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Estimation of building component *UA* and *gA* from outdoor tests in warm and moderate weather conditions

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Abstract

Accurate knowledge of the thermal properties of building components is necessary to implement adequate energy saving strategies in buildings. Outdoor experiments using test cells are very useful tools for realistic estimation of these properties. This paper describes the analyses performed, and the procedure followed in identifying and solving some problems found when building components are tested for *UA* and *gA* in a test cell under warm and moderate weather conditions. A window component was tested in a PASLINK test cell at the CIEMAT's 'Plataforma Solar de Almería (PSA-CIEMAT)' in Tabernas (Almería, Spain) and several data sets recorded under quite different weather and test conditions were analysed. First the problems identified when applying the usual test and linear analysis procedures are described. Then hypotheses about the cause of these problems are formulated. Afterwards, strategies followed for testing these hypotheses are described. Once the cause of the problems had been identified, they were fine tuned to find a model for accurate *UA* and *gA* estimation. This study demonstrated that nonlinear models, in which long wave radiation is considered as non-linear effect, yield remarkably better performance than the commonly used linear models, for estimating the component *UA* and *gA* values.

Keywords: Building energy; Thermal parameters; Outdoor testing; System identification

1. Introduction

Outdoor experiments in a test cell (Strachan and Baker, 2008), are powerful tools for realistic estimation of the parameters characterising the thermal behaviour of building components. These tests are carried out under real weather conditions, involving dynamic testing, and therefore, dynamic analysis is appropriate.

There are a wide variety of approaches to dynamic analysis with varying complexity and accuracy. All of them require the system modelling and identification techniques to find the system parameters. Some of these approaches have been applied to real buildings (Rabl, 1988), for estimating the thermal properties of building components from in situ measurements (ISO 9869, 1994), and to find U and g values of building components from outdoors testing in test cells (SIC 2, 1996; Gutschker, 2004; Jimenez and Madsen, 2008).

Different analysis and test strategies have been used in attempts to improve the final results of this type of analysis, depending on the final application of the model, e.g., Ghiaus (2006), who reports an interesting method for improving the performance of linear models for estimating the energy performance of buildings. One of the problems sometimes related to this type of analysis is the correlation of the physical quantities involved in the tests, for which experimental design strategies can be of help. One of the goals of the PASLINK test procedure is to overcome this problem in building component tests in outdoor test cells.

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Nomenclature

Measured

P_{aux}	energy supplied to the test room by heating and ventilation (W)

Quantities

G_v	global solar radiation on the component surface (W/m^2)
T_i	test room air temperature (°C)
T_e	outdoor air temperature (°C)
T_{sr}	service room air temperature (°C)
T_{ali}	test room surface temperature (°C)
T_{ale}	exterior surface temperature of the PAS system (Fig. 3) (°C)
ϕ	heat flux through the building component (W)
q	heat flux density through the building component ($W\ m^{-2}$)
ΔT	temperature difference between indoor and outdoor air (°C)
Q_{hfs}	heat loss through the test cell envelope (W)

Parameters

U	heat transmission coefficient ($W\ m^{-2}\ K^{-1}$)
U_i	heat transmission coefficient of part i in Fig. 4 (for $i = 1$–4) ($W\ m^{-2}\ K^{-1}$)
g	solar energy transmittance
A	area of the tested building component (m^2)
H_{sr}	heat transmission coefficient between test and service rooms (W/K)
H_{ali}	heat transmission coefficient between indoor surface and test room air (W/K)
H_{ale}	thermal transmission coefficient between the exterior surface of the PAS system and the test room air (W/K)
C_1	heat capacity of the test room air (J/K)
C_2	effective heat capacity of the indoors test room surface (J/K)
α	fraction of solar radiation transmitted through the tested component that reaches the indoor test room surface (–)
K_2	auxiliary constant coefficient (W/K^4)
K_{15}	heat transmission coefficient between test room air and the corresponding sensor divided by the heat capacity of the sensor (W/J)
K_5	auxiliary constant coefficient ($W/J\ K^3$)
K_{mr2}	auxiliary constant coefficient ($W/J\ K^3$)
K_{mr5}	auxiliary constant coefficient ($W/J\ K^3$)
σ_{ii}	system error for $i = 1,2$ (J)
σ_{ii}	system error for $i = 3,4,5$ (K)
e_i	measurement error (°C)

This procedure therefore includes a ROLBS power sequence (Section 3). However, in practice, this approach may be difficult to implement under warm weather conditions because it sometimes leads to overheating. A concrete case occurred during *UA* and *gA* testing of building components under warm and moderate weather conditions in a PASLINK test cell at the PSA-CIEMAT in Tabernas (Almería, Spain). A noticeable discrepancy was found between expected values and the results from traditional linear models, which were unrealistic and far from expected. A very wide difference with different datasets was also observed. A simplified *component-level* analysis (Jiménez and Heras, 2005) showed that multi-output ARX models produced accurate and significantly better parameter estimates than those of single-output ARX models. However, as reported here, the proposed models did not solve the problems (Section 5) observed in the *test-cell-level* analysis. This paper analyses these problems and describes how we were able to solve them. A window component, described in Section 2, was analysed for this study. The tests were carried out in a PASLINK test cell at the CIEMAT's 'Plataforma Solar de Almería (PSA-CIEMAT)' in Tabernas (Almería, Spain). We conclude that, by considering long-wave radiation as a nonlinear effect, nonlinear models yield remarkably better results than the linear models commonly used for estimating building component *UA* and *gA* values.

2. Test component description

In preliminary observations, problems were found to be more severe at higher indoor temperatures. So in order to see any improvement in the analyses, undesirable effects were highlighted by using relatively strong insulation of the test room to avoid heat loss and a window that would contribute to solar heating.

The test component is an opaque wall with a double-glazed window installed by replacing a removable opaque

Fig. 1. Detail of the opaque part of the test component.