Indoor Humidity levels of Houses in Pacific Coastal Climate

Fitsum Tariku*, Emishaw Iffa, Wendy Simpson and Doug Horn

BCIT Building Science Centre of Excellence, Burnaby, BC, Canada

Corresponding email: Fitsum_Tariku@bcit.ca

ABSTRACT

This project studied the relative humidity and indoor temperature variations in three houses in the pacific coastal climates. The houses have been monitored for one month in each four different seasons under different size of occupants, temperature variation and living conditions. These three houses represent different air tightness, number of occupants and floor size. The temperature and RH data loggers are used in every room in each house to better understand which rooms in a certain living conditions are more susceptible to moisture related problems. In addition, three existing models (European Indoor Class Model, ASHRAE 160P simple and intermediate models) are used to generate the indoor humidity level and the calculated values are compared to the measured field data.

KEYWORDS

ACH, Air tightness, Absolute humidity, Excess humidity, Relative Humidity, Temperature.

INTRODUCTION

Indoor air temperature and relative humidity, in addition to other parameters, need to be controlled to an acceptable range in order to attain an acceptable indoor air quality. Problems such as mould growth and their consequential health effects can be minimized by regulating the indoor air temperature and humidity values.

In addition to an indoor environmental quality issues a hygrothermal building performance can also be affected by uncontrolled indoor humidity. Ojanen et. al (1995, 1996) has studied the effects of indoor humidity on building envelope.

In order to avoid these problems, designers need to be provided information on how the indoor level humidity varies under different sets of conditions and weather variation. The indoor humidity levels are commonly calculated based on the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) 160 Standard (2009) simple or intermediate models, the European standard EN ISO 13788 class model (2012) or the BRE model (Jones, 1993) with low and high-humidity class categories.

These models assume every zone in a house to have similar amount of humidity and temperature distribution. However, in reality the temperature and the indoor humidity values tends to vary from room to room based on several causes such as occupant activity, location of window and purpose of the room (ex. Kitchen, laundry and washrooms).

Some research studies have been conducted to compare the existing indoor humidity predictive models based on measured data (Cornick and Kumeran 2008). Indoor climate condition measurements has been conducted by several researchers such as Tariku and

Simpson (2015), Yoshino and Lou (2002), Rose and Francisco (2004), Kalamees and Vinha (2006), Zhang and Yoshino (2010) and Arena et al. (2010).

In this paper, the indoor climate conditions in three different residential houses in marine coastal climate is presented. The three houses are located in Metro Vancouver area of British Columbia, Canada. A one month data of each winter, spring, summer and fall seasons is collected and the indoor climate variation between rooms is studied. The effects of occupant density, building air tightness and living spaces in indoor climate is investigated. In addition, the measured data is compared with the existing indoor moisture predictive models.

INDOOR HUMIDITY MODELS

Cornick and Kumeran (2008) recommend an indoor humidity estimation model should take into account the occupant activity, air leakage, ventilation, humidification/dehumidification or other sources such as rain water penetration. In this paper the measured data is compared to three indoor humidity prediction models namely: ASHRAE simple, ASHRAE intermediate and the European indoor class model.

ASHRAE simple intermediate models

The Design Criteria for Moisture Control in Buildings (ASHRAE, 2009) model comprises three types of indoor humidity estimation models (simple method, intermediate and he full parameter method). The full parameter method requires a thorough hygrothermal performance modelling of building envelope and the whole building performance in general.

The simple model classifies the indoor humidity level into three based on the outdoor temperature. The indoor RH values are estimated to be 40% and 70% when the outdoor temperature is below and equal to -10^{o}C and above or equal to 20^{o}C respectively. The indoor humidity values are computed between 40% and 70% for outdoor temperature between -10^{o}C and 20^{o}C. The intermediate model calculates the indoor vapour pressure as a function of outdoor vapour pressure, moisture generation and ventilation rate.

European indoor class model

The European class model classifies the indoor humidity level is classified in 5 levels based on the type and purpose of the building. The five levels represent buildings (i) storage areas, (ii) shops and offices, (iii) dwellings with low occupant capacity (iv) dwellings with high occupant capacity (iv) special purpose buildings such as Laundry and swimming pool.

