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An Adaptive Neural Network model for thermal characterization of building components

R. Baccoli*[a] , L. Di Pilla[a], A. Frattolillo[a] , C. C. Mastino[a]

[a] *Department of Civil, Environmental Engineering, and Architecture, University of Cagliari, Italy*

Abstract

Building materials are usually characterized in stationary or almost-stationary conditions and mono dimensional heat flow regime. The existing standards (such as ISO 9869 or EN ISO 6946, EN 12664, EN 12667, ISO 8302 etc), require experiments carried out in steady-state conditions, with a very fine control of the measuring parameters with the aim to apply a simple and reproducible procedure for the determination of thermal properties. However, the thermodynamic conditions that lead to a steady-state operating mode and mono dimensional flow are very difficult to obtain (in real conditions) or very expensive and time consuming (in climate chambers). In this paper the authors present the development of a method for thermal characterization of building components, inferring the steady-state conditions, when only measures in transient conditions are available. The method, based on an adaptive linear neural network (ALNN) model also could be have the potentialities to determine the thermal diffusivity from a significant transient behavior ad hoc imposed. The study targets multilayered walls homogeneous and the results are compared with the experimental data measured by a climate chamber that operate according to the standard EN 12667

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Keywords: Transient test conditions; Artificial neural networks; thermal properties identification, inverse problem

1. Introduction

Recently, a growing interest on the adoption of EU Directives in the field of buildings and constructions can be noticed. Consequently, professionals are forced to take care limit performance requirements that the new buildings

* Corresponding author. Tel.: +39 070 6755262; fax: +39 070 6755263.
E-mail address: rbaccoli@unica.it

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must ensure concerning energy, acoustics, lighting and more in general environmental and economic impacts. The European board has recently issued the EU directive “roadmap for moving to a competitive low carbon economy in 2050 [1,2] which lays down recommendations to achieve, by 2015, the 80% reduction of greenhouse gas emission compared with those of 1990.

Nomenclature

Physical quantities
T Temperature throughout the thickness of the wall, [°C]
T_H Temperature in correspondence of the hot side of the wall, [°C]
T_C Temperature in correspondence of the cold side of the wall, [°C]
T_0 Temperature throughout the thickness of the wall at initial time, [°C]
Q_H Heat flux flowing through the hot side the wall, [W/m2]
Q_C Heat flux flowing through the cold side the wall, [W/m2]

Greek symbol
λ Equivalent thermal conductivity of the wall, [w/mK]
cp Specific heat capacity at constant pressure of heat-transfer fluid, [W/(kgK)]
ρ average density of the wall, [kg/m3]
α Thermal diffusivity, [m2/s]

Simulated quantities
$\dot{Q}_{H,ALNN}$ numerically simulated heat flux by neural Neural Network model [W/m2]

In the light of the above task the EU has also defined a strategy for coherent re-search with these objectives. The Strategic Energy Technology (SET) Plan, [3] and the Communication "Investing in technologies low-carbon [3], represent the technological pillar of European policies on energy and climate change. One of the immediately applicable strategies to reach by the goal is the energy efficiency of buildings, as provided for by [4] which introduces and defines the edifice NZEB "nearly zero energy building". and prescribes a set of calculation procedures [5 - 7] which in turn require input certified data.

Three approaches can be applied o estimate U-value in situ, directly on existing buildings [8]:

1. Estimation based on data obtained by “reference buildings” [9] which represent the characteristics of large groups of buildings, classified according to age, size and other specific features. It suffers the increased uncertainty about availability of statistical data on the historical sample of buildings and the lack of an accurate knowledge of materials and of the layers constituting the wall;

2. Estimation based on the nominal design data according to ISO and ASTM standards [7] and [10 - 13];

3. In situ measurements using heat flux meters, whose main error sources may result from the variation of climatic parameters, heat flow and from the temperature gradients through the investigated component during measurements [14].

A fourth approach involves laboratory measurements on samples taken directly "in situ" or reconstructed on the basis of an endoscope method. For such a purpose, the existing standards require the use of specific equipment as guarded hot plates [15 - 17], calibrated and guarded hot box [18 - 20] or heat flux meters [16, 17] and experiments carried out in steady state conditions with a very fine control of the measuring parameters. The aim to apply a simple and reproducible procedure for determination of thermal properties. These methods rely on efficient control of climate parameters, allowing the achievement of almost steady-state operating mode in test environments; but, on the other hand, they suffer from the thermal inertia of the envelope component under investigation that causes very expensive and time consuming tests.