House Indoor Thermal and Health Conditions with Different Passive Designs

Bin Su

***Abstract*—**According to the Auckland climate, building passive design more focus on improving winter indoor thermal and health conditions. Based on field study data of indoor air temperature and relative humidity close to ceiling and floor of an insulated Auckland townhouse with and without a whole home mechanical ventilation system, this study is to analysis variation of indoor microclimate data of an Auckland townhouse using or not using the mechanical ventilation system to evaluate winter indoor thermal and health conditions for the future house design with a mechanical ventilation system.

***Keywords*—**House ventilation, indoor thermal condition, indoor health condition, passive design.

I. Introduction

AUCKLAND has a temperate climate with comfortable warm, dry summers and mild, wet winters. Most Auckland houses are designed for temporary heating not for permanent heating as minimum temperatures during the Auckland winter are rarely lower than 5°C. The World Health Organization recommends a minimum indoor temperature for houses of 18°C; and 20-21ºC for more vulnerable occupants, such as older people and young children. The current New Zealand Building Code does not have a general requirement for the minimum indoor air temperature of a house, although it has a requirement of 16ºC for more vulnerable occupants, such as older people and young children [1]-[4].

Auckland building thermal design not only focuses on the winter thermal performance but also the winter indoor health condition, which is closely related to indoor psychrometric conditions. Visible mould growth on indoor surfaces is a common problem in over 30% of Auckland houses during the wet winter. For controlling the mould growth on indoor surfaces there could be two options to different climate conditions and building designs. One is to use active controls such as permanent heating and mechanical ventilation to control the indoor relative humidity level under 60%, the threshold of mould survival and growth for the building that is designed for permanent active controls. 60% relative humidity is the threshold for the mould survival and growth after the gemmation of mould spores. It is hard for Auckland houses to control indoor relative humidity under 60% by passive control.

To control indoor relative humidity under 60% of Auckland houses must rely on active control such as permanent heating and mechanical ventilation; but from the building thermal design point of view, most Auckland houses are not designed for permanent heating.

Bin Su, Professor of Architectural Science, School of Architecture, Unitec Institute of Technology, Auckland, New Zealand (phone: 0064-9-8154321 ext 7847; fax: 0064-9-8154343; e-mail: bsu@unitec.ac.nz); Visiting Professor, School of Architecture and Urban Planning, Shandong Jianzhu University, Jinan, China.

Another option is to use building passive design and passive controls to control the indoor relative humidity level under 80%, the threshold of mould gemmation for the building that is not designed for permanent active controls. If the mould spores never start gemmation the moulds never grow on indoor surfaces.

Previous studies show the time of available indoor psychrometric conditions for mould gemmation near indoor surfaces during the Auckland winter could be limited through adequate insulation, ventilation through available openings during winter daytime and exhaust fans, available temporary heating and a general awareness by occupants of the need to manage the situation wisely [5]-[6]. Opening window for winter daytime ventilation to remove indoor extra moisture and stale air, which is limited by the winter frequent rain, could cause heat lose and negatively impact indoor thermal condition.

This study is to analysis variation of indoor microclimate conditions of an insulated Auckland two-storey townhouse using and not using a whole home mechanical ventilation system. There are a few of home ventilation systems available in the market. The air intake of a whole home ventilation system, the air change rate is up to 7, is fixed in the roof space of the townhouse. The incoming fresh air is filtered through a superior deep pleat and electrostatically charged filtration system, and then gently and evenly distributed into all indoor spaces through ceiling vents. The ventilation system not only can increase the air change rate but also create a positive pressure indoor space of a house.

Two field studies were carried out by the author to measure internal air temperature and relative humidity data before and after the whole home ventilation system was fixed in an Auckland two-storey town house. The Auckland townhouse used for field studies has four bedrooms with the total floor area of 210 m^2 (see Fig.1). Outdoor, roof space and indoor air temperature and relative humidity adjacent to floor and ceiling of different indoor spaces of the townhouse using and not using the ventilation system were continuously measured at 20-minute intervals 24 hours a day during the winter months of the two different years. Field study data were converted into percentages of time related to different temperature and relative humidity ranges, hourly mean temperatures of winter months and daily mean temperature profiles of the winter months in different indoor spaces of the townhouse, which are used to evaluate indoor thermal and health conditions of the townhouse using and not using a whole home mechanical ventilation system.

