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Indoor Moisture Control of Auckland Houses with Different Ventilation Systems

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***Abstract*—**Auckland has a temperate climate with comfortable warm, dry summers and mild, wet winters. Auckland house design not only focus on winter thermal performance and indoor thermal condition, but also indoor moisture control, which is closely related to indirect health effects such as dust mites, fungi, etc. Most Auckland houses are designed to use temporary heating for winter indoor thermal comfort. Based on field study data of indoor microclimate conditions of two Auckland townhouses with a whole home mechanical ventilation system or a passive wind directional skylight vent, this study is to evaluate and compare indoor moisture conditions of two insulated townhouses only using temporary heating with different ventilation systems.

***Keywords*—**House ventilation, house thermal design, indoor health condition, indoor moisture control.

I. Introduction

AUCKLAND house thermal design not only focuses on the winter thermal performance but also indoor psychrometric condition as Auckland has a temperate climate with comfortable warm, dry summers and mild, wet winters. High relative humidity is a major problem for indoor health condition of Auckland house during the winter. During the winter months, mean relative humidity in Auckland is quite high and apparently higher than 80% (see Fig. 1). Indoor dust mite populations are minimized when the relative humidity is below 50% and reach a maximum size at 80%. Most species of fungi can survive and grow when the relative humidity exceeds 60%, and gemmate when the relative humidity exceeds 80% [1]. The negative influence of high relative humidity on bacteria, viruses, fungi, mites, respiratory infections, allergic rhinitis, asthma, chemical interactions, ozone productions, ozone production, etc. suggests that indoor relative humidity levels should be considered as one of major factor of indoor air quality under Auckland winter climate conditions (see Fig. 2).

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 air-conditioning system to control indoor relative humidity level under 60%, the threshold of mould survival and growth, for the building that is designed for permanent active controls. It is impossible for most of Auckland houses not designed for permanent heating and mechanical ventilation to control indoor relative humidity level under 60%. Another option is to use building passive design to control indoor relative humidity level of the threshold of mould gemmation (see Table I) [2], for the building that is not designed for permanent active controls. Previous studies [3], [4] 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, available temporary heating and a general awareness by occupants of the need to manage the situation wisely. If the mould spores never start gemmation the moulds never grow on indoor surfaces.

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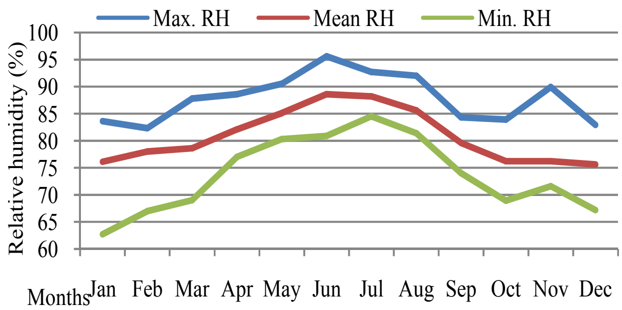

Fig. 1 Auckland monthly relative humidity at 9:00 am 1949-1996 supplied by Auckland Weatherwise

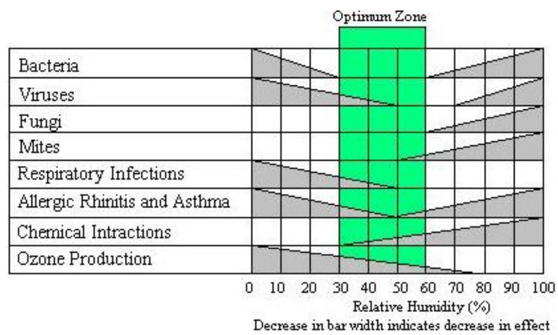

Fig. 2 Relative humidity and indirect health effects

TABLE I
Threshold of Relative Humidity and Time for Mould Gemmation

Substrate	Threshold RH	Time
Porous and dust and fat covered non-porous	100%	1 day
	89%	7 day
	80%	30 days
Clean non-porous	100%	-

Indoor and outdoor air temperature and relative humidity adjacent to floor and ceiling of different indoor spaces of the two townhouse were continuously measured at 20-minute intervals 24 hours a day during the winter months. Field study data that were converted into percentages of time related to different ranges of temperature and relative humidity are used to investigate, evaluate and compare indoor psychrometric conditions of the two townhouses. During the field studies, the house A was 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. The house B has a passive wind directional skylight vent (see Fig. 3) on the roof (see Fig. 4) of the bathroom upstairs. Based on principles of stack effect and wind siphonage, the wind directional skylight vent is designed to provide passive ventilation and increase air change rate for a house [5]. The wind directional skylight vent works as a passive exhaust fan to keep adequate or minimum air change rate for 24 hours when all openings of a house are closed during the winter time. The wind directional skylight vent not only can increase the air change rate but also create a negative pressure indoor space of a house.