HOUSES CONSIDERED FOR THE STUDY

Three houses in the pacific coastal climate region are considered in this study. These three houses, which are located in greater Vancouver area, BC, are selected based on their, airtightness, floor area size, number of occupants and number of bedrooms. From here onwards, in this paper these houses, for brevity purpose, will be referred as House A, House B and House C.

A monthly data for each season (winter, spring, summer and fall) is collected for the three houses in each room using Onset Hobo data logger devices. The devices are placed about 5 feet of off the ground, on an interior wall, away from lights, vents and windows. The data loggers are used to collect temperature and Relative Humidity in 2 minutes interval for 30 days duration. The retrieved data is averaged hourly before it was used in further simulation models. A weather station is used to collect outdoor climate data.

As shown in Table 1, the houses are comprising of different air tightness, number of occupants and volume. In comparison, House B is the most air tight house with larger floor space and number of occupants. House A is the leakiest house with the smallest volume space of the three houses.

Table 1. Houses and their conditions used in the field investigation

	ACH_{nat}	No. of Occupants	No. Bed rooms	Volume (m^3)	No. rooms monitored	Remarks
House A	0.56	3	3	240	4	
House B	0.22	5	4	630	5	No summer data is collected
House C	0.66	4	2	345	5	

RESULTS AND DISCUSSIONS

In this section a representative indoor temperature and RH measurements of living room, bedroom, bathroom and kitchens for Houses A, B and C are presented below. In house A the kitchen and the bathroom have a higher RH values most of the time while the RH values of the living room and bedrooms kept at minimum values. In all seasons the maximum RH value is kept below 70%, see Figure 1.

