as the improvement of performance of air conditioning systems are the key solutions to lowering energy use. In this study, the influence of different roofing systems, commonly used in Iran, on the thermal behavior of building's envelope is examined. The results were presented based on the equivalent thermal conductivity, heat lag, and decrement factors.

Materials and Methods: To assess the impact of buildings' roofing systems, common types of roofing available in Iran market were employed, namely beam with clay, light weight concrete, polystyrene blocks, and Uboot systems. Furthermore, different air cavities were inserted into clay blocks to study the impact of air container's sizes and orientations on the thermal characteristics of roofing systems. To analyze the effects of the span, two different types of roof's span were considered in computations. These spans were assumed to be 6m and 8m. Also, to have fair comparison among the systems, similar boundary conditions were used in calculations assuming that the indoor temperature was kept constant at 25C and outdoor temperature varied with time. In order to decrease computational time, symmetrical boundary conditions were imposed on different geometries. For cases with air containers, convection and radiation heat transfer is considered. Moreover, conduction heat transfer was modeled in solid materials. Structural and unstructured meshes were used for discretization depending on the curvature of solid's boundaries.

Results: The present results were compared against available numerical methods, and good agreement was concluded. From numerical computations, it can be stated that when the number of air containers increases, the equivalent thermal conductivity decreases; this event can occur due to the impacts of walls' cavities on the decelerating of the flow field as well as on the thermal radiation transfer lowered as walls act like a radiation shield. Moreover, for roofs with polystyrene blocks, the lowest value of equivalent thermal conductivity was obtained. This might be due to the fact that thermal bridges are considerably removed in this type of roofing system. To compare the impact of block materials, the researchers considered clay and light weight concrete in computations. It was found that under similar conditions, the light weight concrete showed lower value of equivalent thermal conductivity in contrast with blocks made of clay; this difference could be due to two main factors: first, smaller thermal conductivity of the light weight concrete against the

clay; second, smaller air cavities for the case with the light weight concrete. The worst case in terms of the equivalent thermal conductivity among the studied systems is Uboot roofing. The present results displayed that the equivalent thermal conductivity of Uboot roofing system was almost four times larger than that of the polystyrene blocks both in winter and in summer. Another important parameter for the energy consumption of buildings and the capacity of air conditioning systems is time lag, which represents the delay time between the maximum outdoor temperature and the maximum cooling/ heating load. From the present results, it can be stated that a roofing system with clay blocks and the highest number of air cavities gives the maximum delay time which is favorable. To The reason lies in the lower value of the equivalent thermal conductivity and heavier weight of the block compared with other roofing systems. Apparently, as thermal conductivity decreases, the heat loss through the roof drops; also, the heavier weight of the block results in higher heat capacity and, consequently, more energy storage inside the body and less energy loss with time. Finally, thermal-mass efficiency is an important factor to describe the thermal characteristics of buildings' envelope. As expected, roofing systems with polystyrene blocks give the best thermal-mass efficiency because this type of systems yields the lowest value of equivalent thermal conductivity and mass. As the equivalent thermal conductivity decrease, the thermal resistance increases such condition is desirable in buildings since it decreases the energy consumption of buildings as well as the capacity of air conditioning systems.

Discussion and Conclusion: In this study, differential governing equations of the conjugate heat transfer of air enclosures and solid materials were numerically solved through ANSYS FLUENT software using the finite volume method. The findings of the present work have shown that the overall heat transfer coefficient decreases as the thermal conductivity of materials of roofing systems decreases. Roofing systems with polystyrene blocks deliver the lowest values of the equivalent thermal conductivity both for 6m and for 8m span. Moreover, Uboot roofing systems have the worst thermal characteristics in terms of the equivalent thermal conductivity. It is recommended that the equivalent thermal conductivity and the thermal-mass efficiency of the buildings' envelope be analyzed prior to the construction in order to decrease the charge of energy for cooling and heating of buildings and to lower the initial cost for buying air conditioning equipment.

Keywords: CFD, building envelope, equivalent thermal conductivity, heat lag.

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