IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)
ISSN (P): 2347-4599; ISSN (E): 2321-8843
Vol. 5, Issue 7, Jul 2017, 65-70

THE INFLUENCE OF POROSITY ON THERMAL COMFORT IN AN ISOLATED HABITAT OF THE ROOF BY A POROUS MEDIUM

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ABSTRACT

The large share of energy consumed for the heating or cooling of buildings has led researchers to address the issue of heat exchange between the premises and the environment.

Since much of the heat loss occurs through the roof, insulating materials slow down heat transfer through the building envelope. The quality of the insulation required depends on the climate, the exposure of the roofs and also the materials used for the construction. The choice of a material used as insulation depends naturally on its availability and cost. In this study, we propose to analyze the heat transfer in a ceiling-insulated building by a porous medium (glass wool), based on the effect of porosity on the heat exchange of the building and the external environment. For this purpose, Multiphysics-based Comsol software based on the finite element method was used to solve the equations governing heat transfer in the fluid medium as well as the porous medium. The results will be in the form of current lines, isotherms, temperature profiles and Nuselt numbers

KEYWORDS: Darcy-Brinkman, finite elements, inclined roof, porous medium, thermal insulation

INTRODUCTION

Most building materials have a porous structure in which water in liquid or vapor form can be stored or returned to the surrounding environment. Computer simulations make it possible to study the thermal performance of buildings offering the possibility of improving the design by integrating insulation of different type. The research carried out in this work also aims to use modeling tools to predict the thermal behavior of a building to the presence of an insulator in a porous medium. In this study, we propose to analyze the effect of porosity on heat transfer in a ceiling-insulated building by a porous medium (glass wool).

Physical Model

The physical model studied is represented in FIG. 1. It is a habitat with an inclined roof simulated by an enclosure with a height H and a length L on the roof of a porous layer of thickness Ep and saturated by a fluid the air). The vertical walls are kept adiabatic and impermeable (Neuman conditions), the left wall belongs to a window through which a heat flow passes, while the floor is subjected to a Dirichlet condition (temperature) and the roof has a heat flux q.

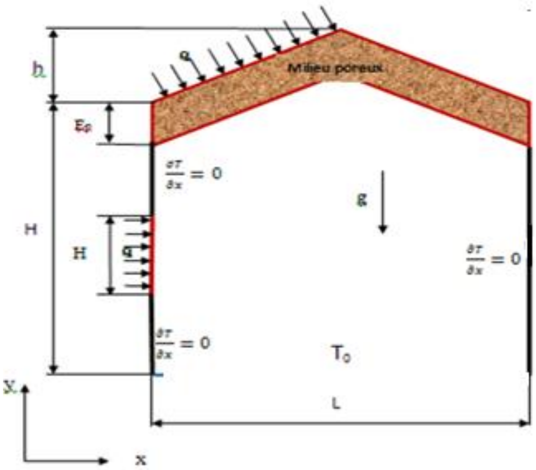


Figure 1: Problem Geometry

THE INFLUENCE OF POROSITY

To describe the effect of porosity ε on the flow structure and heat transfer, the following parameters: (h, H, L, Ep)

MATHEMATICAL FORMULATION

Glide area

$$\frac{\partial u^*}{\partial x^*} + \frac{\partial v^*}{\partial y^*} = 0. \ (1)$$

$$\frac{\partial u^*}{\partial t^*} + u^* \frac{\partial u^*}{\partial x^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{\partial p^*}{\partial x^*} + \Pr\left(\frac{\partial^2 u^*}{\partial x^{*2}} + \frac{\partial^2 u^*}{\partial y^{*2}}\right) \ (2)$$

$$\frac{\partial v^*}{\partial t^*} + u^* \frac{\partial v^*}{\partial x^*} + v^* \frac{\partial v^*}{\partial y^*} = -\frac{\partial p^*}{\partial y^*} + \Pr\left(\frac{\partial^2 v^*}{\partial x^{*2}} + \frac{\partial^2 v^*}{\partial y^{*2}}\right) + \Pr \mathrm{Ra}\, T^* \ (3)$$

$$\frac{\partial T^*}{\partial t^*} + u^* \frac{\partial T^*}{\partial x^*} + v^* \frac{\partial T^*}{\partial y^*} = \left(\frac{\partial^2 T^*}{\partial x^{*2}} + \frac{\partial^2 T^*}{\partial y^{*2}}\right) \ (4)$$

Porous area

$$\frac{\partial u^*}{\partial x^*} + \frac{\partial v^*}{\partial y^*} = 0 \ (5)$$

$$\frac{1}{\varepsilon}\frac{\partial u^*}{\partial t^*} = -\frac{\partial p^*}{\partial x^*} - \frac{\Pr}{\mathrm{Da}} u^* + \frac{\Pr R_V}{\varepsilon}\left(\frac{\partial^2 u^*}{\partial x^{*2}} + \frac{\partial^2 u^*}{\partial y^{*2}}\right) \ (6)$$

$$\frac{1}{\varepsilon}\frac{\partial v^*}{\partial t^*} = -\frac{\partial p^*}{\partial x^*} - \frac{\Pr}{\mathrm{Da}} v^* + \frac{\Pr R_V}{\varepsilon}\left(\frac{\partial^2 v^*}{\partial x^{*2}} + \frac{\partial^2 v^*}{\partial y^{*2}}\right) + \Pr \mathrm{Ra}\, T^* \ (7)$$