Rooms' indoor humidity variations

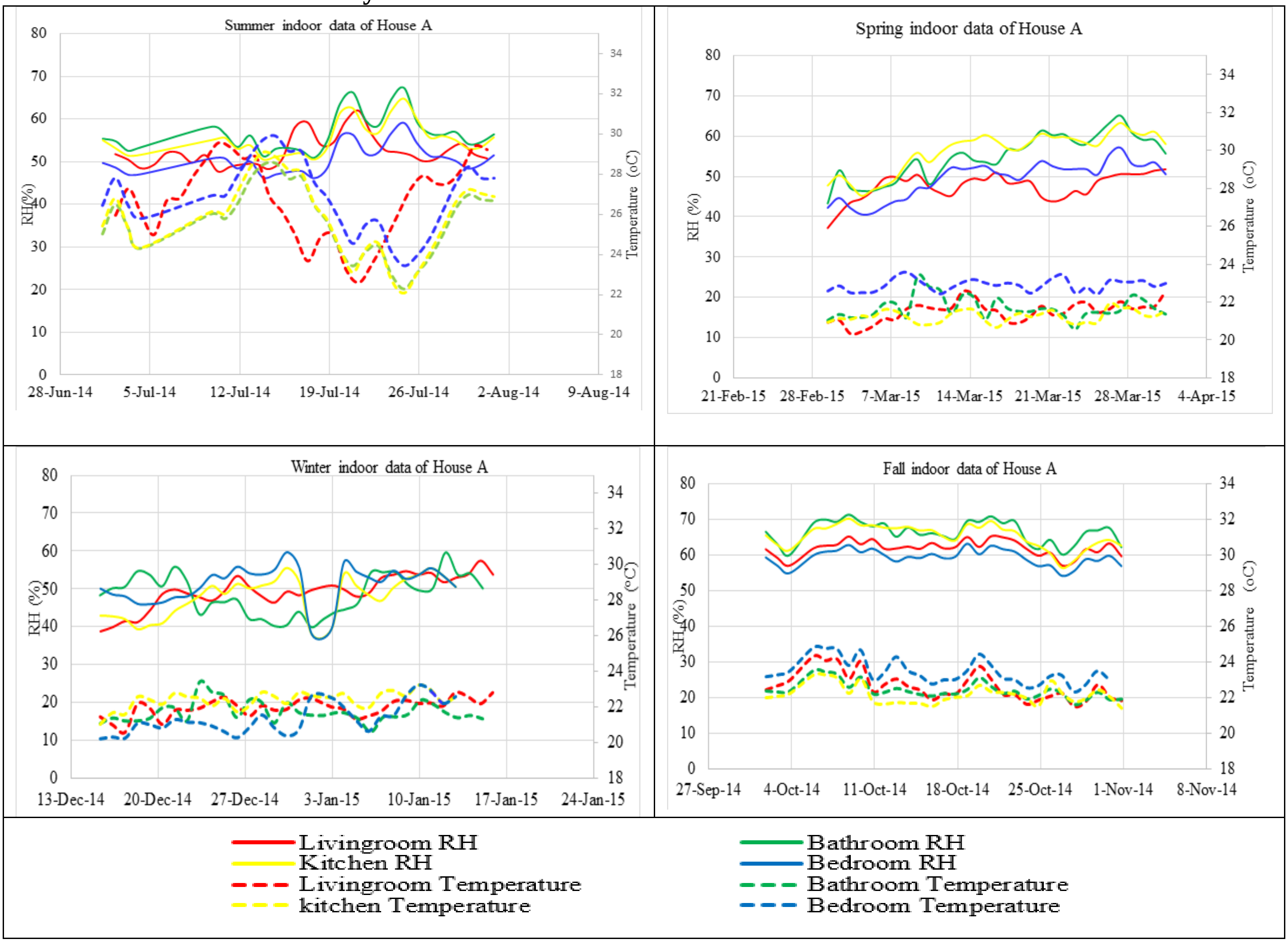

Figure 1. Indoor temperature and relative humidity of different rooms at House A

In House B, as shown in Figure 2, the bathroom exhibits a higher amount of relative humidity during winter while the kitchen's RH value was elevated during spring and fall seasons. The summer data for house B was not collected. In all houses the indoor climate variation is observed to be minimum during fall season.

