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Analytical modelling of Breathing Walls: experimental verification by means of the Dual Air Vented Thermal Box lab facility

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Abstract

Breathing Walls are air permeable envelope components based on porous materials. In *contra-flux* operation air flows opposite to conductive flux, while in *pro-flux* they have the same direction. The Breathing Wall behaves either as a ventilation heat exchanger or as an active insulation.

In literature an analytical model describing steady state heat transfer across a Breathing Wall can be found. Since it lacks an exhaustive experimental validation, a facility developed at the Energy Department of Politecnico of Milano was used to investigate the thermo-physical behavior of a no-fines concrete based Breathing Wall in steady state Dirichlet conditions and contra-flux operation.

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Keywords: dynamic insulation; breathing wall; porous materials; experimental validation; laboratory facility.

1. Introduction

Dynamic Insulation technology, also known as Breathing Wall, has been object of study since the early Nineties [1], as a promising approach for energy needs reduction in buildings, and its operating principles have been discussed in earlier works [2] and very recent ones [3].

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Nomenclature

c, c_p	specific heat, *J/(kg·K)*
L	sample thickness, *m*
t	time, *s*
T	temperature, *°C*
u	airflow velocity, *m/s*
x	coordinate along the sample thickness, *cm*
Greek symbols	
ε	porosity, ND
ϕ	diameter, *mm*
λ	thermal conductivity, *W/(m·K)*
ρ	density, *kg/m³*
Subscripts	
f	quantity referred to the fluid phase
s	quantity referred to the solid phase
w	quantity referred to the overall porous medium

Its thermo-physical behavior has been theoretically investigated mainly in steady state conditions [4],[5], providing analytical equations for the temperature distribution in the wall both for Dirichlet and Neumann boundary condition. These equations show a deviation from the linear trend expected in a traditional wall and identify two working conditions with corresponding temperature distributions: contra-flux (airflow and heat flux have opposite directions) and pro-flux (airflow and heat flux have the same direction).

Even though the physical model has been accepted by the scientific community, the few past experimental works present data related to surface temperatures and heat fluxes in contra-flux operating mode [5]-[7], while the overall temperature distribution inside the Breathing Wall section has never been experimentally investigated and validated.

In this study, the thermo-physical behavior of a Breathing Wall in contra-flux operating mode in steady state conditions is experimentally investigated by means of the Dual Air Vented Thermal Box (DAVTB) apparatus. The DAVTB apparatus, preliminary discussed in [8], is presented, along with the thermo-physical and geometrical characterization of a no-fines concrete sample, which was object of experimental investigation. Data about the temperature distribution inside the sample were collected and compared to the corresponding physical model [4], in order to assess its reliability.

2. The physical model

Considering an isotropic porous medium where local thermal equilibrium between the fluid and the solid phase can be assumed, and taking averages over an elemental volume of the medium, the energy equation that takes into account both conduction and advection is given by [9]:

$$(\rho c)_w \frac{\partial T}{\partial t} + (\rho c_p)_f \nabla \cdot (\mathrm{u}T) = \nabla \cdot \lambda_w \nabla T \qquad (1)$$

where T and u are respectively the temperature distribution and the fluid velocity field across the wall (i.e. Darcy velocity), ρ, c and λ are respectively the density, the specific heat (at constant pressure when related to a gas) and the thermal conductivity, referred to the overall porous material (w subscript) or the air only (f subscript). For steady state conditions in a one-dimensional homogeneous porous medium Equation (1) becomes [4]: