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On site thermal performance characterization of building envelopes: How important are heat exchanges with neighbouring zones

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Abstract

Worldwide, the building sector represents the largest energy using sector, and it is still expanding. To reduce energy use of buildings, policy makers are increasingly demanding with regard to energy efficiency of buildings. Despite best planning effort, in practice some of these demands are not met: studies reveal that a building's energy performance on the design table might differ substantially from its performance when actually built. Typically, an important reason for this difference lies in the delivered quality of a building's insulating envelope.

In this paper, we investigate the characterisation of the overall heat loss coefficient, H, in WK^{-1}, of whole building envelopes on the basis of dedicated heating experiments performed on vacant houses. We focus on steady-state heating experiments performed on buildings that are either terraced or semi-detached and have a floor on ground or unventilated basement. We depart from an extended stationary heat balance, that in addition to heat exchanges between indoor and outdoor environments, also explicitly includes heat exchanges between indoor environment and conditioned neighbouring zones. The first is of interest as it characterizes H, the latter is of interest as it constitutes a phenomenon that is often ignored, but might corrupt the estimate of H significantly.

We show that, for the test buildings considered in this paper, it is advisable to additionally measure heat flows towards neighbouring properties. On the basis of three test cases, we investigate the significance of such heat flows, as well as their influence on the accuracy and robustness of the estimated heat transfer coefficient, H.

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Keywords: Heat transfer coefficient, co-heating test, thermal performance, heat flux

1. Introduction

Worldwide, the building sector accounts for about 40% of total final energy use (Economidou, 2011). It thereby represents the largest sector, and it is expanding. Our building stock thus harbors enormous potential to save energy, and reduce carbon dioxide emissions. In order to reduce energy use of buildings, policy makers are increasingly demanding with regard to the energy performance of new buildings and renovated buildings (European Commission, 2011). A building's actual energy performance essentially depends on three factors: the thermal characteristics of its envelope, the efficiency of its services, and finally, its usage.

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With little exception, the policy makers' demands relate to how buildings are rated in the design phase: a theoretical energy use, calculated on the basis of building plans and specifications, determines the performance category. However, studies show that such a designed performance often differs substantially from the building's actual, as-built performance. Several studies illustrate cases where the building envelope under-performs, both at the scale of individual building elements (Hens et al., 2007) and whole buildings (Bell et al., 2010). Building envelopes might under-perform due to poor workmanship, inadequate building processes, and the use of materials or detail designs other than specified in the project brief.

The building envelope constitutes the integrated building fabric elements that separate indoor and outdoor environment. In this paper we aim to estimate a stationary performance indicator that expresses the amount of heating power that is needed to sustain, over the integrated building envelope, a temperature difference of 1 K, i.e. the overall heat transfer coefficient H, in WK^{-1}. A method commonly used to evaluate H is the co-heating test. This test applies a straightforward linear regression analysis on averaged building performance data, acquired during quasi-stationary heating experiments. During a co-heating test, a vacant building is homogeneously heated to an elevated steady-state indoor air temperature T_i using electric heaters and ventilator fans. During the test, the electrical energy use, indoor and outdoor air temperatures and relative humidities, wind speed and direction, and solar radiation are monitored. By analysing the generated test data using linear regression techniques, we then estimate the building envelope's overall heat transfer coefficient, H, in WK^{-1}. H comprises both transmission and ventilation heat transfer.

Nomenclature

H	Heat transfer coefficient, in WK^{-1}
H'	Heat transfer coefficient, in WK^{-1}, estimated based on model that ignores heating power to neighbouring zones, Φ_n
Φ_h	Heating power to heat indoor environment, in W
Φ_n	Heating power exchange between indoor environment and neighbouring zones, in W
A	Surface area of building fabric that separates T_i and T_e, and T_i and T_g
A_n	Surface area of building fabric that separates T_i and T_n
q	Specific heating power, in Wm^{-2}
T	(Air) temperature, in K
i	Indoor
e	Outdoor
n	Neighbouring
g	Soil mass, or equivalent
<x>	Average value of x
ΔT	Temperature difference T_i - T_e
ϵ	Error term linear regression analysis

We selected three co-heating tests, performed on houses that are either terraced or semi-detached, and have a floor on ground or unventilated basement. For such test buildings, as will be discussed in Section 2, we advise to additionally measure heat flows towards the neighbouring properties, Φ_n. Also in Section 2, we derive one heat balance that only implicitly models the influence of Φ_n, and another heat balance that explicitly incorporates knowledge of Φ_n. For each test case, we use linear regression, to fit respective heat balances to daily averaged co-heating test data. Section 3 briefly introduces the three test cases and depicts Φ_h and Φ_n for each. Estimates of H based on both heat balances in Section 4 illustrate the potential significance that Φ_n has on the estimate's reliability. Based on the limited number of test cases considered in this paper, we formulate guidelines to sensibly organise dedicated heating experiments on buildings that exhibit similar characteristics.

2. Test Scenario

The building envelope is bounded by red and blue lines in Figure 3 and represents the building fabric part that separates the indoor environment, T_i, from the external environment, T_e, and the soil mass, or an equivalent zone, underneath. It does not comprise the fabric part that separates T_i from any neighbouring zones, T_n (ISO 13790, 2008). For instance, it does not comprise party walls between neighbouring properties.

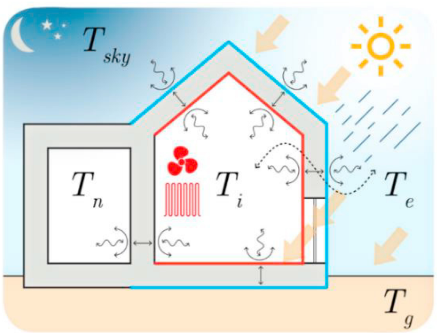

Figure 1: The building envelope separates the indoor environment from the external environment. Apart from the building envelope, there are also building fabric parts that separate the indoor environment from neighbouring zones, or heated adjacent spaces that are not included in the heated volume studied (Bauwens, 2015).