Fig. 3 Wind directional skylight vent

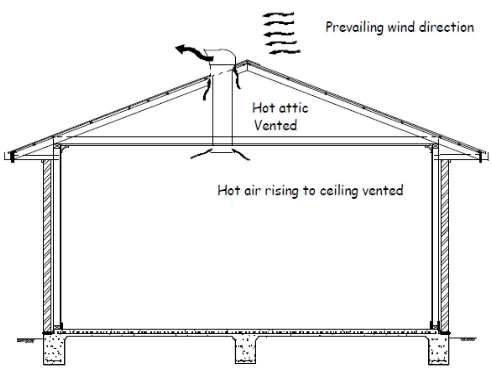

Fig. 4 Wind directional skylight vent on house roof

II. Impact of Ventilation System on Indoor Thermal Conditions

According to previews field studies [6], during the winter daytime, indoor air temperatures of the house A using a whole home mechanical ventilation system are apparently higher than not using the ventilation system (see Tables II, III). During the winter daytime mean air temperature in the roof space of the house A is significantly higher than indoor spaces (see Fig. 5) and air intake of the ventilation system is fixed in the roof space. The whole home mechanical ventilation system can improve indoor thermal conditions of a house during the winter daytime. Winter indoor thermal conditions of the house A using a whole home mechanical ventilation system are generally better than not using a whole home mechanical ventilation system (see Tables IV, V). The whole home mechanical ventilation system not only can control and increase indoor air change rate to remove extra moisture produced by occupants' daily life but also improve the winter thermal comfort. The whole home mechanical ventilation system uses some operational energy during the winter time. The wind directional skylight vent can increase air change rate to remove indoor extra moisture produced by occupants' daily life without using any energy. The vent also allows light transmission for the roof space or the indoor space.

TABLE II
Winter Daytime Indoor Mean Air Temperatures of the House A Using a Whole Home Mechanical Ventilation System

	Temperature Ranges			
Indoor Spaces	≥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

TABLE III
Winter Daytime Indoor Mean Air Temperatures of the House A Not Using a Whole Home Mechanical Ventilation System

	Temperature Ranges			
Indoor Spaces	≥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

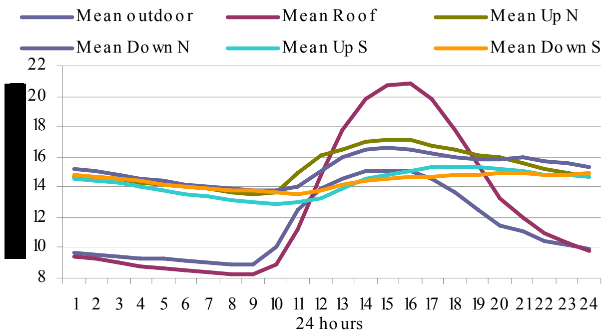

Fig. 4 Mean air temperature 24-hours profiles of indoor, outdoor and roof spaces of the house A during the winter time

TABLE IV
WINTER INDOOR AIR TEMPERATURES OF THE HOUSE A USING A WHOLE HOME MECHANICAL VENTILATION SYSTEM

Indoor Spaces	Temperature Ranges			
	≥16ºC	≥18ºC	≥20ºC	Mean
	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 V
WINTER INDOOR AIR TEMPERATURES OF THE HOUSE A NOT USING A WHOLE HOME MECHANICAL 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

