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ScienceDirect

Energy Procedia 121 (2017) 79–86

Energy Procedia

www.elsevier.com/locate/procedia

International Conference on Improving Residential Energy Efficiency, IREE 2017

Linear regression models for prediction of annual heating and cooling demand in representative Australian residential dwellings

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Abstract

This paper presents the development methodology of linear regression models that were developed for the prediction of annual thermal loads in representative residential buildings across three major climates in New South Wales, Australia, and the assessment of the impact of building envelope upgrades. A differential sensitivity analysis was undertaken for sixteen building envelope parameters, with six parameters being identified as significant. These six parameters were then explored using EnergyPlus simulation, and a number of linear regression models developed from the simulation outputs. Random values for design parameters were generated, and the results of EnergyPlus simulations using these parameters were used to verify the outputs of the regression models. The differences between regression-predicted and EnergyPlus-simulated annual thermal energy requirements were of order 10%-15%. The coefficient of determination (R^2) was over 0.90, indicating a good agreement between simulation and the regression models, and suggesting that the annual heating and cooling energy requirements can be forecasted with an acceptable accuracy using the regression models. It is envisaged that the regression models developed can be used as a quick alternative to building simulation for residential buildings of the area and the climate covered by our study, and can serve to rapidly estimate the likely energy savings/penalty during the retrofitting design stage when different building schemes and design concepts are being considered.

Peer-review under responsibility of the scientific committee of the International Conference on Improving Residential Energy Efficiency.

Keywords: Representative buildings types; Differential sensitivity analysis; Regression model

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1876-6102
Peer-review under responsibility of the scientific committee of the International Conference on Improving Residential Energy Efficiency.
10.1016/j.egypro.2017.07.482

1. Introduction

Improving the efficiency of Australia's existing building stock is crucial to reducing emissions in the near future. The existing building stock is replaced by new constructions in the order of 1-3% per year (Ma et al., 2012), meaning that building new low energy constructions will not necessarily have a significant impact on GHG emissions in Australia in the short term. As a result, the upgrading of the existing stock to be of highly energy efficient buildings, and thereby reducing the GHG emissions, is one of the major challenges faced by Australian building sector in the recent years. Several studies have found that refurbishing of existing buildings is the most cost effective method to reduce emissions (IPCC, 2014, McKinsey & Company, 2008), particularly in the residential sector. This sector is one of the fastest growing areas in the building sector, and energy use and associated greenhouse gas emissions are projected to continue to increase in this sector in the future (Morrissey and Horne, 2011).

There is a significant potential for energy efficiency improvements in the residential building stock. Lechtenböhmer and Schüring (2011) found that up to 80% of residential GHG emission production could be avoided using relatively simple measures, e.g. better insulation of the different components of the existing building stock as well as the new buildings. However, selecting the optimal retrofitting strategy for dwellings and estimating their current and future energy demands loads is a complex task that involves significant knowledge and expertise (Ma et al., 2012, Lam and Hui, 1996, Catalina et al., 2013). Sensitivity analysis has been used extensively for assessing the thermal response of buildings and their energy and load characteristics (Athienitis, 1989, Buchberg, 1969, Lomas and Eppel, 1992, Daly et al., 2014, Thomas, 2011), to allow proper selection of design variables and conditions to achieve higher building energy performance.

The present chapter focused on the sensitivity of energy performance improvement parameters in representative building models developed from chapters 4 and 5. The purpose of the analysis is to assess the significance and influence of input design parameters. This chapter also aims to use regression analysis of building simulation results to develop simple energy estimation models, based on the building parameters which most strongly influence the buildings annual thermal energy consumption. The regression analysis was undertaken for fully air-conditioned models in three major climate zones across New South Wales (NSW). This chapter presents information regarding i) the identification of key building design variables using Differential Sensitivity analysis, ii) the development of simple energy estimation models using regression analysis and the Taguchi method, and iii) the evaluation of the developed regression models.

2. Method

Sensitivity analysis was employed in this study, to explore the sensitivity of simulated annual space heating and cooling energy requirements to changes to building envelope attributes in a range of representative buildings that were developed in previous studies (Aghdaei et al., 2016). The amount of energy needed to maintain indoor comfort conditions within recommended comfortable levels (NatHERS, 2012) was the output variable, and simulations were undertaken for three major climate zones across NSW. Parametric energy analysis was the undertaken to explore the design parameters which were found to be influential. Taguchi method and an Analysis of Variance (ANOVA) process were used for to reduce the modelling cost of the parametric analysis. The results of the parametric analysis were then used to develop a simple regression energy estimation models to estimate annual building energy consumption for the three major climate zones in NSW(NatHERS, 2012).

2.1. Representative's dwellings simulation models

The process followed to develop the representative building types for the existing stock, using statistical analysis of Australian Bureau of Statistics data, has been reported previously (Aghdaei et al., 2016). For the current paper, three representative building dwellings were modelled, namely:

Type A. Brick veneer wall with suspended timber floor with ceiling insulation.
Type B. Double brick wall with suspended timber floor with ceiling insulation.
Type C. Lightweight wall with suspended timber floor with ceiling insulation.