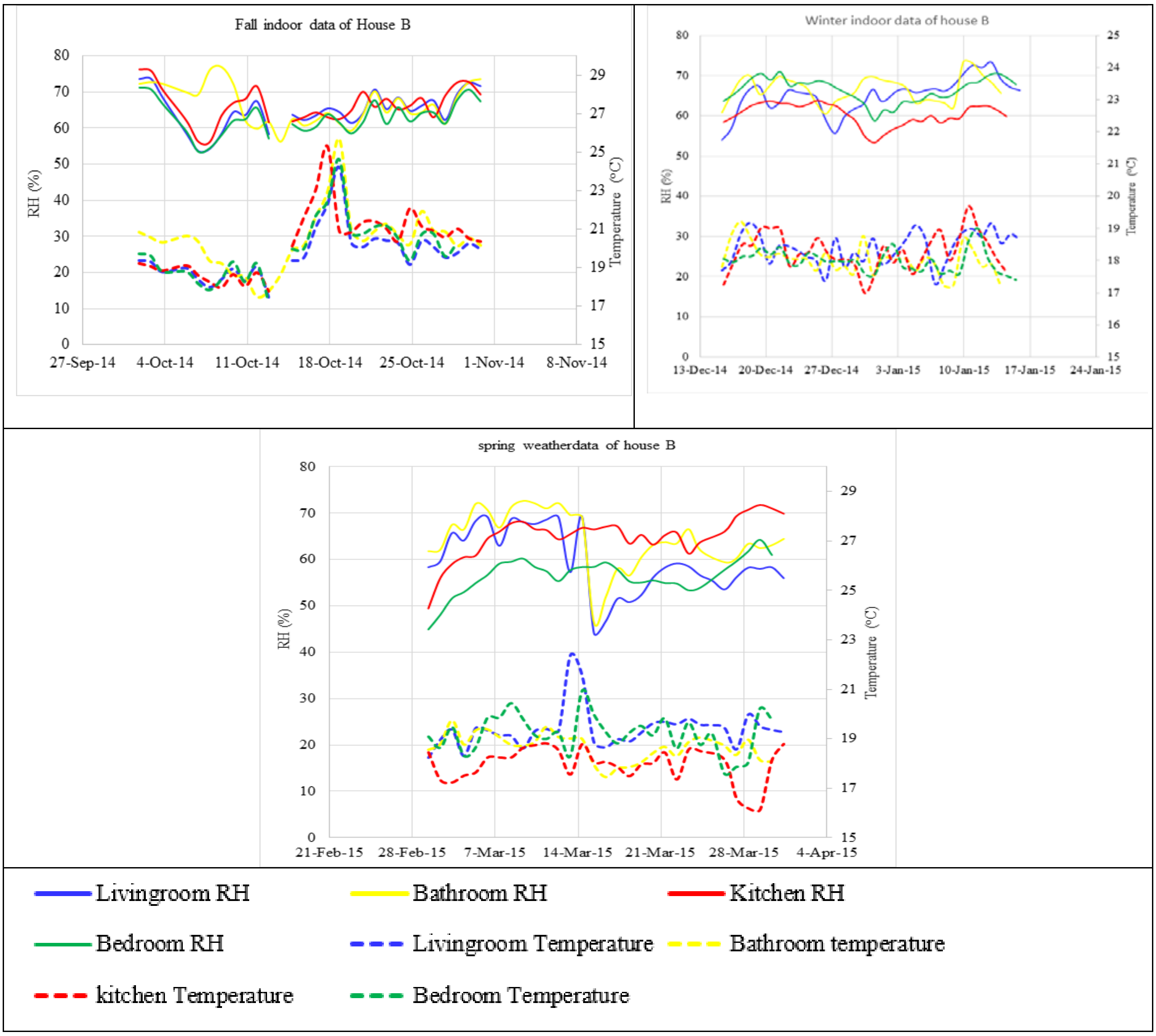

Figure 2. Indoor temperature and relative humidity of different rooms at House B

House C appears to have a minimum temperature during cold seasons and the indoor temperature is relatively higher during summer when compared to houses A and B. The indoor RH and temperature remains similar in all rooms during fall in similar fashion to Houses A and B. The indoor conditions in House C rooms tend to follow a similar profile to the outdoor climate and this is mainly due to the residents' usual habit of opening windows for fresh air circulation.

Measured indoor climate

The data collected in each room has been averaged to find the houses' mean temperature and indoor humidity. The seasonal average temperature of each house is shown in Table 2. House C, a relatively leaky house, exhibits a highest relative humidity during fall season.

Table 2. Seasonal mean RH values

House No.	*Room*	*Spring (%)*	*Summer (%)*	*Fall (%)*	*Winter (%)*
	Living room	52.4	51.6	61.8	49.5
House A	**Bathroom**	55.2	55.8	66.5	49.8
	Kitchen	58.0	55.9	66.7	48.2
	Bedroom	50.81	50.05	59.3	47.9
House B	**Living room**	58.32	n/a	64.6	66.1
	Bathroom	63.6	n/a	64.2	67.7
	kitchen	65.9	n/a	66.0	66.8
	Bedroom	57.5	n/a	61.9	61.3
House C	**Living room**	65.1	58.8	75.6	62.2
	Bathroom	65.0	57.6	73.8	58.5
	kitchen	63.0	58.6	75.0	73.7
	Bedroom	70.9	58.6	74.2	60.6