Fig. 1 The Auckland Townhouse for this study

II. Indoor Thermal Conditions

A. Indoor Mean Air Temperature Profile

Fig. 2-3 show hourly mean temperature profile of 24 hours during the winter months of different indoor spaces of the townhouses using and not using ventilation system. The lowest indoor temperatures occur at about 7-8am; the indoor spaces are initially warmed up by the sun at about 8-9am; then the indoor mean temperatures reach their highest level at about 1-3pm; and after that peak temperature, the indoor mean temperatures steadily decrease. During the night time, indoor mean temperatures generally decrease to their lowest indoor levels, which are affected by temporary heating during the early evening. During the winter daytime (from 9am to 6pm), mean temperatures of the two indoor spaces on north side of house using and not using the ventilation system are higher than two bedrooms on south side of house as north side wall faces to the equator. During the winter daytime, indoor mean air temperatures of indoor spaces of the house using ventilation system are apparently higher than not using ventilation system, and indoor mean air temperatures of the two bedrooms on south side of house not using ventilation system are close to the top of mean outdoor temperatures. When the house uses the mechanical ventilation system, the windows are closed during the winter daytime. Opening window for ventilation during the winter daytime can remove indoor extra moisture and stale air but can negatively impact indoor thermal comfort.

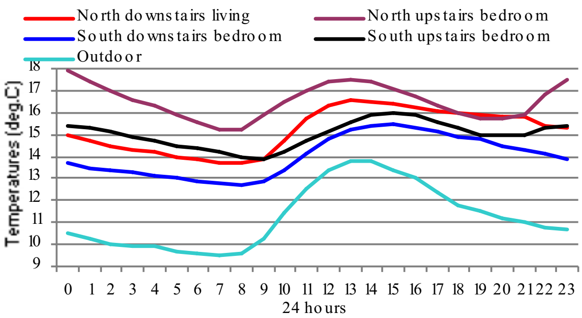

Fig. 2 Indoor mean air temperatures of the house using ventilation system

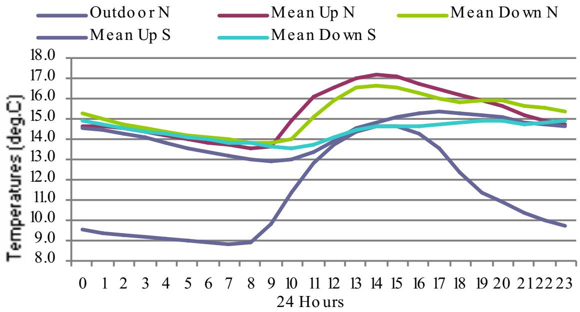

Fig. 3 Indoor mean air temperatures of the house without using ventilation system

B. Indoor Thermal Comfort

Table II-III show indoor air temperatures of the house using and not using the ventilation system during the whole winter time. Indoor thermal conditions of the house using the ventilation system are better than not using the ventilation system. Indoor mean air temperatures of the house using the ventilation system are generally higher not using the ventilation system. Increasing winter indoor ventilation and air change rate does not decrease indoor thermal comfort, which is partially impacted by the temporary heating during the night time. Table 4-5 show indoor air temperatures of the house using and not using the ventilation system during the winter daytime from 9am to 6pm. Indoor thermal conditions of the house using the ventilation system are apparently better than not using the ventilation system during the winter daytime from 9am to 6pm. All indoor mean air temperatures of the house using the ventilation system are higher not using the ventilation system. During the winter daytime, indoor air temperatures are not impacted by the temporary heating as the heaters are only used during the night time for both situations. Mean air temperature in the roof space is much higher outdoor air temperature and higher than indoor air temperatures (see Table 2 and Fig. 4). As the air intake of ventilation system is in the roof space, the warm air from the ventilation system can improve indoor thermal conditions during winter daytime. Air temperatures in the north and the south part of roof spaces were measured at the bottom of roof space, which is close to the upside surface of ceiling in roof space. Fig. 5 shows mean minimum air temperatures in the roof space. During the winter daytime from 9am to 6pm, there are more than 2 ºC difference of mean air temperatures between the north part and the south part of roof space. The air intake should be located at the north part of roof space.

