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Heat Loss via Concrete Slab Floors in Australian Houses

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Abstract

Proper evaluation of ground heat loss is important for modern energy efficient residential houses. In this study, a new method was developed for the calculation of ground heat transfer via the floors with vertical edge insulation and validated by three-dimensional numerical simulations. Using a 2.7GHz laptop computer, the calculation of hourly heat losses for one year (8760 hours) using the new method took less than 0.1 milliseconds. The heating and cooling demand for two typical houses in eight Australian state and territory capital cities were then evaluated with vertical floor edge insulation for R0.5 to R2.5. It was found that in relatively cold climates such as Melbourne, Canberra and Hobart, ground heat loss can contribute up to 49% of the total house heating and cooling energy demand. Vertical edge insulation along the external side of the wall can normally reduce around 15% to 25% of this ground heat loss contribution.

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Keywords: Ground heat loss; Ground model; Building simulation; Residential buildings

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1. Introduction

With the continuous thermal performance improvement in the above-ground building components, ground heat loss via the floor becomes increasingly a major heat loss component for slab-on-ground buildings. Researchers have reported that ground heat loss can contribute up to 50% of the annual heating loads for a building [1,2]. Proper evaluation and minimization of this ground-coupled heat transfer (GCHT) is thus important for modern energy efficient building designs, especially for low-rise residential buildings. Since 1940s, GCHT has been the subject of numerous studies. A variety of GCHT calculation methods ranging from simplified heat loss factor, regression-based, analytical and semi-analytical approaches, one-dimensional numerical simulation to detailed two-dimensional (2D) and three-dimensional (3D) numerical simulation methods are available [3-7]. It is noted that each GCHT

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calculation method has its own advantages and limitations. Detailed 3D numerical simulation can provide accurate GCHT calculations. However, the computation time required often prevents it for use in situations when fast design optimisation is required, such as web-based building simulation applications. On the other hand, simplified analytical and semi-analytical GCHT calculation methods can be fast, but only limited for steady state heat losses and transient heat losses for uninsulated floors with simple foundation configurations [7].

In this study, a new model was developed and implemented in a response-factor building simulation tool. Two typical modern detached houses were then used to investigate the impact of ground heat losses in eight Australian state and territory capital city climates with vertical edge insulations at R0.5, R1.0, R1.5 and R2.5 respectively.

2. Methods

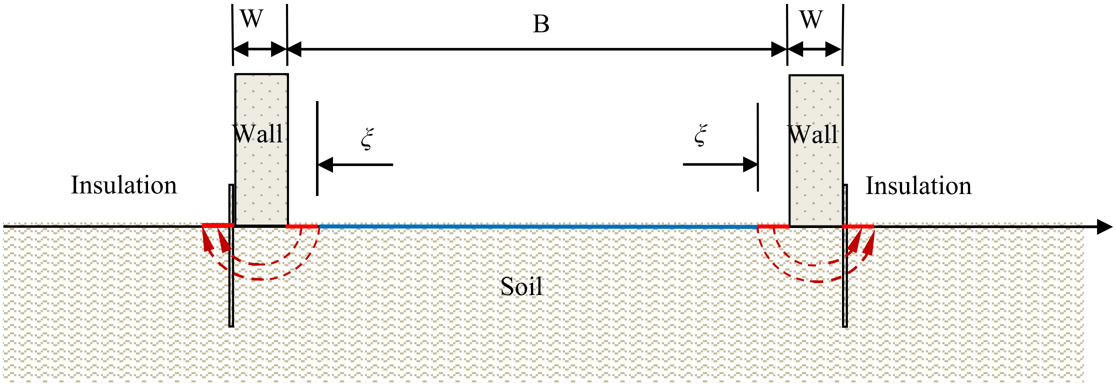

Fig. 1. Schematic view of the insulated slab-on-ground system investigated in this study

Figure 1 shows a schematic view of the vertically insulated slab-on-ground construction investigated in this study. The vertical insulation is a thin layer with 100mm above the ground, and up to 1 m below the ground. Thin layer insulation assumption has been used for facilitating the tackling of the GCHT problem analytically by [8] and [9], although both the previous studies were considering adiabatic vertical edge insulation for steady state heat transfer from two dimensional slabs. The external wall thickness is assumed to be between 0.2m and 0.5m which covers the normal wall thickness range for residential buildings. For steady state heat transfer, one approximation method is assuming that the heat transfer occurs along a half-circular path as illustrated in Figure 1. Assuming that only the heat transfer of the edge of the floor is affected by the insulation, the total floor heat loss can then be treated in two parts: the edge and the core parts respectively. Based on the work by [7], two-dimensional steady state heat transfer from the core and edge of the floor can be derived.

$$Q_{core} = \frac{kL(B-2\xi)(T_i - T_o)}{R_{core}} = \frac{2Lk(T_i - T_o)}{\pi} \times \left\{ \ln\left[1 + \frac{(B-2\xi)}{W+\xi}\right] + \frac{\xi}{W}\ln\left[1 - \frac{W}{W+\xi}\right] + \left(\frac{B-\xi}{W}\right)\ln\left[1 + \frac{W}{B-\xi}\right] \right\} \tag{1}$$

$$Q_{edge} = \frac{2kL\xi(T_i - T_o)}{R_{edge}} = \frac{2Lk(T_i - T_o)}{\pi} \times \left\{ \ln\left[1 + \frac{B}{W}\right] + \frac{B}{W}\ln\left[1 + \frac{W}{B}\right] - \ln\left[1 + \frac{(B-2\xi)}{W+\xi}\right] - \frac{\xi}{W}\ln\left[1 - \frac{W}{W+\xi}\right] - \left(\frac{B-\xi}{W}\right)\ln\left[1 + \frac{W}{B-\xi}\right] \right\} \tag{2}$$