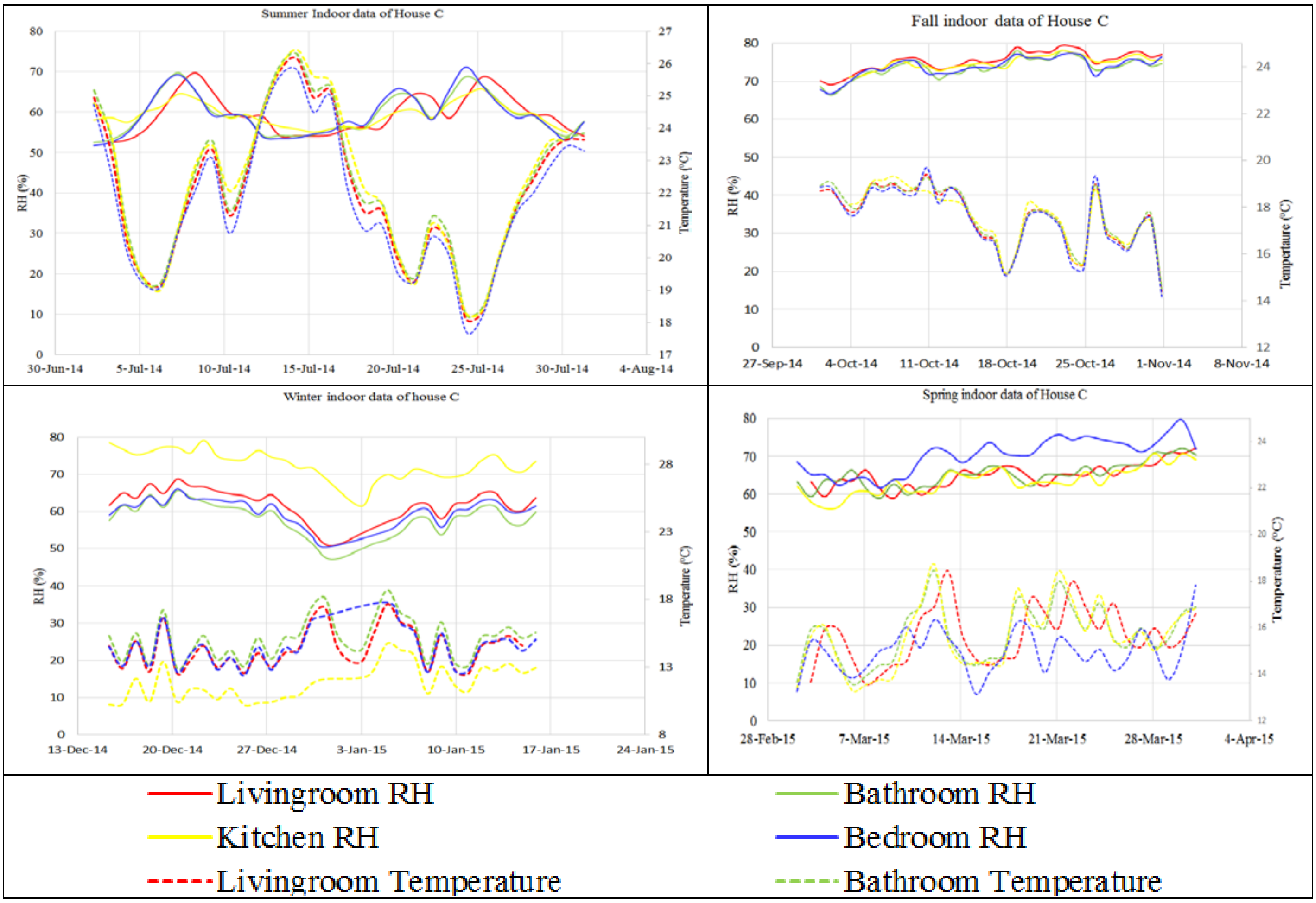

Figure 3. Indoor temperature and relative humidity of different rooms at House C

The absolute humidity value of House C, which has a higher relative humidity value in comparison to House A (as shown in Table 2), is lower than both House A and House B. This is because the indoor temperature of the house is kept low in comparison to other houses.

These preliminary results show that an absolute humidity cannot serve as a good signal while studying the hygrothermal performance of a building envelope.

