THE ROLE OF BUILDING ENCLOSURE AIR TIGHTNESS ON THE LIFE CYCLE COST ASSESSMENTS: A CASE STUDY OF A MEDICAL FACILITY IN MICHIGAN

Guiyuan HAN
The Pennsylvania State University, Univerisity Park, PA, United States of America; goh5067@psu.edu

Elena ENACHE-POMMER
Dow Building Solutions R&D, Midland, MI, United States of America

Jelena SREBRIC
The Pennsylvania State University, Univerisity Park, PA, United States of America;

Summary

Energy used to operate a building contributes to a large percentage of the total energy costs during its lifespan. Therefore, air infiltration, as an influential factor on the building energy consumption, impacts the building life cycle cost. The objective of this study is to improve accuracy of air infiltration accounting in life cycle cost assessment framework by the use of the multi-zone modeling. Specifically, this paper provides results from the life cycle cost analysis performed on a medical facility in Michigan by looking at infiltration rates due to different building components within the building enclosure system. The result shows that the energy consumed due to infiltration rates takes approximately 15.7 % of the total annual energy consumption (standard deviation: 2.3 %). Infiltration has a great influence on building energy consumption during its life cycle. Investments in and maintenance of building enclosure components affecting the building air tightness should be considered to save life cycle cost.

Keywords: life cycle cost assessment, air infiltration rates, building energy consumption

1 Introduction

Energy used to operate buildings contributes to a significant fraction of the total cost. In developed countries, energy consumption of buildings represents 20–40 % of the total national energy in both European Union and United Sates [1].

Air infiltration is the unintentional airflow into a building through different openings. Infiltration rates can have a significant effect on the building energy consumption [2, 3]. A study shows that infiltration is responsible for approximately 13 % of the heating loads and 3 % of the cooling loads for the U.S. office buildings [4]. Specifically for newer buildings, infiltration is responsible for about 25 % of the heating loads and 4 % of the cooling loads due to the higher levels of insulation. The air infiltration rates in buildings result from pressure differences between inside and outside air. Furthermore, the actual infiltration rates also depend on building design and construction properties including building orientation, distribution of leakages and their flow characteristics.

In this study, a typical framework of building life cycle assessment is augmented by additional considerations including the influence of air infiltration on energy consumption by introducing airflow multi-zone modeling into framework.

2 Methodology

The life cycle cost assessment framework, accounting for infiltration via multi-zone modeling, is shown in **Fig. 1**. The multi-zone modeling, using CONTAM, contains both weather files and building properties as inputs. The life cycle cost assessments include capital cost (labor, equipment and material cost), transportation cost, maintenance cost, demolition cost, and annual energy cost during building lifespan.

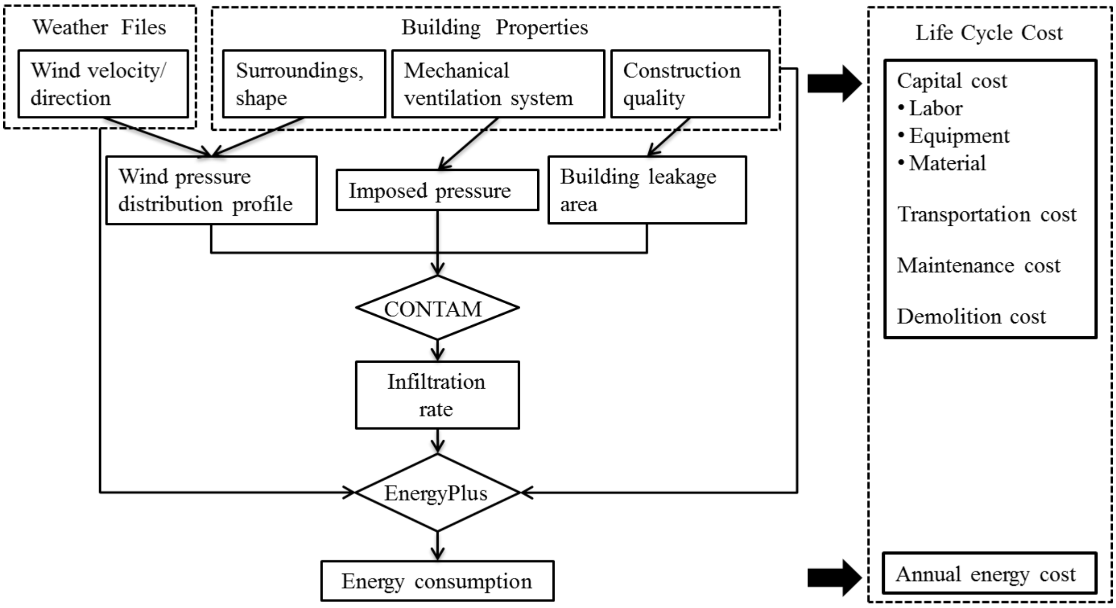

Fig. 1 *Framework of building life cycle assessment*

The difficulty to accurately estimate parameters in simulating infiltration rates is the properties of actual building leakage areas. Ideally, the size, location and characteristics of all leakage areas should be known. However, these properties are difficult to quantify. Besides, the uncertainty of building leakage areas could be greatly increased by different manufacturing and installation processes [5]. Therefore, the effective leakage areas in this case study will be estimated by reviewing values reported in published literature and existing industry standards [5, 6].

3 Case study

Simulations are created for a two-story office building in Saginaw, MI, USA. The building is a medical office building, covering 12,473 ft^2 (1,159 m^2). **Tab. 1** shows the components and options taken into account in this case study. There are a total of more than 800 combinations of building construction options based on the components shown in **Tab. 1**.