III. IMPACT OF VENTILATION SYSTEM ON INDOOR RELATIVE HUMIDITY LEVEL

According to previews field studies [6], during the winter time, indoor relative humidity levels of the house A using a whole home mechanical ventilation system are lower than not using the ventilation system (see Tables VI, VII). Mean relative humidity of all indoor spaces of the house A using the ventilation system are lower than 70% (see Table VI). A whole home mechanical ventilation system can reduce indoor relative humidity levels, and improve indoor air quality and health conditions. Mean relative humidity of all indoor space of the house B using a wind directional skylight vent are lower than 65% (see Table VIII). The house A and the house B have insulation with the same R-values in roof space (R1.9), wall (R1.5) and floor (R1.3), and single glazed window with R0.13. Two houses regularly used temporary heating during the winter time. The house A and the house B do not have mould problems. According to the threshold of relative humidity and time for mould gemmation (see Table I), indoor psychrometric conditions of the house A and the house B are lower than the threshold of mould gemmation (see Tables IV-X).

TABLE VI
WINTER INDOOR RELATIVE HUMIDITY OF THE HOUSE A USING A WHOLE HOME MECHANICAL 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 VII
WINTER INDOOR RELATIVE HUMIDITY OF THE HOUSE A NOT USING A WHOLE HOME MECHANICAL 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%

TABLE VIII
RELATIVE HUMIDITY LEVELS OF THE HOUSE B USING WIND DIRECTIONAL SKYLIGHT VENT

Indoor Spaces	Relative Humidity Ranges			
	≥60%	≥80%	≥90%	Mean
	Winter Time			
Bath Ceiling	65.5%	1.6%	0.4%	63%
Bath Floor	17.3%	1.6%	0.4%	67%
Ups Bed Floor	44.0%	0%	0%	58%
Down Living Floor	37.0%	0%	0%	58%
Down Bed Floor	75.8%	0%	0%	64%
Outdoor	95.9%	68.2%	46.0%	85%

TABLE IX
WINTER TIMES (DAYS) AND INDOOR RELATIVE HUMIDITY LEVELS OF THE HOUSE A USING A WHOLE HOME MECHANICAL VENTILATION SYSTEM

Indoor Spaces	Relative Humidity Ranges			
	≥60%	≥80%	≥90%	Mean
	Winter Time (days)			
Ups N Bed Ceiling	46.8	0.5	0	60.3%
Ups N Bed Floor	67.5	0.5	0	64.2%
Down N L Ceiling	32.4	0.6	0	56.7%
Down N L Floor	82.8	0.5	0	68.8%
Ups S Bed Ceiling	56.7	1.2	0	62.9%
Ups S Bed Floor	85.5	1.6	0	68.6%
Down S Bed Floor	83.7	6.8	0	69.9%
Outdoor	72.9	70.2	68.4	98.2%

TABLE X
WINTER TIMES (DAYS) AND INDOOR RELATIVE HUMIDITY LEVELS OF THE HOUSE B USING WIND DIRECTIONAL SKYLIGHT VENT

Indoor Spaces	Relative Humidity Ranges			
	≥60%	≥80%	≥90%	Mean
	Winter Time (days)			
Bath Ceiling	59.0	1.4	0.4	63%
Bath Floor	15.6	1.4	0.4	67%
Ups Bed Floor	39.6	0.0	0.0	58%
Down Living Floor	33.3	0.0	0.0	58%
Down Bed Floor	68.2	0.0	0.0	64%
Outdoor	86.3	61.4	41.4	85%

During the winter night time (from 7:00pm to 7:00am) the house A and the house B use heaters and all openings are closed, and the whole home mechanical ventilation system in the house A automatically runs on the minimum air change rate. With temporary heating, mean relative humidity levels of all indoor spaces of the house A during the winter night time are slightly lower than the winter time (see Tables VI, XI). Indoor mean relative humidity levels of the house B are lower than the house A during the winter night time. Indoor mean air temperatures of the house B are higher than the house A (see Tables XIII, XIV), which indicates that the house B used more heating than the house B to keep indoor mean air temperature about 16°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 [7], [8]. 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 more vulnerable occupants, such as older people and young children [9]-[10]. Without a general requirement of indoor minimum temperature for Auckland house design, indoor air temperature levels and thermal comfort conditions partially depend on occupants and how to use space heating during the winter time. Increasing indoor air temperature will decrease indoor relative humidity. When the house has adequate insulation and ventilation, indoor mean relative humidity levels depends on indoor air temperature. Indoor mean relative humidity levels can be controlled about 60%, such as the house B, or lower than 60% by adequate or increasing indoor space heating.