TABLE I
Winter Indoor Air Temperatures Of The House Using Ventilation System

Indoor Spaces	Temperature Ranges			Mean
	≥16ºC	≥18ºC	≥20ºC	
	Winter Time			
Ups N Bed Ceiling	75%	34%	8%	17.2ºC
Ups N Bed Floor	58%	11%	0.9%	16.1ºC
Down N L Ceiling	49%	12%	0.8%	15.7ºC
Down N L Floor	23%	0.7%	0%	14.7ºC
Ups S Bed Ceiling	46%	22%	6.5%	15.4ºC
Ups S Bed Floor	31%	6.4%	0%	14.6ºC
Down S Bed Floor	13%	0.6%	0%	14.1ºC
Outdoor	1.4%	0.3%	0%	11.3ºC

TABLE II
WINTER INDOOR AIR TEMPERATURES OF THE HOUSE NOT USING VENTILATION SYSTEM

Indoor Spaces	Temperature Ranges ≥16ºC	≥18ºC	≥20ºC	Mean
	Winter Time			
Ups N Bed Ceiling	37%	10%	2%	15.4ºC
Ups N Bed Floor	30%	3%	0%	15.1ºC
Down N L Ceiling	41%	7%	0.5%	15.7ºC
Down N L Floor	12%	0.5%	0%	14.7ºC
Ups S Bed Ceiling	16%	0.5%	0%	14.4ºC
Ups S Bed Floor	16%	0%	0%	14.1ºC
Down S Bed Floor	22%	0%	0%	14.1ºC
Outdoor	3%	0%	0%	11.4ºC
N Roof space	26%	16%	13%	13.0ºC
S Roof space	17%	10%	6%	12.1ºC

TABLE III
WINTER DAYTIME INDOOR AIR TEMPERATURES OF THE HOUSE NOT USING VENTILATION SYSTEM

Indoor Spaces	Temperature Ranges ≥16ºC	≥18ºC	≥20ºC	Mean
	Winter Daytime			
Ups N Bed	13%	0%	0%	16.2ºC
Ups S Bed	3%	0%	0%	14.4ºC
Down N Living	39%	5%	0%	15.6ºC
Down S Bed	19%	0%	0%	14.3ºC
Outdoor	13%	0%	0%	13.7ºC
Mean Roof	58%	40%	25%	16.7ºC

TABLE IV
WINTER DAYTIME INDOOR AIR TEMPERATURES OF THE HOUSE USING VENTILATION SYSTEM

Indoor Spaces	Temperature Ranges ≥16ºC	≥18ºC	≥20ºC	Mean
	Winter Daytime			
Ups N Bed	67%	23%	4.8%	16.8 ºC
Ups S Bed	38%	12%	1.8%	15.2 ºC
Down N Living	51%	8.4%	0%	15.8 ºC
Down S Bed	24%	2.6%	0%	14.7 ºC
Outdoor	4.3%	0.8%	0%	12.6 ºC

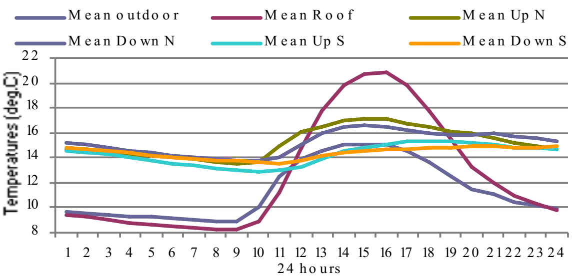

Fig. 4 Mean air temperatures of outdoor, indoor and roof spaces

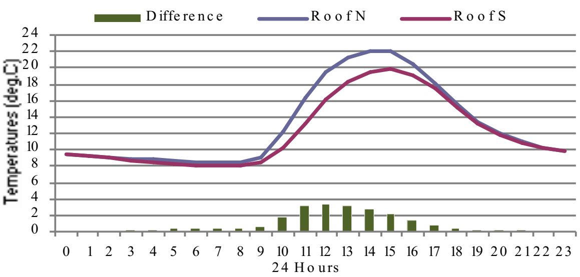

Fig. 5 Winter mean air temperatures in roof space

III. INDOOR HEALTH CONDITIONS

Table V and table VI show percentages of winter time related to different indoor relative humidity levels. Most of the winter time, indoor relative humidity of the house using and not using the mechanical ventilation system are higher than 60%. High relative humidity is a major problem for indoor health condition of Auckland house during the winter. Indoor relative humidity is one of main factors of indoor air quality (see Fig. 6). Mean indoor relative humidity of the house using the ventilation system is apparently lower than not using the ventilation system. Percentages of the winter time while indoor relative humidity is higher than 60% of the house using the ventilation system are also lower than not using the ventilation system. Using the ventilation system increases indoor air temperatures of the house, which can decrease indoor relative humidity level. Increasing air change rate and the indoor positive pressure created by the ventilation system can remove indoor extra moisture from occupants' daily activities and reduce outdoor moisture coming into indoor spaces. A house using the ventilation system not only improves winter indoor thermal conditions but also improves indoor health conditions.