Tab. 1 Options of different building components

Building components	Options	Effective air leakage (at 4 Pa)
Window type[a]	Double horizontal slider (w/nw), Double hung (w/nw), Casement (w/nw)	0.24 cm^2/m-2.5 cm^2/m
Wall to window/ Window frame[b]	Wood (c/uc), Aluminum (c/uc)	0.3 cm^2/m^2-6.5 cm^2/m^2
Window glazing	Standard, Double, Low-E	n/a
Wall assembly	Concrete block, Masonry	4 cm^2/m^2, 4.2 cm^2/m^2
Insulation material	Fiberglass, Foamglass, XPS, EPS	n/a
Insulation thickness (in)	1, 1.5, 2, 3	n/a

a: w-weatherstripped, nw-non weatherstripped;
b: c-caulked, uc-uncaulked.

4 Results

The cases of minimum and maximum life cycle cost are shown in **Fig. 2**. The combinations of building components for minimal/maximum life cycle cost vary with length of building lifespan. The average difference of the total life cycle cost for these two cases is 13.4 %.

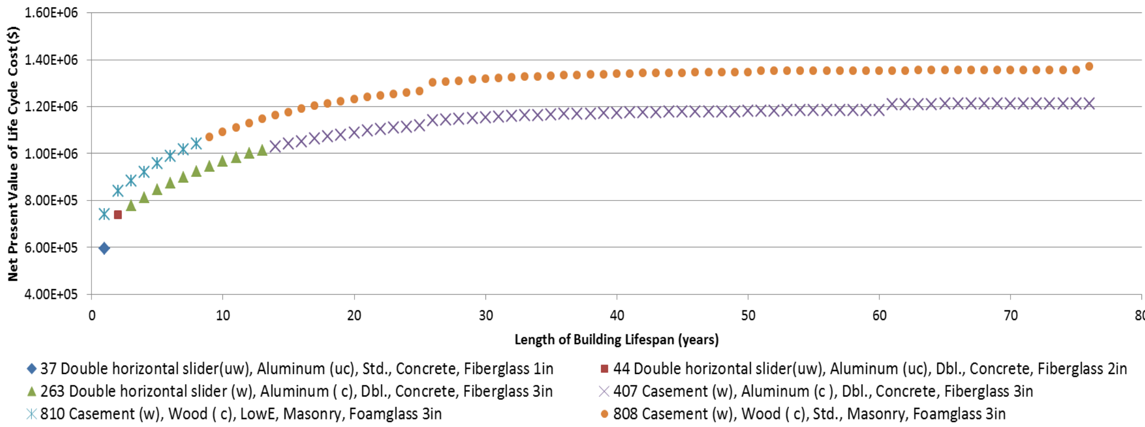

Fig. 2 Life cycle cost based on simulation model for the case study building

Tab. 2 Optimal building components

Lifespan (yrs)	Type	Frame	Glazing	Wall assembly	Insulation	Infiltration rates (ach)
1	Double horizontal slider (uw)	Aluminum (uc)	Std.	Concrete	Fiberglass, 1in	0.400
2	Double horizontal slider (uw)	Aluminum (uc)	Dbl.	Concrete	Fiberglass, 2in	0.400
3–13	Double horizontal slider (w)	Aluminum (c)	Dbl.	Concrete	Fiberglass, 3in	0.347
14–75	Casement (w)	Aluminum (c)	Dbl.	Concrete	Fiberglass, 3in	0.334

According to the simulations, energy consumption due to air infiltration averagely contributes 15.7 % to the total annual energy consumption (standard deviation: 2.3 %). Sensitivity analysis, at 5% significant level, indicates that the major influential factors of infiltration rates are window type, window frame, and wall assembly. The optimal components resulting in the minimal life cycle cost vary with different lengths of building life span as shown in **Tab. 2**.

5 Conclusions

This study examines results of an augmented framework for the building life cycle assessment by deploying it to a case study based on a medical facility building. To improve accuracy of air infiltration rates accounted in the building energy modeling, the framework incorporates the airflow multi-zone modeling. Different combinations of building components are simulated in the framework.

The result shows that the energy consumed due to infiltration rates takes approximately 15.7 % of the total annual energy consumption (standard deviation: 2.3 %). Air infiltration rates have a great impact on the total building energy consumption when building has a longer lifespan. Besides window/door sizes, window types and frame installation quality inputs into airflow modeling could increase uncertainties of the simulated air infiltration rates and associated energy costs. When an expected lifespan of the medical facility building is more than 14 years, air infiltration rates become an important contributing factor in the life cycle optimization. Air tightness is playing an important role in minimizing the life cycle cost. Investments in and maintenance of building enclosure components for improved building air tightness should be emphasized by building designers and owners.

References

[1] Pérez-Lombard, L., Ortiz ,J., Pout , C.*A review on buildings energy consumption information*. Energy and Buildings, vol. 40, no. 3, 2008, pp.394–398.

[2] Sandberg, P.I., Fisk, W.J. *Airtightness issues in the building process*. Proceedings of the 7th Symposium on Building Physics in the Nordic Countries, 2005, pp.420–427.

[3] Liddament, M. W., Orme M. *Energy and ventilation*. Applied Thermal Engineering, vol. 18, no 11, 1998,pp 1101–1109.

[4] Emmerich, S.J., Persily, A.K. *Energy impacts of infiltration and ventilation in US office buildings using multizone airflow simulation*. Proceedings of IAQ and Energy, vol. 98, 1998, pp.191–206.

[5] Weidt, J.L. *Field air leakage of newly installed residential windows*. 2012.

[6] ASHRAE Handbook 1997. American Society of Heating, Refrigerating and Air--Conditioning Engineers, Inc., Atlanta, GA. Chapter 25, Table 3.