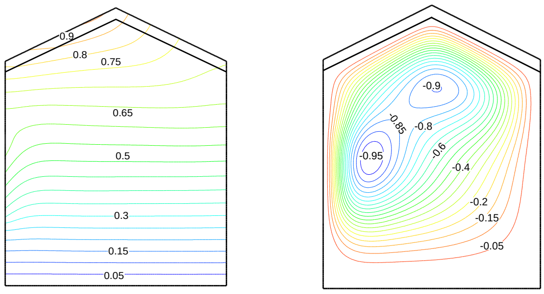
$$\sigma \frac{\partial T^*}{\partial t^*} + u^* \frac{\partial T^*}{\partial x^*} + v^* \frac{\partial T^*}{\partial y^*} = K_r\left(\frac{\partial^2 T^*}{\partial x^{*2}} + \frac{\partial^2 T^*}{\partial y^{*2}}\right) \ (8)$$

RESULTS AND DISCUSSION

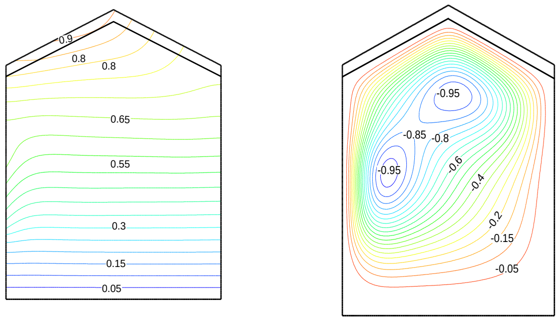
Current Lines and Isotherms

The lines of current shown in FIG. 2 show that, for any value of the porosity the cell deforms and begins to decompose in two, with a value of psi in the top cell which is one may be less. In the case where ε = 0,87. For ε ≥ 0,90 this value increases one can. The effect of porosity and negligible when it exceeds 0.90.

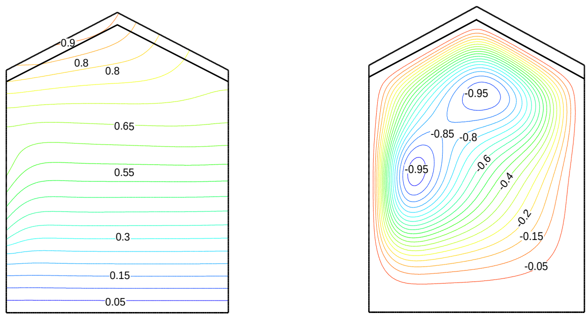
The appearance of isotherms remains almost the same in all cases. The isotherms are almost horizontal in the lower half of the enclosure; the thermal flux is perpendicular to the gravity field, while they begin to tilt on the upper part. The influence of the porosity also appears on the temperature which decreases with a porosity of less than 0, 9.



Porosity ε =0.87



Porosity ε =0.90



Porosity ε =0.93

Figure 2 : Isotherms and Current Lines for Different Values of Porosity

TEMPERATURE PROFILE

From Figure. 3, the temperature falls down to X * <0.2 and becomes constant over the other part of the enclosure, it is found that the temperature gradient increases with the porosity up to ε = 0.90, after which it will be constant. Therefore, the profiles of the temperature will be confused

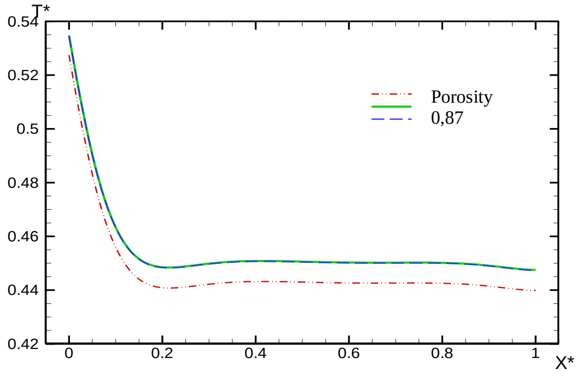


Figure.3. The Temperature Profile at Mid-Height of The Enclosure for DifferentValues of porosity

AVERAGE NUSSELT

From Table 1, it can be seen that, the mean Nusselt increases with the growth of the porosity, and remains the same when it exceeds 0. 90

Table 1. Variation of The AverageNusselt Number as a Function of The Porosity

Porosity	E=0.87	E=0.90	E=0.93
N_{UM}	1.340	1.411	1.410

CONCLUSION

We have presented a numerical study of the transfer of heat by natural convection, in an isolated habitat of the roof by aporous medium. The geometric configuration of the physical model is an inclined roof enclosure, with thermal boundary conditions of Dirichlet and Neuman types.

The variation in the porosity of the insulation, and its influence on heat transfer, has been demonstrated. For a porosity of 0, 87, the minimum heat transfer was found. The effect of porosity on thermal transfer is negligible when it exceeds 0, 90.

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