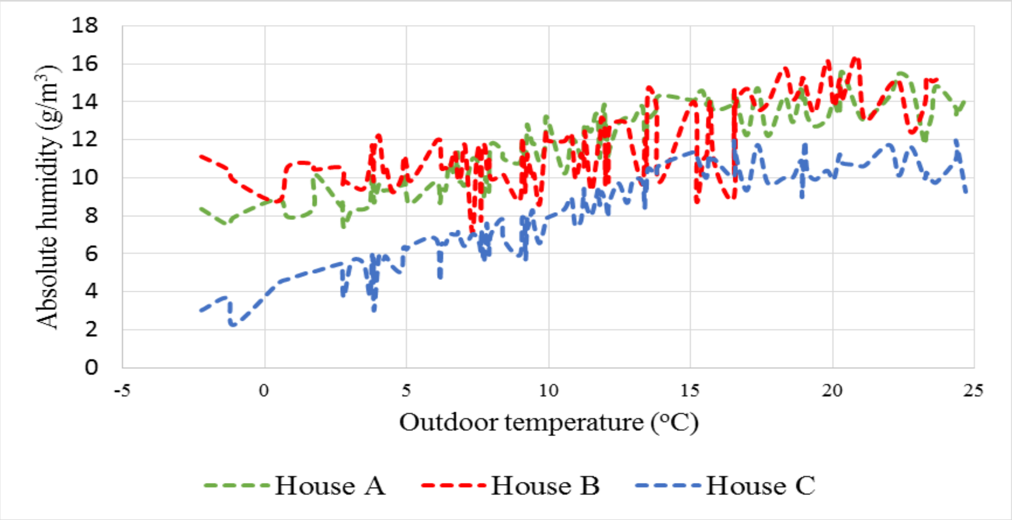

Figure 4. Absolute humidity measurement

Comparison between measured and estimated indoor humidity levels

The measured indoor humidity levels are compared to the indoor climate predictive models discussed above. Figure 5 shows the measured RH values and the respective computed RH value using ASHRAE simple method. As shown in the Figure, the model is in good agreements to RH measurements in the region between 7 °C to 16 °C of the outdoor temperature. This preliminary result also shows that RH cap limit (when outdoor temperature is greater than 20 °C) does not follow a trend to the Measured RH. The reason behind this is believed to be during summer the ventilation rate will be higher. Hence estimating the indoor RH during this season based on outdoor RH than the outdoor temperature seems the better option.

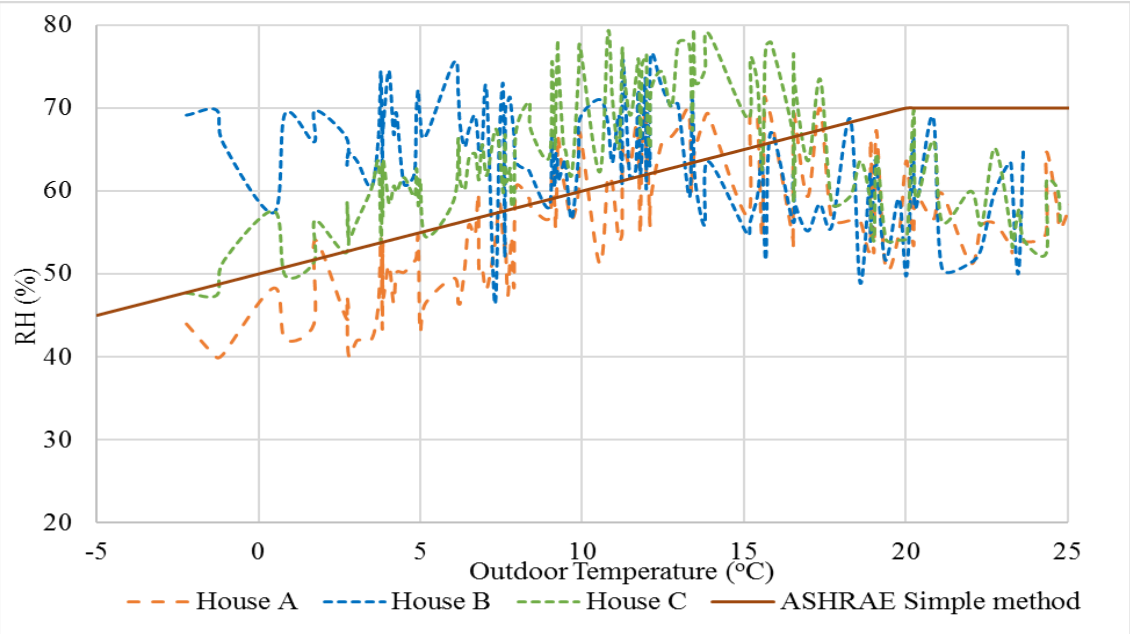

Figure 5. Indoor RH measurements and ASHRAE simple method

The ASHRAE intermediate model takes into account the ventilation rate, the moisture generation which is a function of number of occupants and the exterior vapour pressure. Our findings show for all houses the intermediate model consistently underestimates the indoor RH values. However the gap narrows as the outdoor temperature increases, see Figure 6.

