Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 81 (2015) 995 – 1004

Energy Procedia

69th Conference of the Italian Thermal Engineering Association, ATI 2014

Application of a novel method for a simulation of conductivity of a building material in a climatic chamber

Giorgio Pia[a], M. Ludovica Casnedi[a], Roberto Ricciu[b]*, Luigi Antonio Besalduch[b], Roberto Baccoli[b], Costantino Carlo Mastino[b], Roberto Innamorati[b], Arianna Murru[a], Ombretta Cocco[a], Paola Meloni[a],Ulrico Sanna[a]

[a] *Dipartimento di IngegneriaMeccanica, Chimica e dei Materiali,Università degli Studi di Cagliari, Piazza d'Armi, Cagliari, 09123, Italy*
[b]*Dipartimento di Ingegneria Civile, Ambientale e Architettura, Università degli Studi di Cagliari, Piazza d'Armi, Cagliari, 09123, Italy*

Abstract

This work proposes the application of a new simulation method based on fractal geometry for the calculation of the thermal conductivity for building materials. The results obtained are compared with the measurement, in a climatic chamber, of the heat flow through a material chosen as the sample. The test sample is made with “pietracantone”, a stone widely used as a building material and as an ornamental stone in the areas of Cagliari and Sassari in Sardinia. This material is characterized by a limestone matrix and a porosity which significantly influences the value of thermal conductivity. It is not known to the authors that this material had already been studied for its thermal properties.

Peer-review under responsibility of the Scientific Committee of ATI 2014

Keywords: Thermal conductivity, Thermal transmittance measurement, Fractal geometry, Pore size distribution

1. Introduction

Buildings energy consumption accounts for a 20–40% of total energy use in developed countries [1], so the correct evaluation of thermal conductivity is an important factor in defining the total energy consumption of heating and cooling systems and achieving optimal thermal comfort for occupants. In particular too little attention is paid to the

* Corresponding author. Tel.: +39-070-675-5379; fax: +39-070-675-5818.
E-mail address: ricciu@unica.it

Peer-review under responsibility of the Scientific Committee of ATI 2014
doi:10.1016/j.egypro.2015.12.158

energy consumption of monuments and historic district. For this reason the authors studied the thermal conductivity of stones that compose this ancient buildings. In Cagliari, stone has been used for the construction of historical monuments, from the 13th century, i.e. wall fortifications, pisan towers etc., to 19th century, i.e. municipal building, still inhabited although in the winter season occur thermo hygrometric discomfort. These buildings are often protected by the Superintendence of Cultural Heritage and it is not possible the adoption of typical modern solutions used for new buildings. For this reasons, it is very important to develop a new method to evaluate physical properties of building materials without damage historical sites. One of these is represented by fractal modelling. Fractals are figures characterized by self-similarity, non-integer dimension, irregularity, etc. They are able to reproduce nature shapes and also microstructures of several materials. So, in this paper we compared two test methods: a new computational fractal method [2-5] for the study of microstructures simulation and a simulation in a climatic chamber using a full-sized walls with realistic inner and outer wall climatic conditions. This procedure is carried out using "Pietracantone" (Canton stone). It is a sedimentary rock (limestone) of Miocene age from Sardinia west coast that in technical terms may be defined as calcareous stone, porous, easy workability, but poor durability if maintained in permanent contact with water. This lithotype is, in terms of porosity and mechanical properties, substantially equivalent to others that have been used, like this one, to build in the monuments of many areas of the Mediterranean.

Nomenclature

k_{eff}	thermal conductivity of sample	[W/mK]
k_{calc}	fractal model thermal conductivity	[W/mK]
k_f	thermal conductivity of fluid	[W/mK]
k_s	thermal conductivity of solid phase	[W/mK]
a	height of the specimen	(mm)
b	width of the specimen	(mm)
h	dept of the specimen	(mm)
i	iteration number to cover porosimetric range	
n	B units number (integer)	
D_f	fractal dimension of Sierpinski carpet	
R_{max}	maximum pore ray dimension	(μm)
R_{min}	minimum pore ray dimension	(μm)
ε	fractal model pore fraction	
ε_{exp}	experimental pore fraction	
C_s	Specific Conductance	[W/m^{2}K]

2. Test Methods

The use of fractal geometry was be used to derive analytical expression to obtain physical quantities and to simulate the porous microstructures, this approach is well known in literature [6- 9]. The fractal geometry is also able to describe the heat transference process, and analytical expression can give thermal conductivity value [10], because the heat flow is influenced by the low volume fraction of the solid phase, by the conductivity of the gas enclosed, by the size of the cell and pores, etc. [11]. In order to identify the thermal conductivity of the Pietracantone, the mineralogical phases which constitute this biomicritic limestone, X-ray powder diffraction analysis were carried out using a Rigaku Miniflex II diffractometer operating with a Cu-Kα monochromatic, wavelength at 15 kV. Mercury intrusion porosimetry is used to know porosity and pore size distribution (Auto Pore IV - Micrometrics). In particular an Intermingled Fractal Units (IFU) procedure was be used, in order to correlate the thermal conductivity of the specimen under test with the pore size distribution.

These values are later compared with those obtained with the experimental simulation in the climatic chamber.