TABLE XI
INDOOR RELATIVE HUMIDITY OF THE HOUSE USING A WHOLE HOME MECHANICAL VENTILATION SYSTEM DURING WINTER NIGHT TIME FROM 7PM TO 7AM

Indoor Spaces	Relative Humidity Ranges			
	≥60%	≥80%	≥90%	Mean
	Winter Night Time			
Ups N Bed Floor	70%	0.6%	0%	63%
Down N L Floor	92.2%	6.0%	0%	69%
Ups S Bed Floor	92.8%	1.5%	0%	67%
Down S Bed Floor	93.4%	4.4%	0%	67%
Outdoor	99.7%	98.2%	97.6%	99.2%

TABLE XII
INDOOR RELATIVE HUMIDITY OF THE HOUSE B USING WIND DIRECTIONAL SKYLIGHT VENT DURING WINTER NIGHT TIME FROM 7PM TO 7AM

Indoor Spaces	Relative Humidity Ranges			
	≥60%	≥80%	≥90%	Mean
	Winter Night Time			
Bath Ceiling	62.2%	1.0%	0.3%	63%
Bath Floor	75.3%	1.6%	0%	65%
Ups Bed Floor	44.9%	0%	0%	59%
Down Living Floor	37.0%	0%	0%	57%
Down Bed Floor	77.6%	0%	0%	64%
Outdoor	99.3%	83.7%	57.1%	89%

TABLE XIII
INDOOR AIR TEMPERATURES OF THE HOUSE B USING WIND DIRECTIONAL SKYLIGHT VENT DURING WINTER NIGHT TIME FROM 7PM TO 7AM

Indoor Spaces	Temperature Ranges			
	≥16ºC	≥18ºC	≥20ºC	Mean
	Winter Night Time			
Bath Ceiling	43.2%	6.9%	0.3%0	15.5 ºC
Bath Floor	34.6%	4.5%	0%	15.0 ºC
Ups Bed Floor	64.4%	18.1%	2.3%	16.4 ºC
Down Living Floor	66.4%	25.2%	3.8%	16.6 ºC
Down Bed Floor	50.2%	8.3%	1.2%	15.7 ºC
Outdoor	0%	0%	0%	10.4 ºC

TABLE XIV
INDOOR AIR TEMPERATURES OF THE HOUSE A USING A WHOLE HOME MECHANICAL VENTILATION SYSTEM DURING WINTER NIGHT TIME FROM 7PM TO 7AM

Indoor Spaces	Temperature Ranges			
	≥16ºC	≥18ºC	≥20ºC	Mean
	Winter Time			
Ups N Bed Floor	60.4%	10.3%	0%	16.1ºC
Down N L Floor	15.9%	0.8%	0%	14.4ºC
Ups S Bed Floor	29.9%	5.3%	0%	14.5ºC
Down S Bed Floor	10.4%	0.7%	0%	13.7ºC
Outdoor	0%	0%	0%	10.4ºC

IV. CONCLUSION

It is very common for a conventional Auckland house to open windows for ventilation to remove indoor extra moisture and stale air during the winter daytime. Last ten years more than one hundred thousand houses use a whole home mechanical ventilation system to maintain the minimum air change rate, remove extra moisture produced by occupants' daily life and activities, and control indoor relative humidity levels for improving indoor air quality and health conditions.

This study shows the time of available indoor psychrometric conditions for mould gemmation can be limited to prevent mould growth on indoor surface through adequate insulation, available temporary heating and adequate ventilation of a house using a whole home mechanical ventilation system or a wind directional skylight vent. Using a whole home mechanical ventilation system or a wind directional skylight vent for a house can maintain indoor mean relative humidity about 70% or 60%, which are also closely related to indoor air temperature and impacted by space heating.

Without a general requirement of indoor minimum temperature for Auckland house design, not only indoor thermal conditions but also indoor health conditions partially depend on occupants and how to use space heating. Occupants should manage space heating wisely and aware that adequate space heating not only impacts on their thermal comfort but also their health during the winter time. An Auckland house thermal design not only focuses on the winter thermal performance but also indoor space design and arrangement to be suitable to use temporary space heating for energy efficiency.

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