TABLE V
WINTER INDOOR RELATIVE HUMIDITY OF THE HOUSE USING VENTILATION SYSTEM

Indoor Spaces	Relative Humidity Ranges ≥60%	≥80%	≥90%	Mean
	Winter Time			
Ups N Bed Ceiling	52%	0.6%	0%	60.3%
Ups N Bed Floor	75%	0.5%	0%	64.2%
Down N L Ceiling	36%	0.7%	0%	56.7%
Down N L Floor	92%	0.5%	0%	68.8%
Ups S Bed Ceiling	63%	1.3%	0%	62.9%
Ups S Bed Floor	95%	1.8%	0%	68.6%
Down S Bed Floor	93%	7.5%	0%	69.9%
Outdoor	81%	78%	76%	98.2%

TABLE VI
WINTER INDOOR RELATIVE HUMIDITY OF THE HOUSE NOT USING VENTILATION SYSTEM

Indoor Spaces	Relative Humidity Ranges ≥60%	≥80%	≥90%	Mean
	Winter Time			
Ups N Bed Ceiling	78%	0.5%	0%	66%
Ups N Bed Floor	87%	0.5%	0%	67%
Down N L Ceiling	73%	0.5%	0%	63%
Down N L Floor	95%	4%	0%	71%
Ups S Bed Ceiling	92%	0%	0%	68%
Ups S Bed Floor	100%	0%	0%	72%
Down S Bed Floor	99%	9%	0%	75%
Outdoor	95%	69%	54%	88%
N Roof space	79%	39%	3%	72%
S Roof space	84%	45%	5%	74%

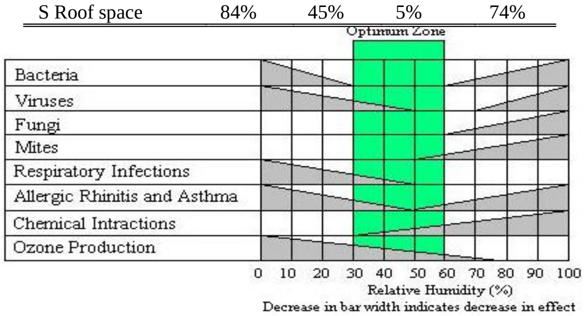

Fig. 6 Relative humidity and indirect health effects

IV. Conclusion

It is very common for a conventional Auckland house to open windows for ventilation during the winter daytime, which can remove indoor extra moisture and stale air but increase heat lose and negatively impact indoor thermal condition. Indoor air temperatures of the house with opened window are close to outdoor temperatures especially for indoor spaces not face to the equator during the winter daytime. Indoor mean air temperatures of the house using the ventilation system, all windows are closed, are apparently higher outdoor temperatures. Without using the heaters, indoor thermal conditions of the house using the ventilation system are apparently better than not using the ventilation system during the winter daytime from 9am to 6pm. Indoor mean air temperatures of the house using the ventilation system are generally higher than not using the ventilation system during the winter. High relative humidity is a major problem of indoor health conditions for Auckland house during the winter, and a major challenge for the local house passive design. Indoor relative humidity data close to ceiling and floor of the house using the ventilation system are apparently lower than not using the ventilation system. The study shows that a house using a whole home ventilation system not only can improve indoor thermal condition but also indoor health condition during the winter.

References

[1] WHO, "Air quality guidelines for Europe 2000 - Second Edition WHO Regional Publications", European Series, N91, 2000.
[2] J. Sateru, "Finnish Society of Indoor Air Quality and Climate (2004) Performance Criteria of Buildings for Health and Comfort", CIB Task Group TG42, published by CIB secretariat, No 292
[3] DBH, "Compliance Document for New Zealand Building Code – Clause G5 Interior Environment," Wellington, New Zealand: Department of Building and Housing, 2001.
[4] SANZ, "New Zealand Standard 4303-1990 Ventilation for Acceptable Indoor Air Quality," Wellington, New Zealand: Standards Association of New Zealand, 1990.
[5] Su, B. (2002). "A field study of mould growth and indoor health conditions in Auckland dwellings." Architectural Science Review, vol. 45, no. 4, pp. 275-284, Dec. 2002.
[6] B. Su, "Prevention of winter mould growth in housing," Architectural Science Review, vol. 49, no. 4, pp. 385-390, Dec. 2006.