The European class model classifies the houses in 5 levels based on their excess humidity values. The excess humidity values of Houses A, B and C lies in the regions of levels 3, 4 and 2 respectively during lower outdoor temperature however all the houses exceed the estimated excess humidity values as the outdoor temperature increases. In this model the major criteria for classification is number of occupants for residential dwellings. The model does not account for other occupant behaviours (such as cooking, laundry and other habits that will lead wind driven rain infiltration) which has a direct influence on increasing excess humidity.

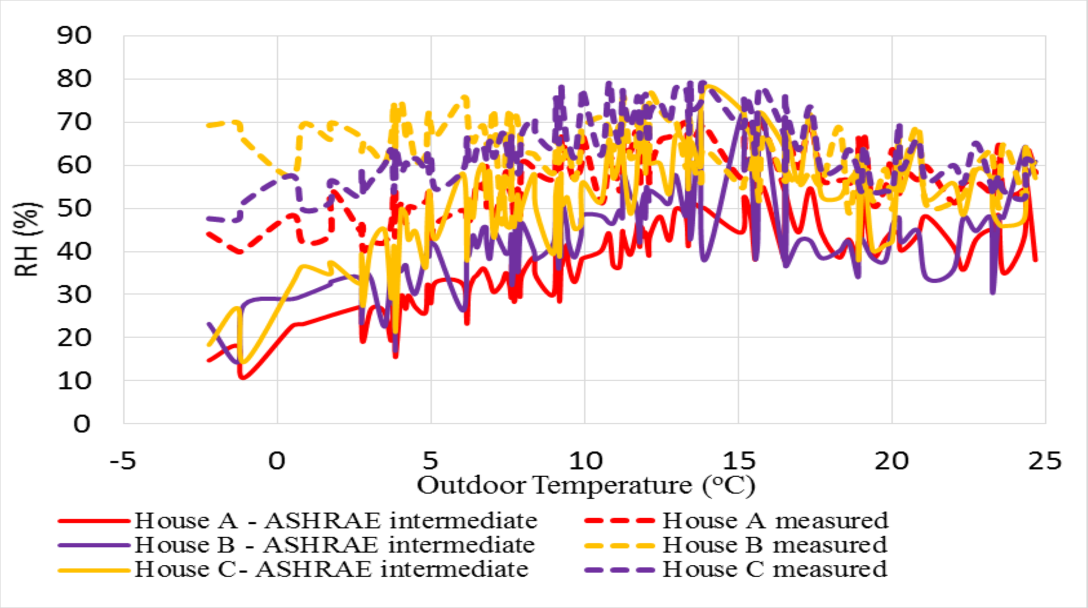

Figure 6. Indoor RH measurements and ASHRAE Intermediate model

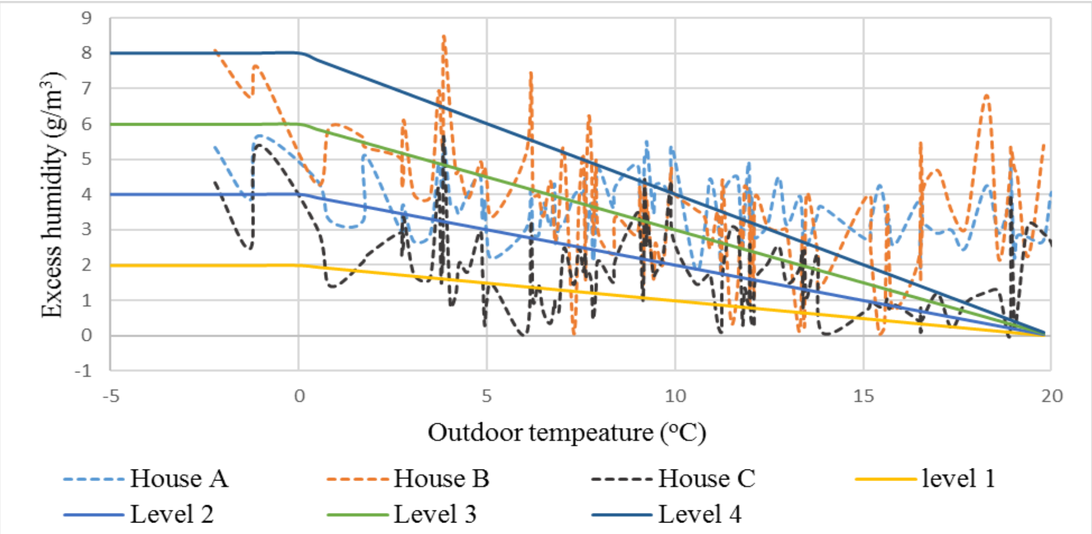

Figure 7. Excesive humidity measurements and European class model.

CONCLUSIONS

In this study, the indoor humidity levels of three houses in pacific coastal climate are monitored. The temperature and RH variations at different rooms are explored. Results show most rooms in a house attain similar temperature and indoor humidity during fall season. The measured indoor humidity values are compared to European Class Model, ASHRAE Simple and Intermediate methods. The ASHRAE simple method prediction was in relatively good agreement to the measured values except at elevated temperatures. The intermediate method underestimates the indoor RH Value throughout every temperature spectrum. However the gap between the measured and the computed RH narrows as the outdoor temperature increases. In our study, the accuracy of the European class model diminishes at higher outdoor temperatures.

REFERENCES

Arena, L. B., Karagiozis, A., and Mantha, P. (2010). “Monitoring of internal moisture loads in residential buildings—Research findings in 3 different climate zones.” Thermal Performance of the Exterior Envelopes of Whole Buildings XI Int. Conf., Clearwater Beach, FL.

ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers). (2009). “Criteria for moisture-control design analysis in buildings.” ASHRAE Standard 160, Atlanta.

Cornick, S. M., and Kumaran, M. K. (2008). “A comparison of empirical indoor relative humidity models with measured data.” J. Build. Phys., 31(3), 243.

EN ISO. (2012). “Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation. Calculation methods.” EN ISO 13788:2012, Geneva.

Jones, R. Modelling water vapour conditions in buildings. Building Services Engineering Research and Technology, Vol. 14, No 3, pp 99-106, 1993.

Kalamees, T., and Vinha, J. (2006). “Indoor humidity loads and moisture production in lightweight timber-frame detached houses.” J. Build. Phys., 29(3), 219–245.

Rose, W. B., and Francisco, P. W. (2004). “Field evaluation of the moisture balance technique to characterize indoor wetness.” Proc., Performance of Exterior Envelopes of Whole Buildings IX Conf.

Ojanen, T.; Kumaran, M.K. "Effect of exfiltration on the hygrothermal behaviour of a residential wall assembly : Results from calculations and computer simulations," International Symposium on Moisture Problems in Building Walls (Porto, Portugal, September 11, 1995), pp. 157-167, September 11, 1995 (NRCC-38783).

Ojanen, T.; Kumaran, M.K. "Effect of exfiltration on the hygrothermal behaviour of a residential wall assembly," Journal of Thermal Insulation and Building Envelopes, 19, pp. 215-227, January 01, 1996 (NRCC-39860).

Tariku F., Simpson W. (2015). Seasonal Indoor Humidity Levels of Apartment Suites in a Mild Coastal Climate. J. Archit. Eng., 2015, 21(4): B401500:1-7.

Yoshino, H., and Lou, H. (2002). “Indoor thermal environment of residential buildings in three cities of China.” J. Asian Archit. Build. Eng., 1(1), 129–136. Zhang, H., and Yoshino, H. (2010). “Analysis of indoor humidity environment in Chinese residential buildings.” Build. Environ. 45(10), 2132–2140.